Motivate and assist elderlies' exergaming-based resistance training by a cyber-physical systems

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A. Active leisure activities (ALAs)

Active leisure activities(ALAs) are normally ignored by the elderly even if many programmes are arranged/designed for increasing their ALAs participation. For example, in Holland, we can easily find communities in which they organize activities like walking, cycling or even doing resistance training in the local gym, etc.

Multiple reasons could contribute to elderly's absence in ALAs, such as: frailty, socially awkward, loneliness or unenjoyable experience, etc. However, one of the main reasons is that these activities can not adapt to their personal situations like: i) personal timeslot, ii) physical conditions, as well as iii) personal preference, etc.

Obviously, personalization is the key when we are arranging activities, services and programmes for elderly people. However, it seemingly unrealistic for the organizers to take every individual's preference into account. It might be a solution if hiring a personal assistant for every single elderly. But it will be undoubtedly very expensive and elderly can hardly afford this in a long run. In this case using a smart system may be an option to learn the preference or other situations of every individual people and arrange personalized services.

B. The capabilities of Cyber-Physical Systems(CPSs)

The paradigm of cyber-physical systems (CPSs) is one of the data-driven and knowledge intensive system. CPSs is usually enabled by cyber-physical computing(CPC) and pursues dynamic computing based on run-time obtained information. In the meanwhile, CPSs are equipped with various forms of cognitive capabilities, such as inferring, reasoning, planning, learning, decision making, etc. This feature enables CPSs to become self-generated intelligence systems instead of embedded intelligent systems. In another words, CPSs are expected to be able to tackle the situations which can hardly be predicted when the system was designed.

C. An example of CPSs Application

There is an example which can clearly reflect the smartness of CPSs. This example is a PhD project in CPS research group in TUDelft, namedly, indoor fire evacuation guiding system(IFEGS). The primary objective of the IFEGS is to provide personalized guidance and instructions for the mobile (smart) phone users to escape from the burning building. The guidance and intructions are inferred on the basis of the context information, such as: the location of fire, the distance between the each individual user and the exits, etc. Obviously, IFEGS clearly reflects the capabilities of CPS to tackle dynamic contexts and situations which can not be expected when it was designed.

D. Why choose CPS to support TG's ALAs

Elderly's ALAs is complicated. Arranging a successful ALAs also requires us to take many factors into consideration, such as timeslot, physical conditions, weather conditions, etc. However, these situations, obviously, is varying and can hardly be predicted. So author believes that it would be very interesting to explore the opportunities for applying smart CPSs to assist elderly's ALAs participation and performance

A. Domain of interest (DoI)

Resistance training is the typical example of ALAs and are usually ignored by senior person due to the reasons like: fear of pain, lack of interest, or shortage of supervision,etc. Obviously, it is not realistic to hire a person to provide constant supervision or arrange joyful training for senior. So smart system can be an option to complement the scarcity of human resources. Cyber-Physical System(CPS) is one of the paradigm of smart system. So in this thesis, the opportunities for applying CPS will be explored.

B. Cyber-Physical Systems (CPSs)

According to Tavčar, J., & Horváth, I. (2018), smart cyber-physical systems (S-CPSs) are complex enigeered systems empowered by cyber-physical computing and equipped with the capability of reasoning, learning, adapating and evolving.

C. Application of Cyber-Physical Systems(CPSs)

CPSs are capable to infer the solutions based on the data captured from real life process in order to respond to the problems, issues or situations happen in real life. In the meanwhile, CPSs can also learn the solutions applied to new situations.

Obviously, each individual user may need personalized support on their training, such as: i) providing customized training plan on the basis of the personal physical conditions, ii) giving specific guidance to correct their motions during the training,

Hence, author assume that CPS can capture the real-life process data or informations like: elderly's motions, moods. On the basis of the captured data/informations, CPS is capable to infer the needed strategy to deal with the situations like: wrong motions, negative moods, etc.

So in exploration phase(Part 2), the application opportunities of CPSs is firstly explored while in conceptualisation phase(Part 3), a CPS will be conceptualised based on the explored opportunities. In detailing phase (Part 4), the software, hardware and cyberware which are needed for implementing the CPS will be explored and elaborated. In the meanwhile, a use case scenario and a demonstrative prototype are made in order to manifest the final concept. This report is ended up with a prototyping test which aims at verifying the desirability and usability of the final concept.

D. Deliverables

This project will be ended up with five following things:

i) A visualized architectural embodiment model (AEM) which consists of needed hardware, software and cyberware components which enable the functions of the cyber-physical system (CPS). (The designed system is called another name which makes it more specific to its functions, but in introduction, it is still called a general name--CPS)

ii) A visualized operational embodiment model which shows how the functions of CPS operate in real life process.

iii) An use-case scenario (UCS) which shows how potential end users from target group come across the operation of the conceptualised CPS. UCS is demonstrated using pictures and illustrative texts.

iv) A demonstrative prototype which aims at showing potential end users how the whole system work and allows them to validate the satisfaction, desirability and usability of the system.

v) Finally the future research work is discussed which indicates that what cyber-physical system can do in the domain of supporting elderly's active leisure activities.

2.1 Short Introduction

The main objective of the "ANALYSIS PART" is to explore the opportunities for applying Cyber-Phsyical System (CPSs) in supporting elderly's active leisure activities(ALAs). 2.1 is considering the overview of the research questions and the approach used to explore the opportunities for CPSs.

Exploration is on the basis of the following 12 research questions:

A. Finding out the focus in this report.

Obviously, both elderly and active leisure activities are very broad concept. So on one hand, a target group should be selected, on the other hand, we should choose a proper ALAs that we would like to support target group to do. Hence we need to firstly answer the following two questions:

- *RQ1-What kinds of elderly most likely encounter subjective/objective barriers in participating and performing active leisure activities(ALAs), so that extra assistance are needed?*

- *RQ2-What category of active leisure activity(ALA) should be the foucs in this report? Why?*

The focused category of active leisure activities may still covers wide range of sub-categories. So the third research questions should be answered:

- *RQ3-What specific activities belongs to the category should be the focus of this report?*

B. Exploring the issues and needed services

When target group and the focused activities are there. It would be necessary to obtain target group's issues in participation and performance as well as the services for addressing the issues. Hence the following two research questions have to be answered:

- *RQ4-What are the issues for target group to participate and perform resistance training?*

- *RQ5-What services or other interventions are needed for addressing target group's issues?*

C.For bridging CPSs with needed services

The main objective or "ANALYSIS" is to explore the opportunities for applying cyber-physical system. So it is necessary to find out proper reasons for applying CPSs. Hence the following research questions should be answered:

- *RQ6-What are the main features of the smart CPS paradigm?*

- *RQ7-Under what conditions, the main features of CPS are needed?*

- *RQ8-How can the features be applied to **implement** the services needed for addressing TG's issues?*

C. For exploring technologies for implementing services

When we found out the proper reasons for using CPSs and the typical features of CPSs, it is time to explore the possibilities to implement the needed services by technologies which are relevant to CPSs. So the following questions should be answered:

- *RQ9-What technologies can be used to sense and model the real-life process?*

- *RQ10-What technologies can be used to infer the knowledge needed for service provisioning?*

D. For finding out added value of CPSs and exepctations towards subsequent conceptualisation

Obviously, designing a complicated intelligent system is not the purpose of this thesis. So it would be necessary to explain the expected advantage of CPSs-based solutions in comparison with other solutions. On the other

hand, it would also be necessary to stress how the concept are expected to manifest the advantage in conceptualisation phase. Hence, the follow-

• RQ11- What are the added value when using cyber-physical system in the context of supporting resistance training?

• RQ12-What are expections towards to CPSs-based concept on the basis of the findings in exploration part?

2.2 The focus in this thesis

Obviously, both elderly and active leisure activities are still broad concepts. Hence the main purpose of 2.2 is to find out the target group on one hand, and the focused active leisure activities on the other hand.

2.2.1 Target group

The main objective of 2.2.1 is to find out the target group who need CPSs based solution to assist them to participate and perform active leisure activities (ALA). The research questions is as follows:

RQ1-What kinds of elderly most likely encounter subjective objective barriers in participating and performing active leisure activities, so that motivations and assistance are needed? Why?

Author assume that target group could be defined in terms of four following variables: i) Age, ii) Health status, iii) economic status, as well as iv) educational level.

A.Variable 1-Age

Leitner, M. J., & Leitner, S. F.(2012) believed that the younger elderly (aged 55 to 75) have better health status than those aged more than 75 and over. Most younger retirees can participate in leisure activities that people in any age group enjoy. This is consistent with the theory proposed by Torpy JM et.al (2006) which reflected that in the industrialized nations, most people 65–74 years of age are still living independently and are in relatively good health while the status of adults over 75 years becomes increasingly worse in terms of mental and physical health.

B.Variable 2-Health status

According to Gobbens, Luijkx,et.al (2010a), frailty is a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological, social). Approximately half of all elderly aged 75 and over living independently can be classified as 'frail' (Gobbens, Van Assen, Luijkx, Wijnen-Sponselee, & Schols, 2010a) while percentage in residential center is 75%. Author assume that elderly above 75 usually are more likely to be frail compare to younger age group, so they may need assistance for performing leisure activities.

C. Variable 3-Economic Status.

Leitner and Leitner (2011) reflected that leisure activities participation is associated with the economic status. The elderly with good or intermediate economic status may more likely participate leisure activities. According to Carolien H.M.Smits et.al.(2013), on average, Dutch elderly are financially well-off due to the Dutch pension systems and extensive home ownership. However, the average income of non-western older immigrants is relatively lower. (Statistics Netherlands [CBS], 2012d) It seems that the people with intermediate or lower income may more likely need intervention to assist and motivate them to participate leisure activities.

D. Variable 4-Education level

According to Netz(1989), elderly with more than 10 years education seem to have greater command of their free time and more optimistic attitude towards life. On the other hand, higher educations are usually correlated with higher incomes, better nutrition, and having health care. On the contrary, the health care, or nutrition may be lacking in the group with lower education level. But again, the diversity of education level might be good for investigate the difference and similarity, and investigate which group are more likely need the assistance.

E. Summary

• Generally speaking, the target group should be above 75 because their mental and physical health tend to get worse in comparison with younger people, so they more likely need assistance to help them to participate active leisure activities.

2.2.2 Focused active leisure activities

Obviously, active leisure activities (ALAs) covers wide range of activities. So it would be necessary to find out the focused type of active leisure activities. So the following research questions should be answered:

RQ2-What categories of active leisure activity(ALA) should be the foucs in this report? Why?

Author assumes that the focused ALAs should fulfill two requirements:
i) the activities should be able bring typical benefits of ALAs,
ii) target group's participation rate to this activities are low.

A. Definition of ALAs

Leitner&Leitner. (2011) define leisure as unobligated time during which work, life sustaining functioning and other obligatory activities are not performed. Leisure activities are the activities conducted during leisure for the purpose of enjoyment. But leisure activities are basically classified as passive leisure and active leisure. Instead of purely for enjoyment, active leisure activities(ALAs) are also for the benefit of well-being, health and life satisfaction (D.W.Cho, J.Post, S.K.Kim 2017).

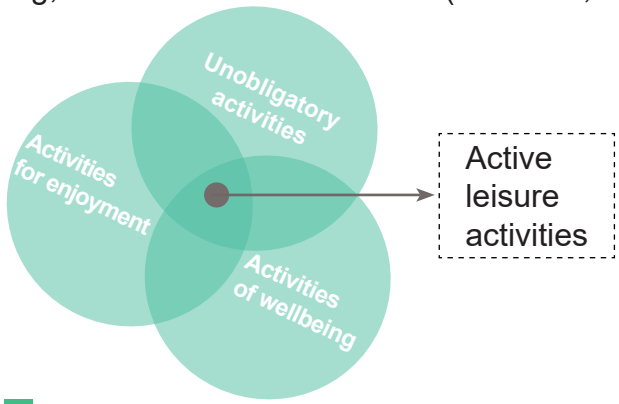


Figure 1-As shown in this figure, active leisure activities should be unbligatory, for the purpose of enjoyment and well-being.

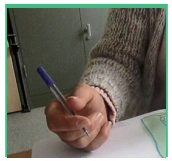
B. The focused ALAs selection

B1-Particpants

In order to select a focused type of active leisure activity (ALAs), several short interviews were conducted. Four following participants were interviewed:


Caregiver1


Caregiver2


Coordinator of elderly activities


Gerontologist

B2-Approach

The approach can be briefly described as follows:
• S1.Choose the most important benefits from ALAs for target group,
• S2.Choose the benefits which are most relevant to ALAs,
• S3.Choose the ALAs which may most likely bring relevant benefits,
• S4.Choose the ALAs which have lowest participation rate.

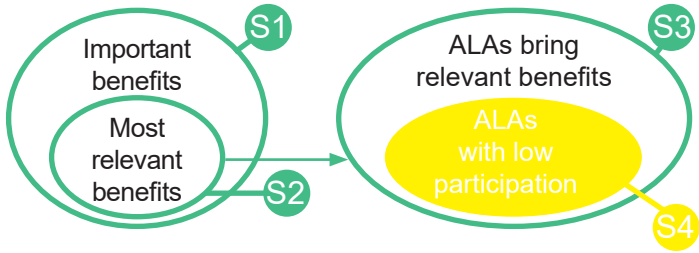


Figure 2- The visualized approach for selecting focused ALAs.

B3-Findings

• The most relevant benefits of ALAs are slowing down the decline of mental and physical functions.

• Resistance training(RT) was finally choose to be the focused ALAs. On one hand, RT can contribute to slow down the function decline, on the other hand, resistance training can easily be ignored by target group.

More materials considering this short interview can be found in APPENDIX A

2.2.3 Focused type of resistance training

Obviously, resistance training still covers wide range of training. So it would be necessary to explored the focused type of resistance training. Hence, the following research question should be answered:

RQ3-What specific activities belongs to the category(resistance training) should be the focus of this report?

The informations were obtained through website sand a short interview.

A.5 types of resistance training

There are basically five types of resistance training shown as follows:

- ***Body weight training***, such as push up, squats,

- ***Free weight training*** which uses dumbbells, barbells,kettlebells, this type of training is usually considered as most effective,

- ***Machine weight training*** which uses weight machines. It is an safe option for people who are new to resistance training,

- ***Elastic band training*** which uses elastic. It is cost effective training which can be managed at home,

- ***Fold-away gym*** *which* provides a 50-exercise body-sculpting workout. It uses uses six elastic cords that provide three levels of resistance.

Figure 3-Fold-away gym

Source: https://www.fitday.com/fitness-articles/fitness/exercises/what-is-resistance-exercise.html https://aparadiseforparents.com/9-easy-senior-resistance-band-exercises/ https://www.hammacher.com/Product/Default.aspx?sku=88300

B.Focused types of resistance training

In order to find out the focused type of resistance training, a short interview was conducted. The interviewees are two personal trainers. They believed that machine weight training is suitable for target group the most because it is a safe option and more effective compare to free weight and elastic band training. But fold-away gym can also be interesting, because it is also machine-based training but can be managed at home. So machine weight training will be the focus.

2.3 Participation issues and needed services

In 2.1, we have already decided the target group, the focused ALAs as well as the focused type of resistance training (RT). In 2.2, two aspects will be explored: The one is target group's participation issues in participating resistance training while another is needed services for addressing these issues.

2.3.1 TG's issues in RT participation and performance

The objective of 2.3.1 is to answer the following research question:

- *RQ4-What are the issues for target group to participate and perform resistance training?*

2.3.1 begins with literature review(LR) which aims at discovering the common issues for target group to participate and perform resistance training. LR is followed by two focus group interviews which aim at verifying the findings from LR as well as get new inputs. It worth to mention that six participants were hired. Three participants were elderly from target group while another three were personal trainers. 2.3.1 is ended up with a summary.The procedures of the 2.3.1 is also visualized as follows:

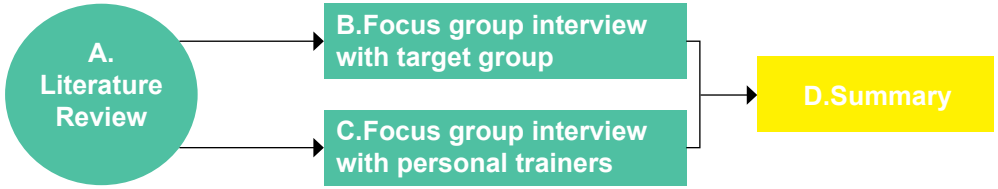


Figure 4-Visualized procedures of 2.2.1

A. Literature review

Large body of researches can be found online considering the obstacles and issues for elderly to participate and perform resistance training. There are some examples listed as follows:

Van Roie, E., Bautmans, I., Coudyzer, W., Boen, F., & Delecluse, C. (2015) conduceted a survey considering elderly's long term adherence and motivation in resistance training participation. The results

shows the following reasons like: i) elderly are more interested in other physical activitites than resistance training, ii) the importance of training are not fully realized, iii) seasonal reasons is one of the biggest barriers for continuing resistance training, iv) subscription fee is too expensive, etc.

Burton E, Farrier K, Lewin G, et al. reflected that the participation barriers may include: health issues, pain, tiredness/fatigue, lack of social support and exercise facilities.

According to Guest, A., & Apgar, M. D. (2002), users usually need prescribed range of exercises to match their energy and functional level. In the meanwhile, self-efficacy also plays a role in elderly's rate of participation.

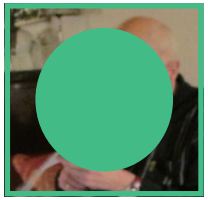
In general, the issues can be categorized into several categories, such as: i) health issues, ii) motivational issues, iii) environmental issues (e.i: bad weather), vi) financial issues, etc. More findings from this literature review can be found in APPENDIX-B-01

Above mentioned issues are not necessarily apply to the elderly from target group. So these issues were shown in next two focus group interviews. On one hand, respondents can verify whether these issues are applicable to target group, on the other hand, these issues were expected to stimulate respondents' thinking so as to allow respondents come up more issues specific to target group.

B.Focus group interview with target group

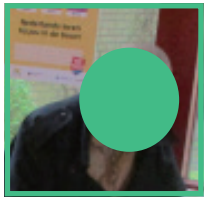
B1-Participants

• 75 years old
• Barely workout



• 80 years old
• Workout twice a month

• 80 years old
• Workout sometimes not quite often



• 85 years old
• Occationally workout

B2-Research questions

It worth to mention that the way of asking research questions in interviews is slidely different from the way we wrote the questions in report.The purpose is to make the questions easy to comprehend for respondents.

- RQ1- What kinds of issue may usually hold you back from participating resistance training?
- RQ2- What difficulties do you encounter when you are performing your resistance training?
- RQ3- To what extend do you believe the factors shown on this paper (the finding from literature review) apply to you?

B3-Procedures

Step 1-Introduce respondents the background of this interview and the informations that are expected from them.

Step 2- Ask respondents research questions and present the findings from literature review.

Step 3- Respondents were allowed to contribute their owns informations about the participation issues as well as the opinions towards the findings from literature review.

Step 4- Author summarized the inputs from the interview.

Note: More information about this interview can be found in APPENDIX B

B4-Findings

• Bad weather may hold elderly back from going to gym because bad weather might lead to joint pain and bad emotion.

• The training process is not enjoyable or even boring because resistance training is composed of several groups of repetitive motions.

• The insufficient supervision lead to poor training quality which may affect elderly's commitment and confidence towards their training.

C.Focus group interview with personal trainers

Participants

Strength training instructor in 65+ programme

Strength training & spinning instructior in 65+ fitness programme

Coordinator of 65+ programme

Research questions

- RQ1- what issues do you usually observe which may make your elderly clients leave their resistance training?
- RQ2- What difficulties do you usually observe when your elderly clients are performing their resistance training?
- RQ3- To what extend do you believe the factors shown on this paper (the finding from literature review) apply to your clients?

Findings

1.Target group has **low adherence** to resistance training due to the reasons like: i) boredom of repetitive motions training, ii) bad weather.

2.Target group's **training quality can not be guaranteed** due to insufficient amount of training which usually correlate with target group low motivation and low commitment to their training.

3.Target group sometimes perform their resistance training wrongly. The regular communication between elderly and trainers can contribute to make training successful.

Notes-More information about this interview can be found in APPENDIX B-02

D. Summary

On the basis of the main points from the literature review and two focus group interviews, the issues are summarized as follows:

- Low adherence is one of the main issues and the reasons could be multiple. However, the main reason is the unenjoyable training experience as well as the low motivation. Additionally, bad weather could also hold target group back from gym.
- Training quality can hardly be guaranteed. The main reasons for poor training quality is low motivation as well as the insufficient supervision and limit communication with trainers.

When the participation and performance issues are ready, the services for addressing the issues are explored in 2.3.2

2.3.2 The needed services for tackling the issues

The objective of 2.3.2 is to answer the following research question:

- *RQ5-What services or other interventions are needed to address target group's participation and performance issues?*

As mentioned in 2,3.1, the main issues for low adherence are unenjoyable training experience as well as low motivation. So 2.3.2 begins with literature review which aims at exploring the potential ways to increase enjoyment and motivation. In subsequent website browsing, the current solutions for increasing resistance training quality are explored. The two things are followed by two focus group interviews which aim at verifying whether the findings from literature review and website browsing are useful for target group. On the other hand, respondents were also allowed to propose their

own expections and ideas. 2.3.2 is ended up with a list of service requirements. The procedures of 2.3.2 is visualized as follows:

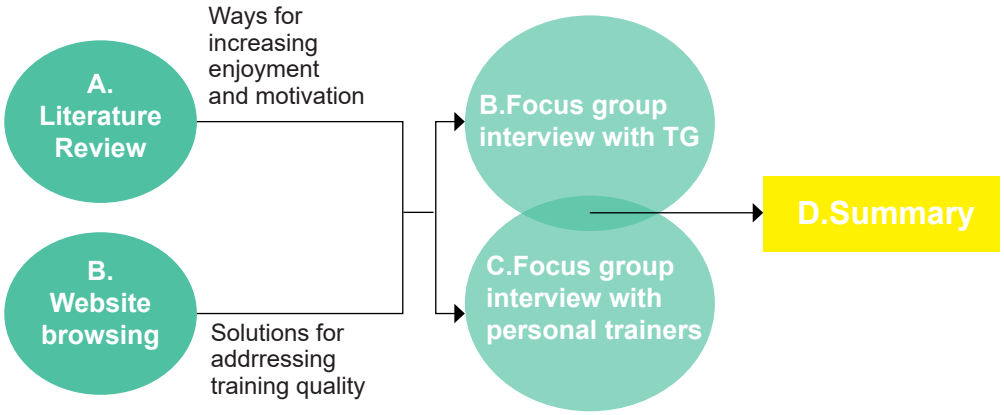


Figure 5-Visualized procedures of 2.2.1

A. Literature review

As mentioned above, literature review aims at finding out the potential ways for increasing target group's enjoyment and motivation in the process of training. Hence the following research question should be answered:

• *What services or other interventions are needed to address target group's issues? (The issue is unenjoyable training process and low motivation)*

A1-The influence of Indoor environments on enjoyment

Author assume that the indoor environment may possibly influence elderly's level of enjoyment in the process of resistance training. Author assumed four aspects can contribute to influence indoor environments: i) lighting, ii) music, iii) indoor temperature & vi) indoor humidity. In order to verify this assumption, a literature review is done in order to investigate the extend to which the four aspects can contribute to increase enjoyment.

i. Lighting

According to Baron, R. A. (1990); Baron, R. A., & Thomley, J. (1994), lighting can alter environmental conditions to increase positive mood, decrease fatigue, and improve cognitve performance. Mills et al. (2007) reflected that high colour temperature fluorescent workplace lighting can reduce worker fatigue while Erikson, C., & Küller, R. (1983) stated the evidence that low color temperature might promote fatigue and negative mood states.

ii. Music

According to Creech, A., Hallam, S., McQueen, H., & Varvarigou, M. (2013), a compelling body of research demonstrates that music continues to offer powerful potential for enhancing health and wellbeing in old age. Active music making has been found to provide a source of enhanced social cohesion, enjoyment, personal development throughout the latter stages of adult life.

iii. Temperature and humidity

According to Seppanen, O., Fisk, W. J., & Lei, Q. H.(2006), indoor temperature is one of the fundamental characteristic of the indoor environment. People's performance increases with temperature up to 21-22 °C, and decreases with temperature above 23-24 °C. The highest productivity is at temperature of around 22 °C.

Cui, W., Cao, G., Park, J. H., Ouyang, Q., & Zhu, Y. (2013) stated that motivation improves when people were more comfortable and performance also increase because higher motivation. Warm discomfort environment had negative effect on both motivation and performance. The optimum temperature range was between 22 °C (slightly cold) and 26 °C (a little higher than neutral).

According to Chang, K. F., Chou, P. C., & Lui, Y. T. (2008), environmental factors also include humidity. Lee, F. S., & Scott, E. L. (1916) proposed that human being in a hot and humid atmophere feels a disinclination to perform muscular work. In a comfortable condition, the average temperature is 20.6 °C and the relative humidity is 52 percent.

To sum up, both temperature and humidity play essential role in maintaining the indoor comfortness.

A2-Influence of elements on motivation enhancement

According to Sween, J., Wallington, S. F., Sheppard, V., Taylor, T., Llanos, A. A., & Adams-Campbell, L. L.(2014). , exergames, the coupling of physical activities and video gaming, offer an enjoyable and promising new approach to increase physical activities in individual that are among the least likely to engage in regular physical activities. So let us see what exergaming elements can contribute to increase physical activities participation.

According to Höchsmann, C., Walz, S. P., Schäfer, J., Holopainen, J., Hanssen, H., & Schmidt-Trucksäss, A. (2017), exergaming are experimental and interactive and immerse the players in worlds that offer compelling challenges and immediate progress feedback while Hawley-Hague H, et al (2014) reflected that digital games hold the potential to increase adherence to exercise by providing regular feedback and motivational message to older adults.

According to Wollersheim D, et al. (2010), adding social factor could also be perceived advantage of exergaming. Promoting social interaction is an area in which exergaming can excel. According to Gajadhar BJ et al. (2010), some games can be played online allowing those who have difficulty to leave home to have playful social interaction.

Other charateristics of exergames that seem to hold an advantage over traditional forms of exercising are the possibilities of training at home, rather than center based setting (Sherry JL et al. 2006).This characteristic could be used to tackle the issue of bad weather which can hold elderly back from going to gym.

Additionally, exergaming also allow elderly to temporarily escape from reality to have some private time (Nap HH et al. 2009).

To sum up, the following six elements can contribute to enhance people's motivation:

- a.Compelling challenges,
- b.Regular feedback to users' behavior
- c.Motivational message,
- d.Enabling social interaction,
- e.Can be managed in home-based setting,

Obviously, the six elements are still very abstract, so it would be necessary to see how these elements are manifested in real exergames. So some examples are shown in A3

A3-The reflection of the elements in real game

According to Richards, C., & Graham, T. C.(2016) commericial exergaming for strength training usually focus on exercise quality over game quality. In these games, players tasks is to mimic the movement of trainers on the screen. Additional points are awarded for more closely matching trainer's movement. "*Nike+Kinect training*", *"Fitness evolved"* are the typical examples.

i. Mimic trainers movement and get score

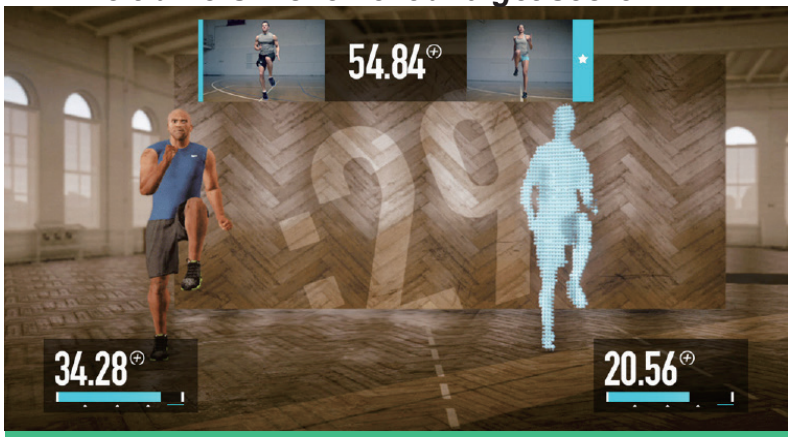


Figure 6-Nike Kinect.

As shown in Figure 6, in Nike+ Kinect training, players are following the motions of trainers and get rewards which can indicate the level of similarity between player's motion and trainer's motion, in the meanwhile, player can get reminders if their motions is deviate too much from trainers' motions. Player's motions are captured by Microsoft Kinect Sensor.

Exergaming elements
1. Players are rewarded score if their motion is similar to trainers. The score can be considered as the motivation for users.

2. Players can get reminder if their motion is not correct, so the reminder can be considered as feedback.

ii.Compete in virtual world by performing physical activities

Figure 7-Squat to the moon.

According to Chad Richards & T.C.Nichaolas Graham (2016), on the contrary of pursuing the quality of the training, the focus of this kind of exergames is on pursuing the enjoyment of the game at the expense of the training quality. *"Squat me to the moon"* is a typical example.

Exergaming elements
1.Players can compete against with each other online through doing physical exercises, so this can be considered as an example of social interaction.

2.Players can see whether they are at a perfect speed or they have to speed up, this feature can be considered as an example of feedback.

iii.Simulating the real training scenairos

Figure 8-UFC Trainers

UFC Trainers simulate the real boxing training session. The trainers in the virtual world guide players to perform some pre-heat exercise or strength exercises, then players started to perform boxing training. In the process of the training, players are constantly encouraged by virtual trainer, for example, "let us see how many extra reps you can do, that is a good elbow,etc". In the meanwhile, players can also see their score on the right side of the screen.And sound can indicate players motions is correct.

Exergaming elements
1.Players are rewarded score if they perform the training properly.

2. Trainer gives users encouragement if he/she perform the training properly, this is obviously the motivational message.

vi.Strength training make avatar evolve in virtual world

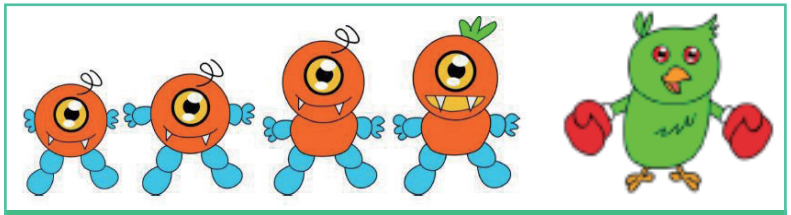


Figure 9- Exermon

Alf Inge Wang et al (2016) proposed an exergaming named "*Exermon".* Exermon refers to a digital monster and player have to take care of the monster through the exercise like push-up, tables up,etc. The amount of training is counted by accelerometers in smart phone.

When players are exercising, the exermon will gain stats based on the exercise and repetitions.The monster get stronger by rising stats. but also can risk death of the monster if player is not exercising over a period of time.

Additionally, players can connect with their friends to compare their monsters and fight them.Unlike many other exergames, players do not interact with the game in the process of exercises. The purpose of this feature is to allow players to fully focus on their exercises and reap the fruit of training afterwards.

Exergaming elements

1.The growth of the character/avatar in virtual world can be regarded as an example of motivational feedback.

2. The players can compare and fight their character/avatar online. This could be regarded as an online social activities.

3. The competition between avatars can be considered as compelling challenges which motivate users to do resistance training constantly.

A4-Summary of finding from literature review

i. Multisensory services for increasing enjoyment

• The color temperature, brightness of lighting can be adjusted to increase elderly users' positive moods.

• The music can be contribute to enhance people's level of enjoyment.

• The indoor temperature should be controlled within 20-22 °C while humidity should be controlled around 52%. Controlling temperature and humidity can contribute to increase indoor comfortness.

ii. Messages/feedback for enhancing motivation

• Score/points can be given as a way of motivating users.

• The music/sound which can indicate the correctness of players' motion may contribute to motivate players.

• Elderly's strength training can affect their character/avatar in the game world and the growth of their character/avatar can remind elderly their accomplishment in resistance training.

• The message like " Do not be afraid of making mistakes, keep up" or "I know you can do it" can be considered as the content of motivational message.

iii. Enable social activities between different users

• Online competition is very common social activity in the context of exergaming. Competition can potentially contribute to motivate users to continuously work on their training.

B.Website Searching

The objective of website searching is to explore potential services used for improving people's resistance training quality. These services are not necessarily designed for target group, but some functions can still contribute to improve target group's training quality, So the following research question is answered:

What services or other interventions are needed to address target group's issues? (The issue is unguaranteed training quality due to limited supervision)

B1-Exergaming based services

Some exergaming are designed for guiding users' exercise. There are two typical examples shown as follows:

i. Nike&Kinect-When users are mimicing the motions of the trainer shown on the screen, their motions are monitored by KINECT ™. When their motions are found to be inaccurate, a textual guidance will appear on the screen to correct inaccurate motions.

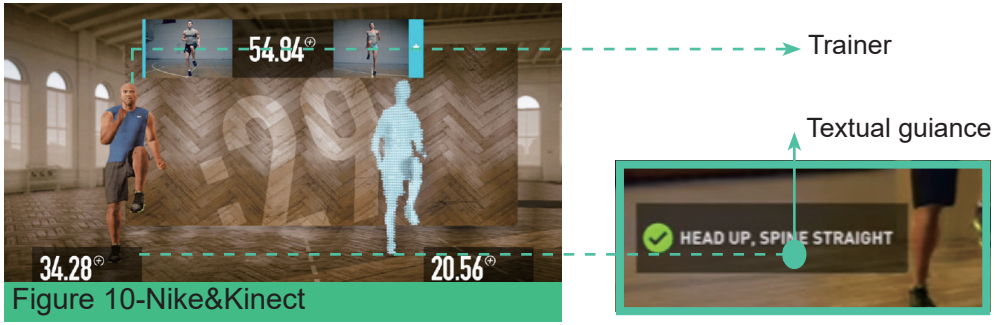


Figure 10-Nike&Kinect

ii.Fitness evolved-Similar to "Nike&Kinect", users can also follow the motions of the trainers. But the additional feature of "Fitness evolved" is that the training task is visualized on the screen, so that allows users to know the training amount that they have already completed and they still have to do.

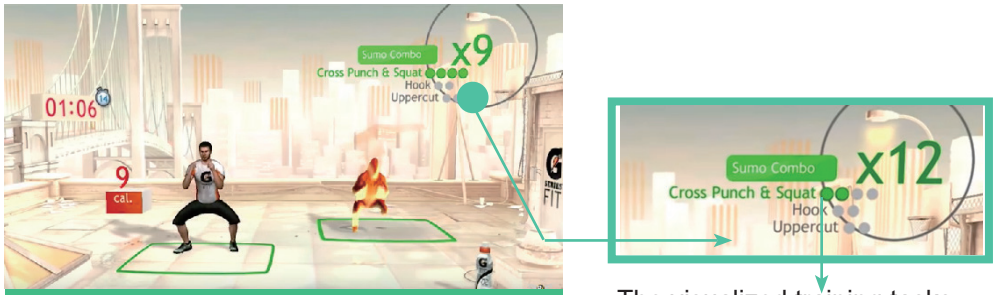


Figure 11-Fitness evolved

B2-Fitness tracker

Fitness trackers are the products designed for tracking people's training performance. In this report, three typical trackers are elaboratedly introduced as follows:

i. Training plan recommendation + training monitoring

The product is called "Push band" which is composed of a fitness tracker and an APP. The main functions of "Push band" are shown as follows:

• Users are allowed to set their fitness training purpose in the APP. The purpose could be: i) enhance strength, power, ii) increase speed, iii) increase muscular hypotrophy, or iv) increase muscular endurance, etc.

Figure 12- Push Band+APP

• The recommendation function named "Push assistant". It is an analytics program within the mobile app. It makes specific recommendations in terms of exercise and weight on the basis of users' fitness training purpose

• The "push band' can captured sets, repetition as well as velocity. However, exercise type and lifed weight can not be automatically captured

Source: https://www.youtube.com/watch?v=oFmDSRdbeMw&t=234s

ii.Muscle activities monitoring+coaching

The product is called " Gymwatch" which is composed of "Gymwatch sensor" and an APP. The main functions are shown as follows:

• Gymwatch sensor is composed of gyroscope, accelerometer and magnetometer. The trio is able to track muscle movements and measure the tension in different muscle contractions in real-time.

• GymWatch sensor can detect elderly's incorrect exercise execution. Incorrect execution may include: i) user is overextending his/her arm, ii) user is not moving his/her arms enough, iii) users are going too fast or too slow.

• There are two training modes: free mode and guided mode. In free mode, users can start their training immediately without have a fixed training plan while in guided mode, users can choose from workout template, then the smart phone becomes personal trainer. it can automatically calculate the optimal weight for individual users to avoid overloading or underloading.

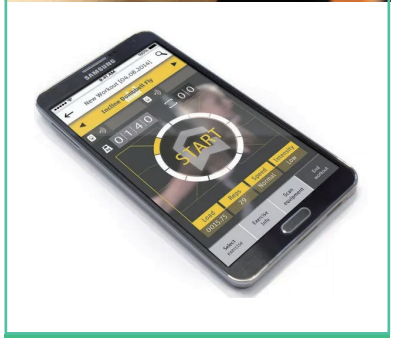


Figure13-GymWatch Sensor + APP

• The device uses algorithms to analyze and determine users' specific target goals. It combines users' personal data and the recorded training data, then creates a personalized training plan for users. It automatically calculates the optimum weight to achieve goals more quickly. For example, the device might recommend users to go up ten pounds after one set of concentration curl.

Source: https://www.wareable.com/fitness-trackers/gymwatch
https://www.youtube.com/watch?v=jqF4VCL7X34&t=219s
https://www.youtube.com/watch?v=XHdqHOtBxcA
http://gadgetsandwearables.com/2016/02/13/gywatch-review/

iii. Measure velocity+Reps counting

Figure 14-Beast sensor+APP.

• Beast sensor(BS) is composed of a sensor (Yellow color) and an APP installed on smart phone.

• The sensor(BS) is composed of three accelerometers, three gyroscopes and three compass with a lithium ion battery inside.It can either be attached to a wristband or it can be magnetically attached to weights or cable machine plates to measure the movement.

• The APP of beast sensor(BS) not only guide users to develop their muscles like increasing maximum strength, vertical elevation or the ability to accelerate and outrun opponents online, but also record the reps, sets and even velocity of elderly's resistance training.

Source: https://www.thisisbeast.com/en

A3-Summary of finding from literature review

• Users can mimic trainers' motion shown on TV screen,

• The training plan can be visualized on the TV screen. So users can see i) how many repetitions, sets have they completed or will complete,

• Audio or visual feedback should be provided in order to keep users informed of their training quality, such as: quality of motions, velocity,

• Users should get suggestions on training plan. The suggestions could be based on users' objective. The suggestions should contribute to not only avoid over training, but also help users achieve their goals.

• Reptitions, sets and velocity should be accurately measured.

C-Focus Group (FG) interview with TG-2nd round

The main purpose of this interview is to verify the effectiveness of the services found through literature review(LR) and web searching(WS). This interview is based on the research question shown in C1

C1-Research Questions for interview

- What services do you think may effectively contribute to enhance your motivation and enjoyment in RT participation?
- What services do you think can effectively contribute to improve your training quality?
- What services/something else do you want to add?

C2-Participants

The participants are still the elderly who participated the last focus group interviews with target group.

C3-Procedures

Step 1-Introduce the background of the research, such as i) who is the target group, ii) What is the purpose of this focus group interview, iii) What information are expected, etc.

Step 2-Introduce the respondents the findings from both literature review and website searching.

Step 3-Start to ask the first two research questions one by one. If participants disagree with the findings, or have something to add, the third research question should be asked.

Due to this interview lasted 30 minutes which are shorter than normal because the elderly respondents had something else to busy with.

More information about this focus group can be found in Appendix B-03

C4-Findings

i.Sevices for increasing enjoyment&motivations

- The adjustment on indoor lighting is probably necessary in the rainy day or cloudy day,
- The temperature may affect motivation as well as the comfortness, but they were not sure about the effect of humidity,
- Music can increase enjoyment to some extend, however it can also be a double edge sword. Music can also be distracting.
- The growth of the characters could be motivational because it can intuitively reflect elderly's accomplishment in training,
- Elderly normally incline to contribute their effort to group instead of competing others in competition.
- Motivational message could be encouraging through reminding elderly that their training are meaningful.

ii.Services for improving training quality

- Elderly sometimes fail to accurately count their repetitions, sets. So the repetition and sets should be accurately counted somehow,
- Feedback are needed to let users know that they are doing wrong,
- The visualized training plan are always needed to remind elderly how much training they still need to perform,
- Following trainers motions on the screen can increase the chance to complete the training plan,
- The suggestions on training plan is always needed. In the meanwhile, the training plan should be regularly updated, otherwise, people may easily get bored.

iii.Extra information from interview

• Elderly need more concern from trainers, especially the inquiry like:" how do you feel", "do you want to have a short break", " are you feel tired" or " do you feel exhausted" etc.

• Wearable sensors are not comfortable, but bracelet or fitness tracker are acceptable.

• The message provisioning should be dependent on elderly's sight and hearing. For example, the visual message should be the priority if the user have poor hearing.

D-Focus Group (FG) interview with trainers-2nd

The main purpose of this interview is also for verifying the effectiveness of the services got from literature review and website searching. The interview are based on the research question shown in D1

D1-Research Questions for interview

• What services do you think may effectively contribute to enhance your elderly clients' motivation and enjoyment in RT participation?

• What services do you think can effectively contribute to improve your elderly clients' training quality?

• What services/something else do you want to add?

D2-Participants

The respondents are still the trainers who participated last focus group interviews which aims at discovering participation issues.

D3-Procedures

The procedures of this interview are exactly the same as those mentioned in last page.

More information about this focus group can be found in Appendix B-03

D4-Findings

i.Sevices for increasing enjoyment&motivations

• The lighting should be brighter in cloudy and rainy day in order to make clients more comfortable. But it is hard to tell the extend to which the lighting can contribute to increase motivation.

• Adjusting the temperature and humidity can also make clients feel more comfortable. The comfortable training places can probably attract more clients or increase users' participation.

• Music plays a role in increasing people's(not only elderly) positive moods in the process of training. Hence gyms usually choose to play enthusiasitc music in order to cheer their clients up.

• Motivational message could be useful, but the same content should not be repetitively appear within a short period of time.

• Giving score could be useful in short term, however, the long-term effect is questionable.

• The competition between characters in the game world can be very motivational. The competition could be "fighthing" and "racing". Two trainers could even imagine that the competition can keep long-term motivation. *(But they are not sure if this feature suits elderly people)*

ii.Sevices for improving training quality

• Repetitions, sets should be accurately counted and recorded, otherwise the successful training can hardly be achieved,

• Reminders and feedback are needed to make elderly realize that their motions are wrong and tell elderly that how to corret their motions,

• Mimicing trainer's motions can possibly pushes elderly to complete their training.

• Elderly's training plan which includes exercise type, weight, repetitions and sets should be regularly adjusted in order to adapt to elderly's objective or physical conditions which are constantly changing.

iii.Extra information from interview

• People's (not only elderly) physical condition can be assessed using a simple method. People can be asked to perform repetitve motions, such as: " sit and stand for 10 times, stand on the legs for 5 seconds." Experienced trainers can judge whether the motions are deviated from healthy people. If yes, the relevant muscles are considered as "weak".

• Trainers agreed that regular inquiry are needed during training. It is difficult to judge whether the arranged training plans are suitable for the users until they are really working on it. It would be better for trainers to ask users how they feel. Based on trainers' feedback, trainers can tell whether the training plan should be changed or not.

• Fatigue should be avoided. If fatigue happens during the training, the training plan should be changed because the training load is too heavy for this elderly. Heart rate is the indicator of fatigue.

• Although trainers incline to support gym-based training, but they did not deny that home-based training could also be an option when the weather is bad, gym is too far away, gym environment is not enjoyable, etc. But the issues are also clear, no supervision and no social communication.

E. Summary-List of service requirements

The findings from the two focus group interviews is merged together and list of service requirements are formulated:

E1-Services for increasing enjoyment and motivation

i. The adjustment on lighting, temperature as well as humidity can possibly contribute to increase the level of enjoyment of training environment, but more evidence are needed.

ii. Music provisioning can contribute to increase people's enthusiasm. However, music also could be double edge sword.

iii. Motivational message can contribute to remind people that their training is meaningful, however, the message content should not be always the same, otherwise the message would became useless.

iv. The growth of avatar in game world can be motivational, and the cooperation or competition between the avatars of different users can possibly increase the long-term motivation even more.

v. "Giving score" can also be motivational. But the long-term effect is questionable.

E2-Services for improving training quality

i. Repetitions, sets as well as velocity should be accurately measured.

ii. Feedbacks are needed if users motions are found to be wrong. The feedbacks should not only tell users their mistakes, but also let users know what they should do to correct their motions,

iii. Suggestions on making training plan are needed. The suggestions should be based on users' physical conditions or objective. Physical conditions can be assessed by comparing users' motions with healthy people's.

iv. Inquiry are needed during the training in order to verify whether the training plan is suitable for users. Fatigue is one of typical situations that users should avoid.

v. Mimicing trainer's motions on the screen may contribute to increase users' likelihood to complete their training.

In 2.3, services for increasing target group's participation and performance have been obtained. The next step is to explore the possibilities to implement the services using cyber-physical systems. So in 2.4, the relevant informations about cyber-physical systems are explored.

2.4 CPS exploration

In 2.3, the needed services for increasing target group's issues in active leisure activities (ALAs) have been obtained. However, before implementing these services, one more step is needed.

Obviously, designing a complex system is not what this thesis is aiming at. Hence it is very important to find out proper reasons for applying cyber-physical systems. So the following questions have to be answered:

RQ6-What are the main features of the smart cyber-physical system paradigm?

RQ7-Under what conditions, the main features of cyber-physical system are really needed?

RQ8-How can the features be applied to implement the services needed for addressing target group's issues?

All of the relevant information were obtained through literature review.

2.4.1 Paradigmatic features of smart CPSs

Firstly, it would be necessary to figure out the typical features of smart CPS, hence the following research question should be answered:

RQ6-What are the main features of the paradigm of smart cyber-physical system?

I.Horvath et al (2017) proposed five following paradigmatic features of smart CPSs:

A. Penetration into real-life processes

Smart CPS are networked knowledge-intensive system of systems that are intended to penetrate into real-life physical processes. In another words, the operation of CPS are based on run-time data acquired through sensors.

B. Diverse functional semantics

Smart CPS are not gear-boxes which do the same in every application. They are conceived to be tailored to the expectation of all elements (actors) of the embedding environment as well as to the changes in the objectives and circumstances of operation. CPSs are multifunctional systems. In short, the functions should be adaptive to varying environment

C. Aggregate complexity

As mentioned by J. Tavcar and I. Horvath (2018), S-CPS are complex engineered systems. The complexity of CPSs could be attributed to multiple factors, such as: the number of components (Cyberware, hardware, software and network).

D. Cognitive capabilities

CPS is equipped with various form and level of cognitive capabilities, such as reasoning, learning, decision making, etc. These capabilities differentiate S-CPS from other non-intelligent system.

D. Run-time variation

The competence of run-time variation is needed since the operational circumstances may vary in a short time.

To sum up, the operation of S-CPS should be based on run-time acquired data. S-CPS should be multi-functional. These functions should be adaptive to varing environment. The adaptive functions are enabled by cogntive capabilities which include reasoning, learning, etc. In order to achieve the above mentioned capabilities, S-CPS requires the integration of multiple components, so S-CPSs is a complicated system.

2.4.2 Application conditions for S-CPS application

Secondly, we should also know the optimal conditions for applying S-CPSs, so the following research questions should be answered:

RQ7-Under what conditions, the main features of cyber-physical system are really needed?

Karrar Hameed et al (2017) listed several application domain of cyber-physical system. Author assumes that these domains can probably reflect the characteristic of the application opportunities of S-CPS.

A. Example 1-Healthcare

The new advances like cloud computing, wireless sensor network provide CPSs with capabilities to remotely observe the condition of patients and can help in taking right actions regardless of the locations of patients (Haque and Aziz, 2013).

B. Example 2-Emergency management systems (EM)

EM aims at minimize the impact of emergency impact, such as natural diaster. Computer software can be used to identify the disaster and ascertaining the evacuation route and shelters based on the data captured by wirelss senosr networks (WSN).

On the basis of the output from computer software, response in the real world happens in order to handle and resolve the emergency events, such as disaster. The response ususally includes mobilization of emergency services, such as the police, fire fighters, ambulance, etc.

C. Application conditions

From above mentioned two domains, some characteristeristics of application conditions are summarized as follows:

• If situations have to be identified based on the data acquired from real-life process. In order to achieve the identification, the system have to penetrate in real-life process and infer the situation using cognitive capabilities.

• If the actions and response are needed to respond to the dynamic situations happen in the real world process. Penetration in real life allows the system to acquire needed data constantly. Cognitive capabilities enables the provisioning of adpative actions and response.

• If the learning capabilities is required. Obviously, learning capabilities allows the system to learn from the real-life operations so as to allow the system to quickly arrange the adaptive actions for the similar situations next time. Learning process is enabled by cognitive capabilities.

• If the components for sensing (WSN), computing, adapting have to be included in order to be capable of identifying situations and take adaptive actions. The involvement of multiple components lead to the complexity of the system.

The relations between the application conditions and paradigmatic features are visualized as follows:

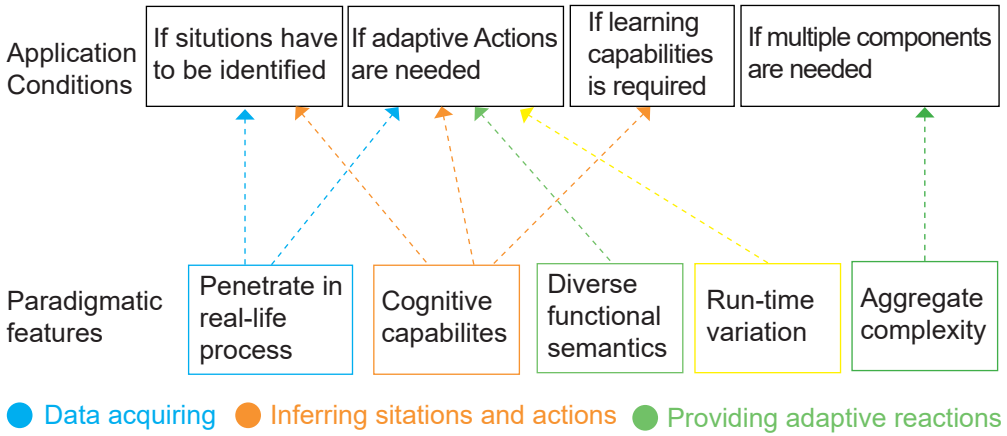


Figure 15-The relation betweem application conditions and paradigmatic features

In 2.4.3, we will figure out how the application conditions and paradigmatic features be applied to implement the needed services.

2.4.3 The bridge between CPS and needed services

Thirdly, we should pave the way to implement the needed services using CPSs. So it would be necessary to figure out how to bridge the application conditions, paradigmatic features with the needed services. Hence the following question has to be anwsered:

RQ8-How can the features and application conditions be applied to implement the services needed for addressing target group's issues?

A. Data, situations and actions

As mentioned in 2.4.2, situations are identified using cognitive capabilities (Reasoning) based on run-time acquired data. So the following aspects should be explored:

1) The data needs to be acquired and technologies for acquiring the data,
2) The situations need to be identified based on the data and technologies for identifying the situations.

In the meanwhile, adaptive actions should be taken in order to respond to identified situations. Hence the following aspect have to be explored:

1) The adaptive actions needed to respond to the situations and the technologies for reasoning the actions.

B. Sensing, reasoning

Obviously, in order to implement the services by S-CPS, there are two types of technologies that have to be explored. The one is technologies for sensing while another is the technologies for reasoning. As shown in Figure 16, sensing is for acquiring data from physical world and reasoning is for identifying situations and reasoning actions in cyber world. So sensing and reasoning represent the essence of Cyber-physical system.

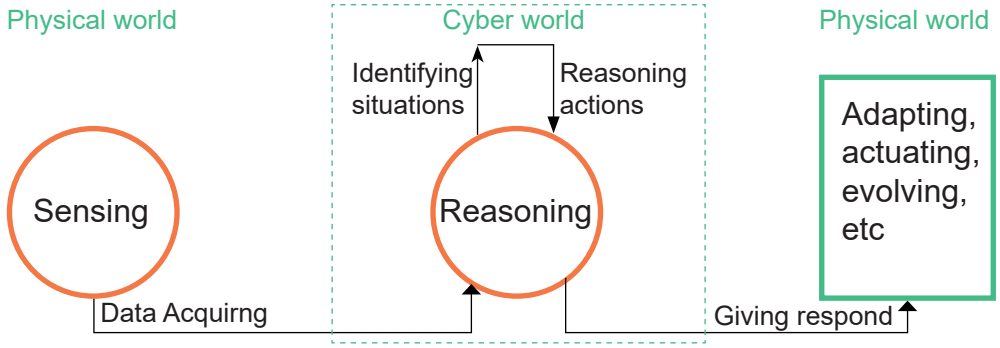


Figure 16-Sensing and reasoning of cyber-physical systems

C. Learning

It worth to mention that learning capabilities is also important for CPS-based solutions. As mentioned in 2.4.2, CPSs have to quickly react to varying real-life situations which requires the system to quickly reason the proper actions. In this case, the learning capabilities allows the system to find out the exisitng actions which is proven to be effective in similar situations.

D. Summary

On basis of the analysis above, two research questions considering sensing and reasoning are elicited. In 2.5 and 2.6, the following three research questions should be answered:

RQ 9-What data can be sensed from real life process? What sensing technologies are used?

RQ10-What situation can be reasoned based on acquired data? What technologies are used to perform the reasoning?

RQ11-What actions can be reasoned based on situation? What technologies are used to perform the reasoning?

(Because learning is usually the treasoning, so when it comes technologies scouting, only the technologies for sensing and reasoning are scounted, but learning capabilities will be considered in conceptualizations session)

2.5 Technologies for implementing the services for training quality improvement (TMI)

The purpose of the 2.5 is to find out the technologies for implementing the services to improve training quality. As mentioned before, the following research questions are answered:

RQ 9-What data can be sensed from real life process? What sensing technologies are used?

RQ10-What situation can be reasoned based on acquired data? What technologies are used to perform the reasoning?

RQ11-What actions can be reasoned based on situation? What technologies are used to perform the reasoning?

2.5 is composed of three parts. The three research questions are distributed in the three parts. The information shown in 2.5 is collected through literature review and website browsing.

2.5.1 Technologies for acquiring data

2.5.1 begins with the assumption which reflects the needed data. The assumption is made based on the services for improving training quality. Then the assumed data are ready, the technologies for acquiring the data are explained.

A. Assumption

A1- Reps, sets and velocity of training should accurately be measured,

A2- Elderly's motions during training should be captured based on which motion quality can be assessed.

A3- As mentioned in 3.3, heart rate is the indicator of fatigue, so heart rate should be capture somehow.

B. Technologies for acquiring data

B1-Technologies for measuring reps, sets, velocity

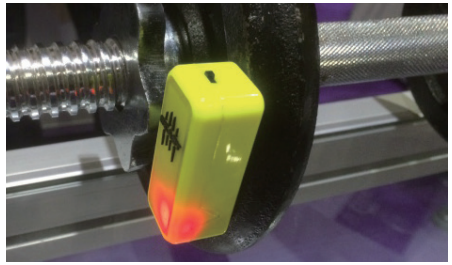


Figure 17-Beast sensors

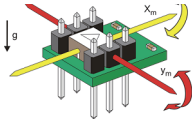


Figure 18-Accelerometers

As mentioned in 2.4.4-B, there are already some commercial products appear in the market for measuring repetitions, sets as well as velocity, such as "Beast sensor" (Figure 25). Beast sensor(BS) is composed of three accelerometers, three gyroscopes and three compass.

B2- Technologies for capturing motions

Figure 19-Kinect

Kinect is a line of motion sensing input devices that was produced by Microsoft for Xbox 360, Xbox One video game consoles and Microsoft Windows PCs. It can be used to capture motions.
Source: https://en.wikipedia.org/wiki/Kinect

B3- Technologies for sensing heart rate

Figure 20-Braclet

According to wikipedia, physical fatigue, or muscle fatigue, is the temporary physical inability of a muscle to perform optimally. Heart rate (pulse) is an indicator of fatigue.
Source:https://www.trainingpeaks.com/blog/follow-your-heart-using-hr-to-gauge-fatigue/

Bracelet or other fitness tracker is obviously the common gadget for monitoring people's heart rate, such as fitbit, Letsfit and applewatch. Source:https://www.verywellfit.com/best-heart-rate-monitor-4157709

C. Summary

C1- Reps, sets and velocity should be captured by the combination of accelerometers, gyroscope and compass.

C2- Motions should be captured using KINECT ™.

C3- Heart rate should be capture using bracelet.

2.5.2 Technologies for reasoning situations

2.5.2 begins with the assumption which is relevant to the situations reasoned based on acquired data mentioned in 2.5.1. Then the technologies for reasoning the situations are explained.

A. Assumption

A1-Obviously, the type of ongoing exercises should be firstly identified because current products can hardly identify the ongoing exercises.

A2-Users' motions quality should be assessed based on captured motions

A3-Users' physical conditions should be assessed somehow,

A4-The level of fatigue should be assessed,

A5-The sufficiency of repetitions, sets should be assessed,

B. Technologies for reasoning situations

B1-Technologies for reasoning type of ongoing exercise

According to Geetanjali Vinayak Kale & Varsha Hemant Patil (2016), humanoid body model uses structural representation and represents a person using his/her joint positions a set of 2-D (X,Y) or 3-D (X,Y,Z) points in space. A different number of joints and their degree of freedom(DoF) are considered for representation of the human pose.

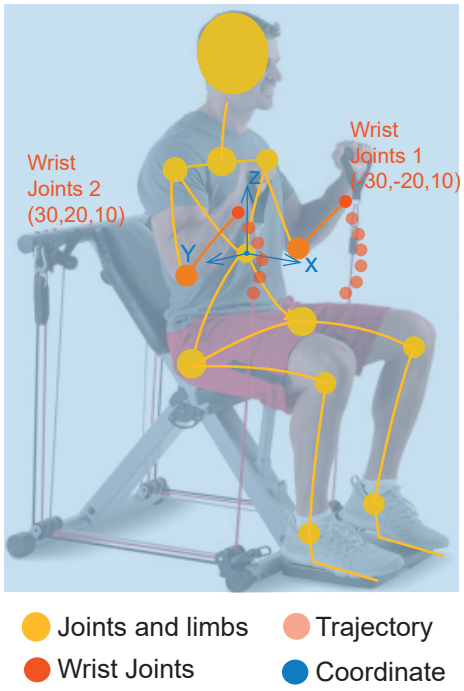


Figure 21- The trajectory of joints can indicate the exercise type

Changes in persons joint positions while performing an action are stored as space-time trajectories. 3-D XYT or 4-D XYZT space time trajectories are used for the representation of these actions (C Rao, A Yilmaz, M Shah 2002). Johansson (1973) also recommended that the tracking of joint position are sufficient for humans to distinguish the actions.

It worth to mention that the trajectory of joints are captured by KINECT V2 and based on trajectory, the exercise type is reasoned using KINECT Studio

B2-Technologies for assessing motion quality

Zhao, W., Lun, R., Espy, D. D., & Reinthal, M. A. (2014, December). proposed a rule-based approach to real time motion assessement for rehabilitation exercises based on the integration of comprehensive kinematic modeling with fuzzy inference.

During the actual execution of a rehabilitation exercise, the similarity between the measured motion data and the kinematic model is computed in terms of their distance. The Architecture of the real-time motion assessment system are shown in Figure 22 and the visualized Kinematic model are shown in Figure 23. The motions are captured by Kinect V2

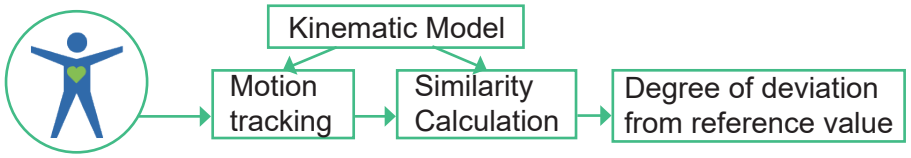


Figure 22-The Architecture of the real-time motion assessment system

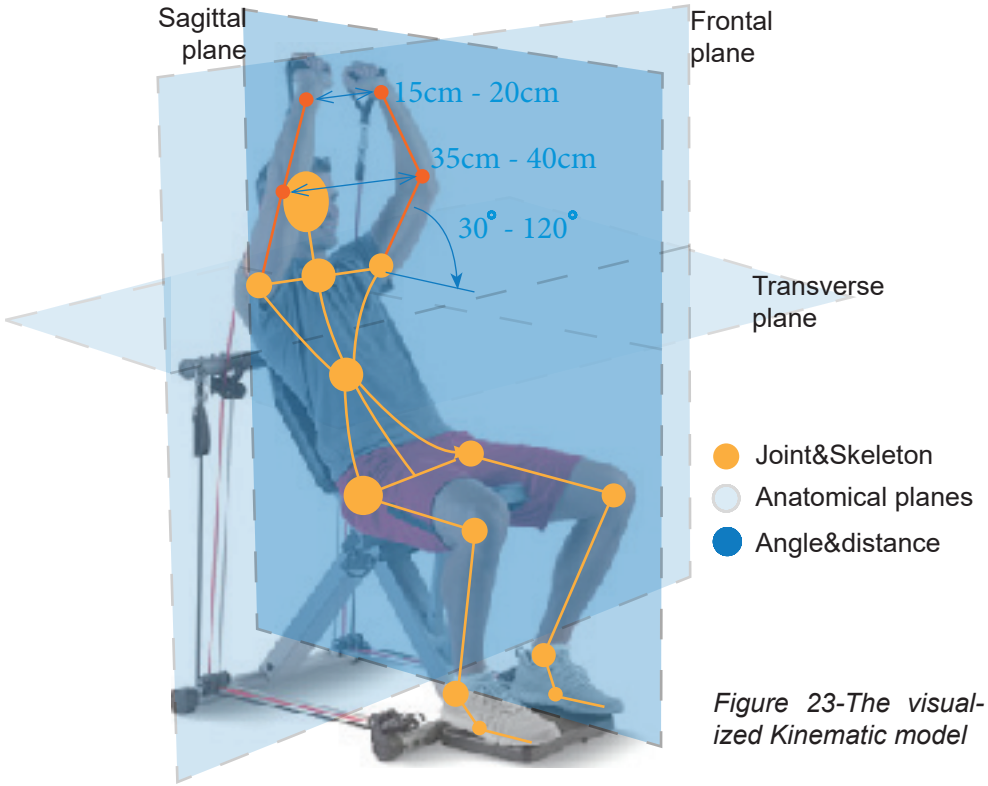
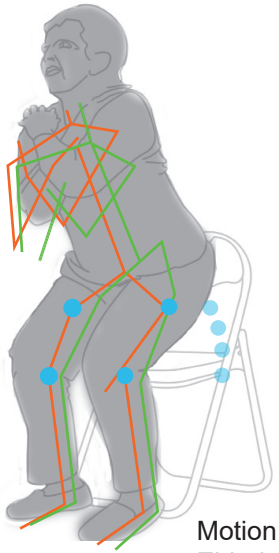
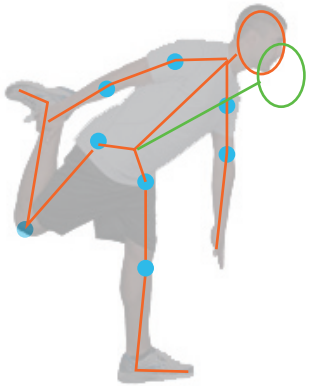


Figure 23-The visualized Kinematic model



Motion 1
Elderly stand from chair and sit back. The quality of this motions can indicate whether users can step of out of bathtub with ease or not.

Figure 24-A



Motion 2
Elderly stand on one leg for couple of seconds.The quality of his posture can indicate the strength of elderly's lower limb

Figure 24-B

B3-Technologies for assessing physical conditions

Kusunoki M et.,al (2018) mentioned that KINECT V2 and Kinect Studio are effective for physical condition assessment. The indicators for physical condition is the quality of moitions. In their study, subject is required to perform 18 sets of motions. These sets of motions were developed to cover nearly all movements of the main parts of the body.

Elderly have to perform these motions repetitively and their motions are captured by KINECT V2 and analyzed using KINECT Sudio (Microsoft). Kinect Studio compares the captured motions of the subject with typical motions of healthy persons. (The motions are represented by the trajectory of joint coordination. The example of the motions can be found on the right:

B4-Technologies for assessing sufficiency of training amount

According to A.Håkanssona et.,al (2015), if the task is to find conclusions for a set of true data, then a deductive strategy(DS) should be used. In order to assessing the sufficiency of training amount, the measured repetition, sets have to be compared with standard, so in this case, deductive reasoning strategy should be used.

B5-Technologies for assessing fatigue

Obviously, the assessment of fatigue should be based on the comparison between the heart rate measured by bracelet with normal heart rate. So in this case, deductive reasoning strategy should be used.

C. Summary

C1-Exercise type can be recognized using tracjectory based approach. The motions are represented by joint trajectories and captured using Kinect V2. Kinect studio can match captured Joint trajectories with specific trajectories of certain exercise, so that the exercise type can be recognized.

C2-Motions can be captured using Kinect V2 and motion quality can be assessed using rule-based approach(RBA). The assessment can be performed by a software named Kinect Studio. It can compare captured motions with standard motions.

C3-The approach used for assessing physical condition is similar to RBA. Elderly are firstly required to perform a set of motions needed for activities of daily living and the motions are captured by Kinect V2. Kinect Studio is used to compare the captured motions with healthy people's motions and infer the weak muscle groups.

C4-Both fatigue and the sufficiency of training amount can be assessed using deductive reasoning strategy. The software and hardware for performing the reasoning will be discussed later.

2.5.3 Technologies for reasoning actions

In 2.5.3, we are going to explore the possible actions that can be reasoned based on the data and situations found in 2.5.1 and 2.5.2. In the meanwhile, the technologies and stategies used for reasoning the actions are also found out.

A. Assumption

A1- The suitable feebacks should be reasoned when target group's motions are not accurate or training amount are not sufficient.

A2- The personalized training plan should be reasoned on the basis of personal physical conditions.

A3- The interventions should be reasoned when fatigue is found in the process of resistance training.

B. Technologies for reasoning actions

B1-Technologies for reasoning feedbacks

The feedbacks are needed when target group motions are found to be wrong or they leave the training with insufficent training amount. The feedbacks should be tailored for specifiic situations.

According to A.Håkanssona et.,al (2015), case-based reasoning(CBR) in cyber-physical systems is applied to provide solutions to stiuations that are based on similar cases.

The feedback could be about i) how can the user correct his/her motions, ii) how many repetitions/sets are still needed. Case-based reasoning (CBR) can be used to choose the content of feeback for specific situations.

B2-Technologies for reasoning personalized training plan

When providing training plan, CBR can be also used to choose proper training plan which is proven useful for other people with similar physical conditions.

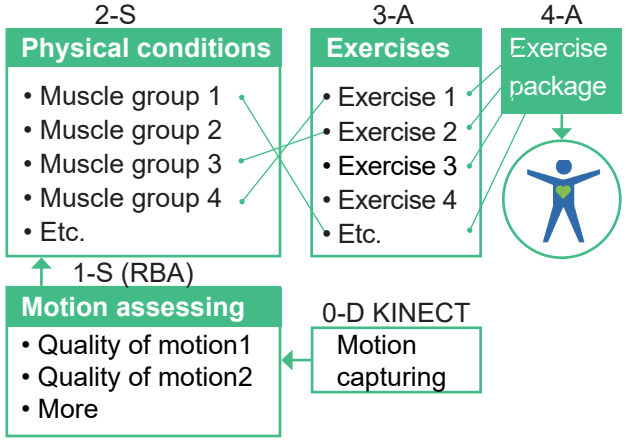


Figure 25- Reasoning process

1.The quality of motions are assessed using rule-based approach (RBA).
2.On the basis of quality of motions, the system decides which muscle group have to be enhanced.
3. System matches exercises with muscle groups using case-based reasoning.
4. System combines multiple exercises into an exercise package and recommends the package to users.

1. D=Data, S=Situation, A=Action

B3-Technologies for reasoning interventions

The interventions are needed when heart rate is found to be abnormal. Obviously, the interventions can be considering two things: i) inquiry about users' feeling, ii) the suggestions about what to do next. The suggestions should be based on feedback to inquiry.

Obviously, CBR can be used to reason the content of inquiry and suggestions. The process is shown as follows:

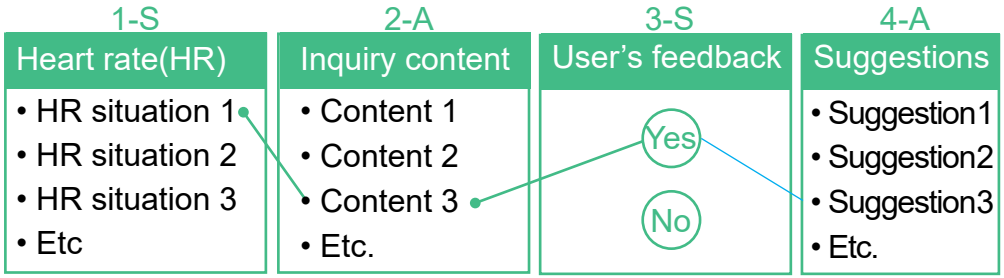


Figure 26- Reasoning process.

1. Heart rate is captured and compared with standard heart rate. The result of comparison can be considered as heart rate situation,
2. System match inquiry content with heart rate situation using case-based reasoning (CBR) strategy,
3. Users' give Yes/No feedback to the inquiry,
4. System matches suggestions with users' feedback using CBR. The suggestions tell users what to do.

C. Summary

Obviously, case based reasoning(CBR) is used for matching:

- feeback content with inaccurate motions and insufficient training amount,
- exercise package with physical conditions,
- inquiry content with heart rate situations,
- suggestions with users feedback towards inquiry content.

2.5.4 Conclusion

A.Data

• Data includes repetition,sets counting, trajectory of joints (indicator of motions and heart rate capturing).

B.Situation

• Based on the captured motions, three situations can be reasoned: 1) exercise type identification, 2) physical condition assessment, 3) motion quality assessment. The first on can be identified using trajectory based approach (TBA). Second and third one can be assessed using rule-based approach(RBA).

• The level of fatigue and the sufficiency of training amount can be reasoned using deductive reasoning(DR)strategy. (Comparing the captured fatigue and amount of training with standard value)

C.Actions

• Case-based reasoning (CBR) strategy can be used to reason: i) feedback content when users' motions are found to be wrong or when users leave their training without completing their training tasks, ii) personalized training plan based on physical condition, iii) inquiry content when users' level of fatigue is high. iv) suggestions about what to do when fatigue is detected.

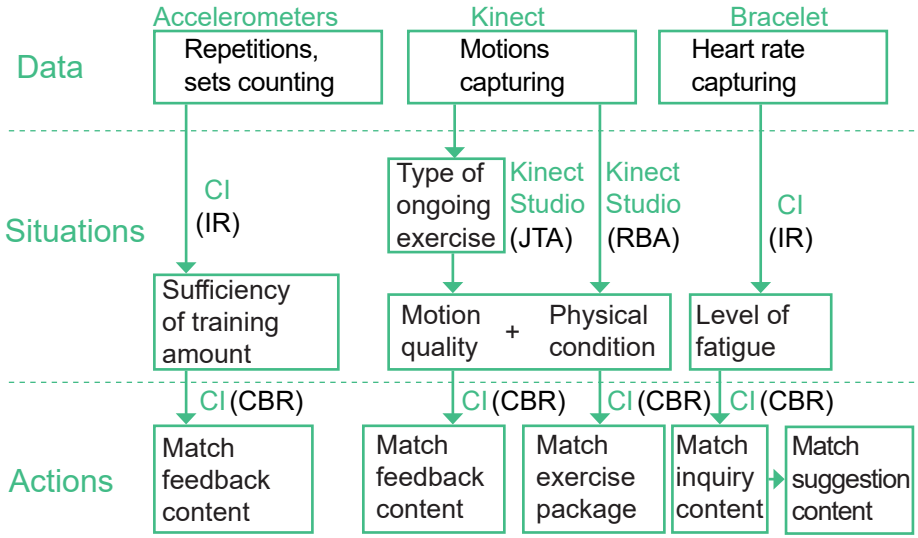


Figure 27- Overview of data acquring, situations and actions reasoning as well as the relevant technologies

1. D=Data, S=Situation, A=Action

2.6 Technologies for implementing the services for enhancing enjoyment and motivation.

The purpose of the 2.6 is to find out the technologies for implementing the services for enhancing enjoyment and motivation. Same as in 2.5, the following research questions have to be answered in 2.6:

RQ 9-What data can be sensed from real life process? What sensing technologies are used?

RQ10-What situation can be reasoned based on acquired data? What technologies are used to perform the reasoning?

RQ11-What actions can be reasoned based on situation? What technologies are used to perform the reasoning?

There are also three parts in 2.6. The three questions will be answered in this three parts respectively. The information in 2.6 is collected through literature review and website browsing.

2.6.1 Technologies for acquiring data

2.6.1 begins with the assumption which is relevant to needed data based on the services for enhancing enjoyment and motivation. Then the technologies for acquiring the data are explained.

A. Assumption

A1-As mentioned in 2.3, TG's level of enjoyment in the process of resistance training (RTs) may be associated with their motivation and long-term adherence to the training. Author assume that moods could be the indicator of enjoyment, so moods should be captured somehow.

A2-As mentioned in 2.3, indoor temperature and humidity are usually associated with elderly's enjoyment. Hence, indoor temperature and humidity should always be sensed.

A3-As mentioned in 2.3, visual motivational message should attract TG's attention. So the indicator of elderly's focus attention should be sensed and assessed somehow.

B. Technologies for acquiring data

B1- Technologies for capturing and processing TG's moods.

Webcam is the most commonly used tool for capturing the movement of people's facial muscle.
Source:https://www.mathworks.com/matlabcentral/fileexchange/61613-real-time-face-recognition-with-webcam-using-pca

Figure 28-Webcam

Insight software development kit (SDK) can be used to analyze the single user in controlled environment. Uniquely combines emotion recognition, demographics and eye tracking technologies in one solution. Insight SDK can track subtle movements of facial muscles in a single users' face and translate it into facial expression like: happiness, surprise, sadness, anger, fear, etc.

Source:http://sightcorp.com/insight/

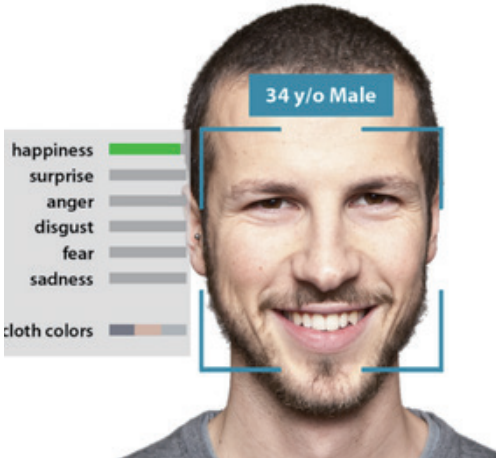


Figure 29-Face muscle analyzing

B2- Technologies for sensing indoor temperature/humidity.

Xiaomi Mijia sensor is used to check the home temperature and humidity anytime and anywhere to create a comfortable environment.

Source:https://www.banggood.com/Xiaomi-Mijia-Bluetooth-Thermometer-Hygrometer-with-LCD-Screen-Magnetic-Suction-Wall-Stickers-p-1232396.html

Figure 30-Xiaomi Mijia bluetooth temperature & humidity sensor

B3- Technologies for sensing and modeling focus attention.

R.Stiefelhagen et.,al (2002) proposed that identifying human gaze or eye-movement ultimately serves the purpose of identifying an individual's focus of attention.

K,Wang and Q.Ji proposed to perform gaze tracking with consumer level depth sensor (KINECT). In the meanwhile, Kinect Studio is able to perform facial landmark tracking, from which we can obtain the rough regions of left and right eyes.

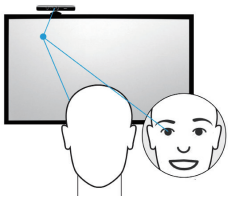


Figure 31-Gaze capturing

C. Summary

C1-The intuitive indicator of enjoyment is positive mood which can be reflected by movement of facial muscle. The movement is captured by webcam and processed by Insight SDK.

C2-Xiaomi Mijia bluetooth temperature and humidity sensor is used to sense temperature and humidity.

C3-The indicator of people's focus of attention is the coordinate of the gaze position. Kinect ™ or Kinect V2 can be used to track gaze.

2.6.2 Technologies for reasoning situations&actions

Because all the services are for increasing target group's positive moods. So the common situations are target group's moods. Hence in 2.6.2, we only have to consider what actions are needed.

A.Assumptions

A1-As mentioned in 2.3, music provisioning can contribute to improve TG's negative moods. So author assumed that the system should be able to reason what music can effectively contribute to reduce target group's negative moods.

A2-As mentioned in 2.3, the adjustment on lighting parameters (e.i color temperature and brightness) can possibly lead to mood change. So it might be necessary to reason the parameters of lighting for increasing positive moods.

A3-As mentioned in 2.3, the indoor temperature and humidity can also influence TG's mood. The ideal range of temperature is 22-26 ° while the ideal humidity is around 54%. So the system should be able to reason if the adjustment of T&H is needed or not.

A4-As mentioned in 2.3, the motivational message are always needed for motivating target group, but at the same time, the system should be able to reason i) the effective content of the message, ii) the effective way of conveying the message.

B. Technologies for reasoning situation and actions

B1-Technologies for reasoning the music for increasing enjoyment

BJ Han, S Rho, S Jun, E Hwang (2010) proposed a system which is for mood classification and context-based Music Recommendation. The steps of this system is briefly introduced as follows:

S1.The music is recommended on the basis of people's listening history.

S2.The system extract and analyze seven features from listened music.

S3.The system predicts the arousal and valence of each music.

S4.The system labels the music with different moods (B5)

S6.When situations (e.i: the user is late and feels frustrated) happen, the system could recommend the music labelled with positive moods to user.

The visualized workflow of the system can be found on the right (Figure32)

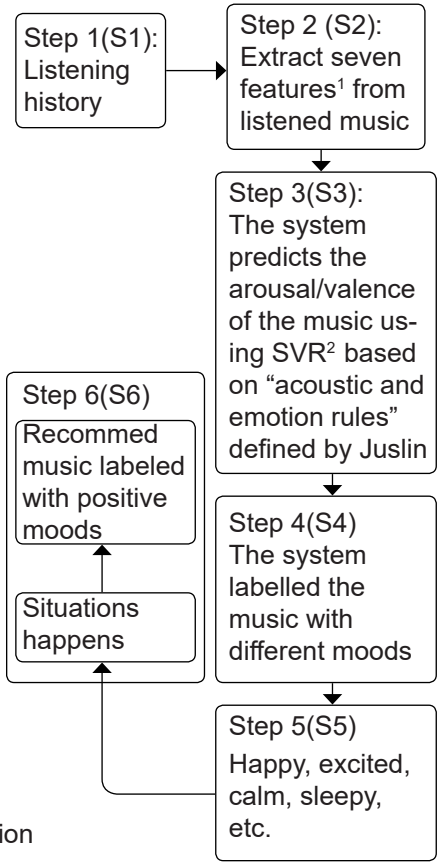


Figure 32-Context-based music recommendation

Obviously, the music recommendation system mentioned above can be a good reference in this thesis. On the basis of the system, author develops a reasoning model for inferring the music which can contribute to change elderly's mood.

The recommended music are still selected from users' listening history. The listened music are labelled with various moods.

When target group's negative moods are detected, the music labelled with positive moods are recommended to target group. When the music is provided, if users' positive moods are detected, the features of the music will be saved. The features may include: tempo, rhythm as well as genre, etc. If no positive moods is detected, the features will be adjusted. If positive moods are still not detected. the music would be changed.

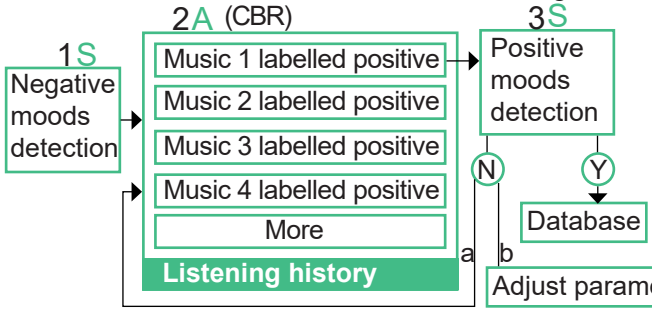


Figure 33- Reasoning process

B2-Technologies for inferring proper parameters of lighting to increase the enjoyment of indoor environment.

As mentioned in 2.3, lighting adjustment can contribute to increase people's enjoyment. However, before the adjustment on lighting, several situations have to be taken into account. These situations may include: weather conditions, time period, etc.

In this case, inductive reasoning strategies(IR) should be used to reason the situations which may lead to TG's negative moods. A. Håkansson et.,al (2015), in inductive reasoning, the system can request for more data from the devices and rules needed for increase the certainty of the conclusion. When situation reasoning is done, Case-based Reasoning (CBR) can be used to infer the proper parameters of lighting to increase the enjoyment of the indoor environment.The reasoning process can be found in Figure 34.

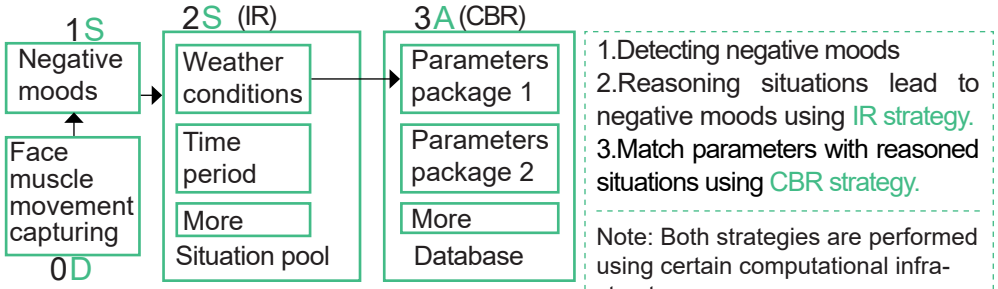


Figure 34- Reasoning process

1. D=Data, S=Situation, A=Action CBR=Case-based reasoning

B3-Technologies for reasoning whether the adjustment on temperature and humidity is needed

The preference on music, lighting vary from people to people. However the ideal temperature and humidity is relatively fixed for people. Hence, if the system want to know whether the adjustment on temperature and humidity is necessary, the reasoning process would be very simple. The reasoning process are shown as follows (Figure 35):

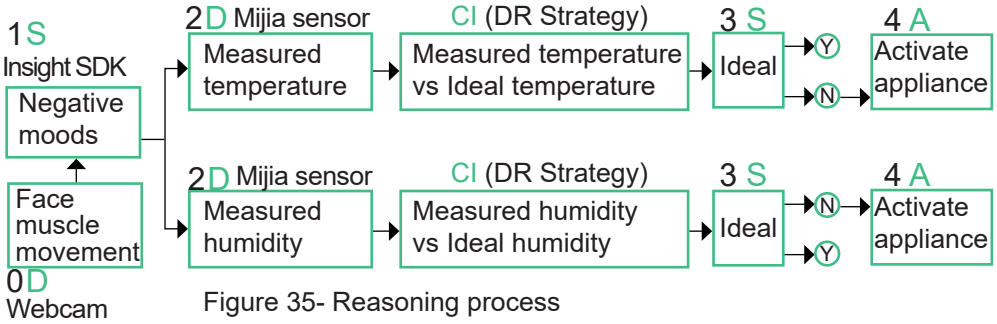


Figure 35- Reasoning process

1- Detecting negative moods using webcam and insight SDK,
2- Measuring temperature and humidity using Xiaomi Mijia sensor(T&H),
3- Using deductive reasoning strategy to reason whether indoor T&H are ideal or not,
4- if not the relevant appliance should be activated.

Notes: Deductive reasoning (DR) strategy could be performed by certain computational infrastructure

B4-Technologies for reasoning the motivational message which can effectively motivate the individual users.

Unlike music provisioning and lighting adjustment, motivational message can always be provided once negative moods are detected. All of the motivational message content saved in the database can be selected to users. System can reason which message content can effectively motivate target group by observing users' mood change. The reasoning process is shown on the right:

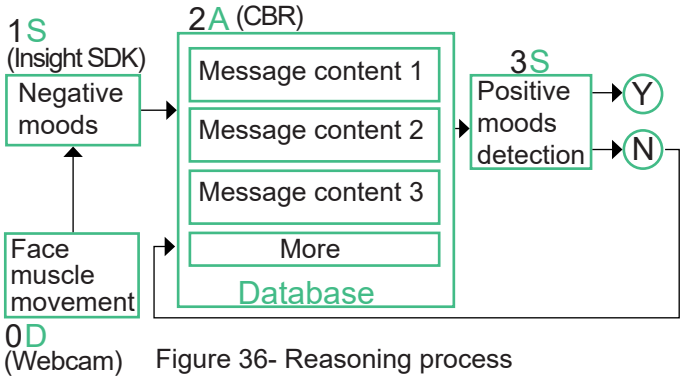


Figure 36- Reasoning process

1-The negative moods are detected. (Eg: Boredom)
2-System matches message content with negative moods using case-based reasoning strategy
3-If postive moods are detected, the message will be recognized as effective.If no positive moods are detected, the content will be changed.

The message have to attract target group's attention. When it comes to providing visual message, the position of visual message should overlap with target group's gaze position. If visual message fails to get attention, Other format of message should be given, such as audio message

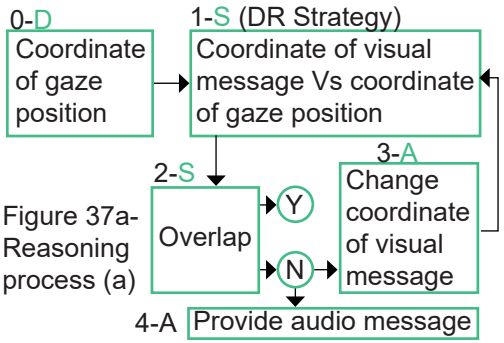


Figure 37a- Reasoning process (a)

1- System compare the coordinate of visual message with gaze position using deductive reasoning (DR) strategy.
2- The comparison can indicate whether the two are overlap or not.
3- If not, the coordinate of visual message will be changed.
4- Another option for attract attention is to provide audio message.

As mentioned in 2.3, people should also be invited to provide motivational message. But the system have to decide who should be invited to provide the message.

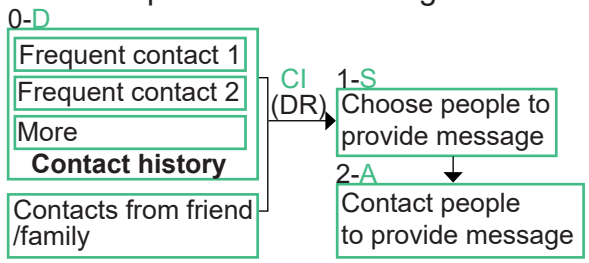


Figure 37b-Reasoning process (b)

0-Frequent contacts and the contacts from friend and family can be found in users' phone.
1-Based on the two, the system can choose people using deductive reasoning,
2-The system then contact the people to offer message.

D=Data, S=Situation, A=Action CI=Computational infrastructure

C.Summary

C1- Inductive reasoning(IR) strategy is used to reason the situations that may lead to target group's negative moods.

C2- Case-based reasoning (CBR) is still the most commonly used strategy to match the proper parameters (e.i brightness, color temperature) of lighting, content of motivational message with specific situations, such as negative moods, bad weather, etc.

C3- Deductive reasoning(DR) strategy is used to reason whether the indoor temperature and humidity should be changed by comparing the measured temperature and humidity with standard.

C4- Deductive reasoning (DR) strategy is also used to reason which one from contact history should be invited to provide motivational message

C5- The three reasoning strategies (IR, CBR, DR) are performed using certain computing infrastructure.

C6- The music are extracted from target group's listening history. Some music are labelled positive using Support Vector Regression(SVR). When

2.6.3 Conclusion

A.Data (D) acquring and relevant technology

Generally speaking, three data can be captured by sensors. They are i) movement of facial muscle captured by webcam, ii) the coordinate of gaze position catpured by Kinect ™ as well as iii) indoor temperature and humidity measured by Xiaomi mijia sensor.

B. Situations and actions reasoning and technologies

Obviously, moods are the most important situations for indicating whether users feel enjoyable. It is reasoned based on facial muscle movement captured by webcam and processed by Insight SDK.

Inductive reasoning (IR) strategy is used to reason the situations lead to negative moods while deductive reasoning (DR) strategy is used to assess users' focus attention and the indoor T&H based on the gaze coordinate tracked by Kinect and Xiaomi mijia sensor.

Case-based reasoning (CBR) strategy is used to reason the actions for reducing negative moods. The three reasoning strategies are performed by certain computational infrastructure.

The following figure shows the overview of data, situation, action, relevant technologies as well as reasoning strategies:

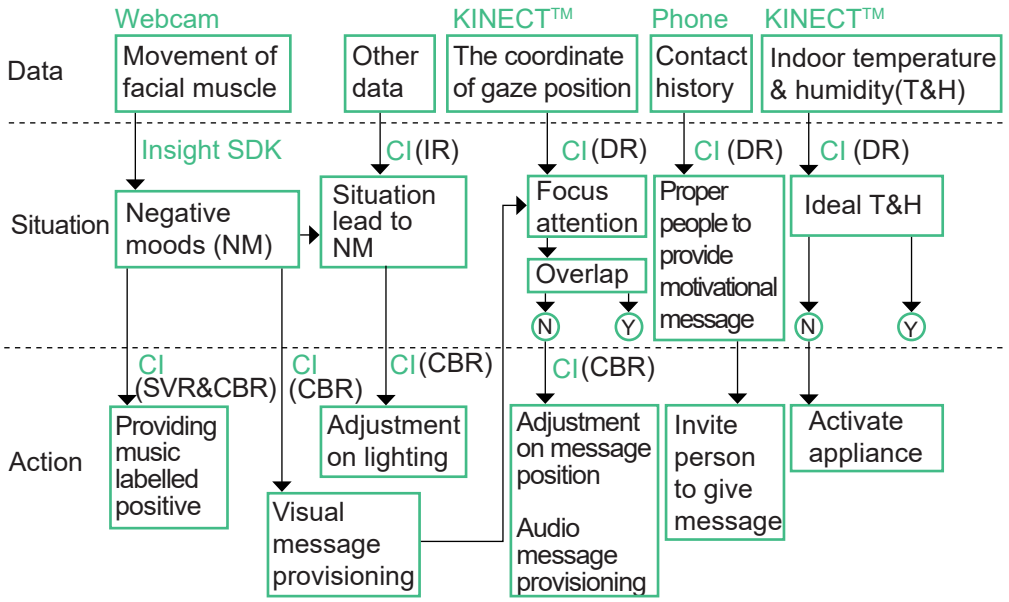


Figure 38-The overview of data, situation, actions and relevant techologies

Obviously, the functions mentioned in 2.5 and 2.6 are still independent. Some of them will be integrated in order to create a cyber-physical system. Before integrating these functions, we should firstly figure out the added value of using cyber-physical systems(CPSs). The added value can be translated into the expectation towards CPS-based concept Hence in 2.7, the added value of CPSs and the expectations towards conceptualisation are explained.

1. D=Data, S=Situation, A=Action CI=Computational infrastructure

2.7 Added value and expectations

As mentioned before, designing a complicated system is not the aim of this thesis. So at the end of exploration part, it is necessary to prove the added value of applying cyber-physical systems in the context of supporting target group's resistance training(RT). Hence the following research question has to be answered:

• RQ11- What are the added value when using cyber-physical system (cps) in the context of supporting resistance training (RT)?

The added value can be transformed into the expectations towards the conceptualization session. In the meanwhile, some findings in 2.3 can also be translated into expectations. So the following research questions will be answered

• RQ12-What are expections towards to CPSs-based concept on the basis of the findings in exploration part?

2.7.1 The issues in supporting training and necessity of CPSs

2.7.1 aims at finding out the added value of CPSs in supporting RT. The informations are extracted from the findings from 2.4-2.6

A. Network integration to address multi-faceted issues

According to the findings from the focus group interviews as well as literature review, achieving a successful resistance training requires the consideration of multiple following issues:

- The suitability of the training plan performed by elderly,
- Target group's performance in their resistance training,
- The sufficiency of target group's amount of training,
- Level of target group's motivation during the training,
- Level of target group's enjoyment during the training,
- Target group's long-term motivation in resistance training participation,

Obviously, a standalone product or system can hardly address all of the above mentioned issues. According to the finding from literature review, current relevant products are either focusing on improving users' quality of exercise, or addressing the issues of enjoyment, joyfulness. We can barely see products or systems which are designded for hoslitically addressing multi-faceted issue related to successful training. On the other hand, some relevant technologies for addressing specific issues have not commercialized yet. Hence, a networked system are needed which integrates the capabilities of multiple products, system in order to holisitically address multi-faceted issues. Obviously CPSs is an option in this case.

B. Sensing the data from changing real-life situations

As mentioned in 2.4, the real-life situations are always changing, so it is necessary to constantly sense/monitor the changing situations by acquiring data, such as the followings:

- the motions (indicator of physical conditions and training performance),
- the moods (indicator of enjoyment and motivation)
- heart rate (indicator of fatigue which reflect suitability of training).

On the basis of the acquired data above, the changing situations can be reasoned, in the meanwhile, the adpative actions can also be reasoned to react to the changed situations.

C. Adpative actions to react to changing situations

As mentioned above, real-life situations are constantly changing. For example, physical conditions, moods as well as health conditions can hardly be static. In this case, adaptive actions are needed to react to the changing situations, such as: the updating training plan to respond to changing physical conditions, the personalized motivational interventions to react to changing moods.

Obviously, some changes happened suddenly and subtly, such as mood change. In this case, elderly can hardly even realize the change, but it does not mean the actions/interventions are not needed. Hence cognitive capabilities of CPSs are needed to reason i) the sudden situation change and ii) the adaptive actions to react to the change.

D. Learned actions to react to similar situations

As mentioned above, the quick reasoning of interventions are sometimes needed to react to changing situations, so it is necessary to find out the existing actions/interventions which are proven to be effective in similar situations. In this case, learning capabilities of CPSs are needed to learn the effective actions for various situations.

1. In subsequent parts, interventions is equivalent to actions.

Obviously, network integration, sensing, reasoning and learning are the four pillars of cyber-physical system. The advantage brought by the four pillars can be summarized as follows:

- The network integration of components allows the system to address the issues belong to multiple realms. Addressing these issues can lead to successful resistance training. Addressing multi-faceted issues can hardly be achieved using stand alone product or system.
- The technologies of sensing, reasoning allows the system to quickly recognize and react to changining situations like moods, physical conditions as well as heart rate.
- It worth to stress that some changes of situation are subtle and suddenly happen, such as moods. People can hardly observe and realize the changes, not to mention have reaction to the changes. Only the system possess the cognitive capabilities can realize the situations and reason the adaptive reactions.
- Learning capabilities can contribute to save and provide actions which are proven to be effective in similar situations. Learning capabilities of CPSs allows the quick reaction to suddenly happend situation, such as moods.

2.7.2 The expectation towards the concepts

On the basis of the added value of cyber-physical system and list of service requirements (2.3), the expectation towards the concepts are extracted.

A. Functions integration

In 2.5 and 2.6, several technologies-based functions for sensing and reasoning were proposed. As mentioned above, CPSs is the network integration of multiple devices, apps, applicances or even systesms which possess the capabilities of sensing, reasoning as well as actuating. Hence, one of the most important task in conceptualisation is to find ways to properly combine these functions.

B. Functions categories

As mentioned above, in order to be able to achieve successful resistance training, multiple aspects have to be taken into account. The functions have to cover the aspects of training management, motivation and enjoyment enhancement.

C. Sensing and monitoring changing situations

The concept should be able to sense and monitor the motions, moods as well as heart rate. The indicator of motions is trajectory of motions. Movement of facial muscles indicates users' moods.

D. Adaptive interventions

Adaptive interventions can most likely reflect the advantage of cyber-physical system. So the adpative interventions should be included in all the concepts generated in conceptualisation phase. In the exploration phase, we have already known that the adaptive interventions include personalized training plan, motivational message as well as parameters of lighting, music which can contribute to change users' moods.

E. Learning capabilities

As mentioned above, case-based reasoning(CBR) strategy is used to reason the adaptive actions/interventions. And learning capabilities are the enabler of CBR.So the learning capabilities should be highlighted in the concepts generated in conceptualisation phase.

F. The exergaming elements

The exergaming elements were mentioned in list of service requirements. Every users should have their own avatar and elderly's training can lead to the growth of avatar. The grown avatar can compete and cooperate with each other

G. The general experience

As mentioned in 2.3, users needs suggestions on training plan, concerns about their feelings, and encouragement when they get bored. So it seems that a users need a companion to give them holistic concern.

Obviously, the expectations above can be translated into design goal, interaction vision as well as part of list of requirements(LoR). In the meanwhile, the list of service requirements proposed at the end of 2.3 should also be taken into account when formulating interaction vision and LoR.

3.1 Brief Introduction

In Chapter 2, several technology-based functions have been proposed. These functions can either be helpful to optimize TG's quality of resistance exercises or contribute to enhance TG's motivation and enjoyment during their training.

The main objective in Chapter 3 is to conceptualize a Cyber-Physica System(CPS) which is the synthesis of some above mentioned technologies-based functions. In the meanwhile, the interaction between CPS and potential users should also be taken into account.

3.1.2 Procedures

A. Design goal, interaction vision and list of Requirements(LoR)

Before starting to find out three directions for concept generation, a design goal, an interaction vision as well as a list of requirements have to be firstly formulated on the basis of the expactation shown at the end of the exploration phase (Chapter2).

The design goal indicates the general objective we want to achieve in the generated concept while interaction vision tells people the expected quality of user-system interactions. Finally, list of requirements should indicate the important characteristics that design should meet.

B. Find out 3 design directions for concept generation(CG)

Several how to's questions are proposed on the basis of design goal, interaction vision as well as the LoR. Three directions will be formulated based on the how to's questions.

C. Concept generation

Three concepts are generated on the basis of the three directions. The three concepts are explained using brief use case scenario which are followed by the explaination about the relevance of this concept to CPSs.

D. Concept selection&modification

When the three concepts are ready, the most interesting concept is selected, in the meanwhile, some interesting features from other unselected concepts can also be retained. In concept selection session, harris profile is used. The respondents include informal caregivers and gerontologist.

The visualized procedures of conceptualisation can be found as follows:

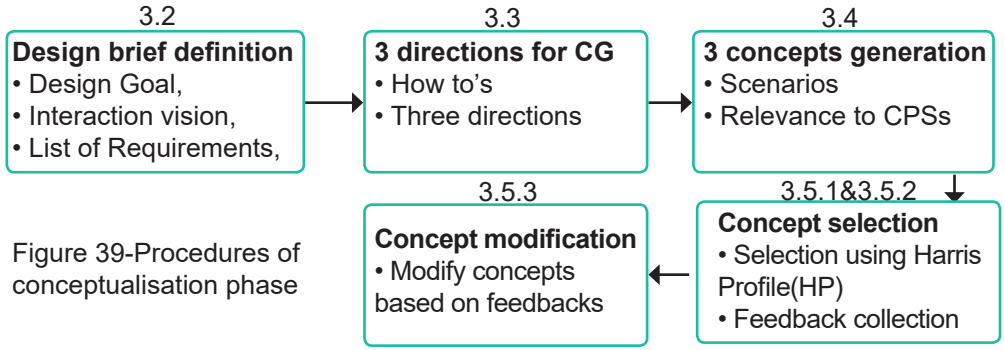


Figure 39-Procedures of conceptualisation phase

3.1.3 Persona

According to Delft Design Guide, persona are archetypal representations of intented users, describing and visualizing their behavior, values and needs. Some persona are shown as follows:

- Tom
- 76 years old,
- Not fit due to sedentary lifestyle,
- Went to gym twice a month, but the main intention is to make friends

• Andrew
• 80 years old,
• If weather is good, he usually goes to gym once a week,
• Bad weather usually hold him back

• Frank
• 83 years old,
• Barely go to gym,
• He sometime performs resistance training at home using elastic,

• Laurens
• 81 years old,
• Regularly go to gym,
• Only perform aerobic exercises,
• The resistance training is boring in his opinion

Three out of four persona will be used as the protagonist in the scenarios of the three concepts.

3.2 Design Brief

3.2.1 Design Goal

Accoriding to the expectations mentioned at the end of exploration phase, CPSs based concept should address multi-faceted issues and functions should be relevant to i) training management, ii) motivation and enjoyment enhancement, etc. The system should be able to sense the real-life data and reason the situations.in the meanwhile, the adaptive interventions are needed to react to changing situations. Finally, learning capabilities should be stressed because it is important for quick reaction to changing situations. On the basis of the expectations, the design goal are shown as follows:

“ Conceptualize a CPS-based digital trainer (CPS-DT) which monitors, assesses, improves TG’s training quality, and optimzes the training environment ,as well as gives quick motivational interventions so as to reduce elderly users’ negative moods.”

Besides design goal, an interaction vision should be needed which can indicate the expected interaction quality of user-product interaction.

3.2.2 Interaction vision

According to the expectations towards the general experience, the following interaction vision is formulated:

Create a digital companion which provides quick reactions to the situtions like: wrong motions, negative moods as well as the abnormal heart rate, so as to make user feel that they get concern from the CP-DTS (Ambient intelligent system)

When design goal and interaction vision are ready, a more elaborated description about the expected characteristics of design are needed. So a list of requirements(LoR) is described in 3.2.3.

3.2.3 List of Requirements(LoR)

According to Delft Design Guide, LoR states the important characteristics that our design must meet in order to be successful. As mentioned in exploration part, LoR is formulated on the basis of the expectations mentioned in 2.7 as well as the list of service requirements mentioned in 2.3.

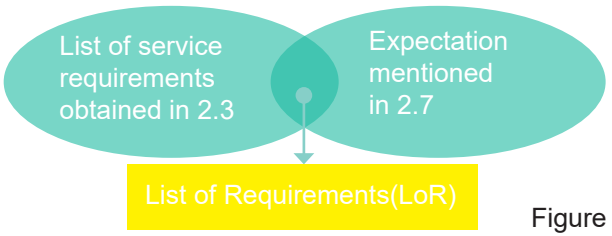


Figure 40-How LoR is formulated

A- General function categories

The following categories of function should be included in the concept:

A1. Functions are needed to manage TG's training and improve their training quality.

A2. Functions are also needed to increase TG's level of enjoyment as well as motivation in the process of training,

A3. Exergaming elements should be included so as to keep TG motivated in a long term.

B- Relevance to cyber-physical systems

B1-The concept should be the network integration of the functions of multiple products, systems and APPs.

B2-The concept should be able to sense and monitor the real-life process such as: i) motions, ii) moods, iii) heart rate as well as vi) indoor temperature etc.

B3- The adaptive interventions have to be included in the concept. The interventions can include: i) personalized training plan, ii) preferred music, iii) guidance for correcting motions, vi) motivational message,etc.

B4-The concept should be able to learn from real-life process.

C- Exergaming elements

C1-Target group's resistance training should lead to the transformation of the avatar in the game world.

C2-The transformed avatar should be allowed to participate the competition or cooperative tasks online.

C3- Users should be allowed to choose his/her preferred character in the game world. (This is added by author)

D-Experience

D1-The wearable sensors should be avoided if possible.

D2-Target group should be allowed to mimic the motions of the digital trainers shown on the screen,

D3-The visualized training plan should be shown on the screen, so as to remind target group: i) how much training they have completed and will complete.

D4-All of the actions/interventions happen in the physical world should not be intrusive, otherwise potential users would have negative impression towards the system.

D5-The audio interventions should be conveyed by human's voice instead of robotic voice.

E-Other

E1- The concept should be used for home-based resistance training instead of gym-based because author assumes that some adaptive actions can hardly be used in public context.

E2- There should not be too many specfic hardwares and softwares which requires specific person to install them for users. This requirement is not relevant to the finding from exploration but author's assumption. Author assumes that too many hardwares and softwares would affect the desirability of the concept in potential users.

3.3 Design directions

In 3.2, three design directions are formulated on the basis of design goal, interaction vision as well as list of requirements(LoR). Obviously, the difference among the three directions lies in not only the dffierent combination of technology-based functions, but also the expected experience that the CPS-DT can bring to elderly.

3.3.1 “How tos questions” based on LoR

As aforementioned, the main objective of phase 3 is to conceptualise a CPS by synthesizing functions proposed in exploration phase. So the first "how to question" should be as follows:

1.How to coherently synthesize the diiferent technology-based functions (improving training quality, enhancing motivation as well as increasing enjoyment) together.

The main objective of this thesis is to generate a multifunctional digital trainers, so the “how to question“ should be as follows:

2. How to properly combine the functions for improving training quality and the functions for enhancing motivation together?

As mentioned in LoR, all of the actions/interventions happen in the physical world should not be intrusive, so the following "how to question" should be answered:

3.How to unintrusively provide interventions (e.i: guidance, reminders, lighting, music) to potential users?

As mentioned in interaction vision, CPS should be like a companion who can give guidance, encouragement as well as concern. So the following how to question should be answered:

4.How to make target group feel that CPS is a companion instead of a robot and system?

On the basis of the 2nd-4th how to questions, three design directions are formulated in 3.3.2.

3.3.2 Three directions

On the basis of the “how to questions”, three directions are proposed and shown as follows:

A. Training supervision + motivation enhancing

The focus of this direction is on managing training amount and quality. In the meanwhile, the motivational message and music are provided when users’ negative moods are detected. The learning mechanism(SLM) is mainly used to learn the most suitable training plan for specific user and the music which can contribute to increase user’s enjoyment.

B. Joyful training experience

The focus of this direction is on delivering training guidance, motivational message as well as the interventions for increasing enjoyment in a joyful and unintrusive way.

C. Fitness companions

The focus of this directions is on creating a digital companion which gives concern and interventions in following conditions:
1) if users’ motions are found to be wrong,
2) if the abonormality of users’ heart rate are detected,
3) if users’ negative moods are found.

3.4 Concept Generation

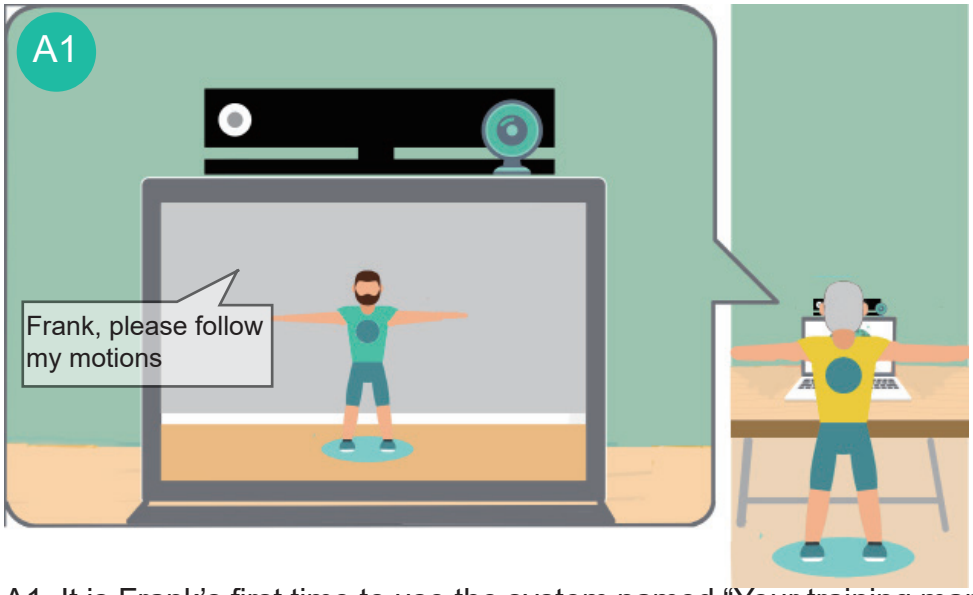
In 3.3, three directions have been proposed. Based on the three directions, three concepts are generated. All of three concepts are manifested using use case scenarios which can clearly present how users come across the whole system and get benefits.

In the meanwhile, the relevance of each concept to cyber-physical system will also be elaborated. The relevance is explained in terms of the aspects like: sensing, reasoning, actuating as well as learning.

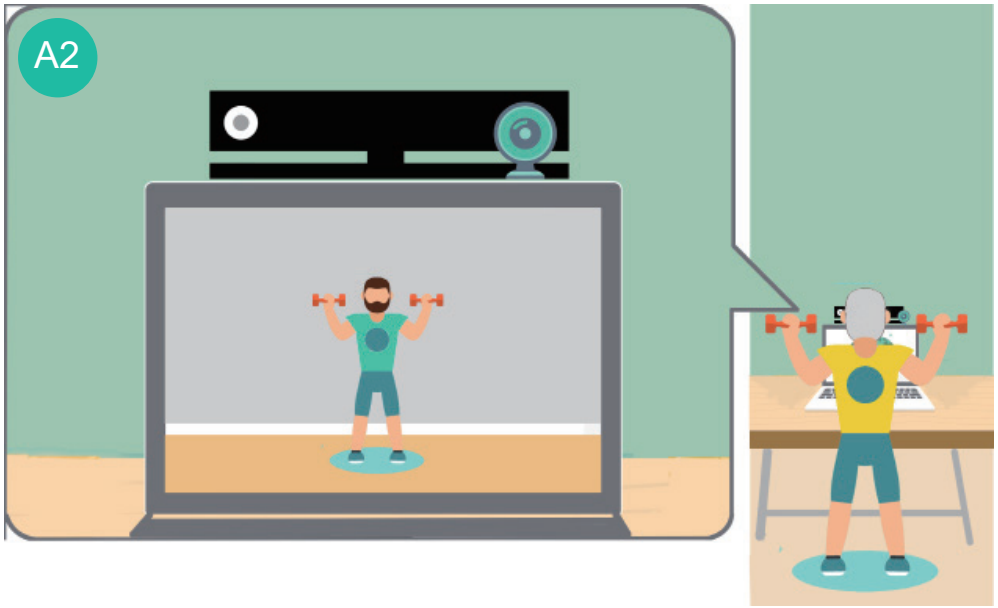
3.4.1 Concept One--“Your training manager”

As mentioned in 3.3, the focus of concept one is mainly on “Training management. But at the same time, the issues considering enjoyment and encouragement is also addressed

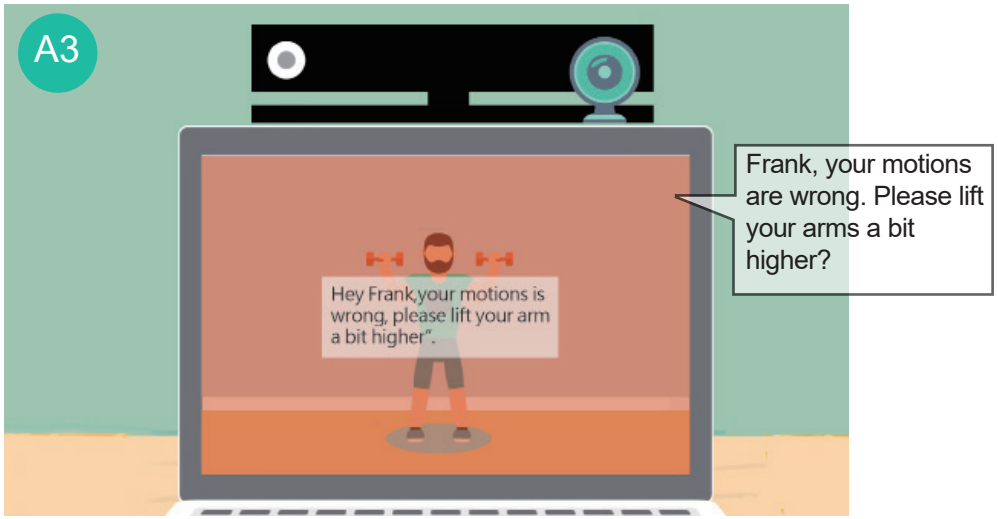
A. Scenario



A1. It is Frank’s first time to use the system named “Your training manager”. So the virtual trainer guides Frank to perform a set of motions and assesses his physical conditions.

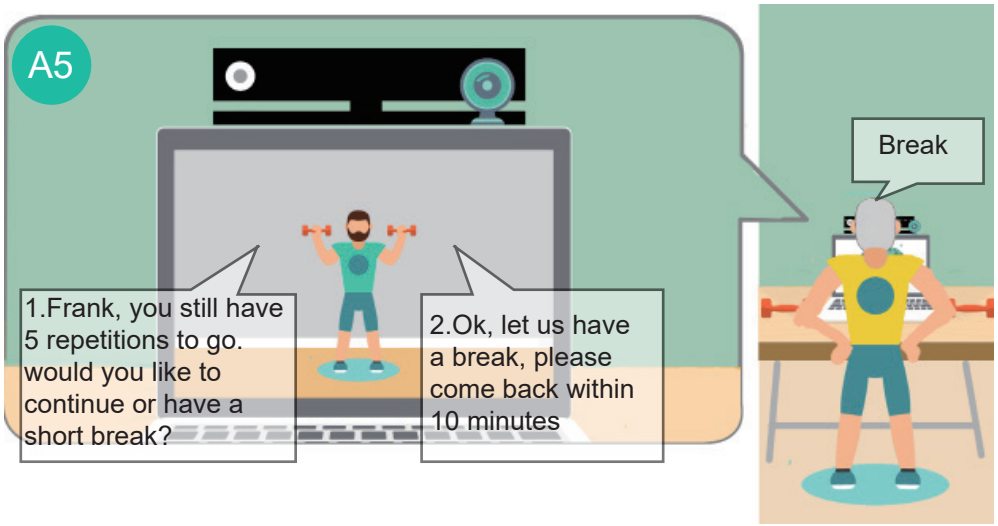


A2. When training plan is ready, Frank starts to follow trainers’ motions shown on laptop screen.

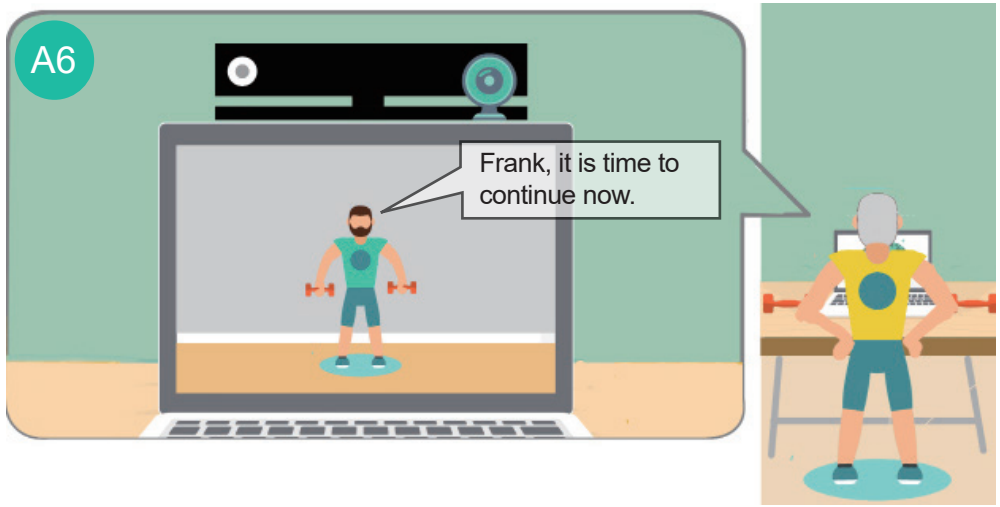


A3. Frank is unfamiliar with the training, so his motions can not meet the standard. So the background of the laptop screen becomes red and a paragraph appears says that :” Hey Frank,your motions is wrong, please lift your arm a bit higher”.

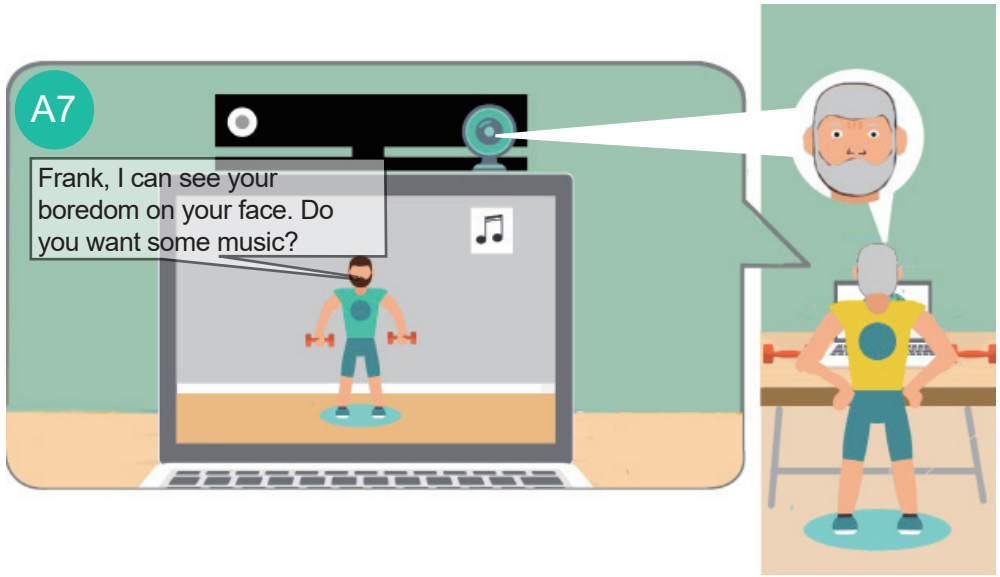
A4.Frank corrects his motions and the screen recovers and the virtual trainers says that “Frank, your motions are correct now. well done.we can continue now.”



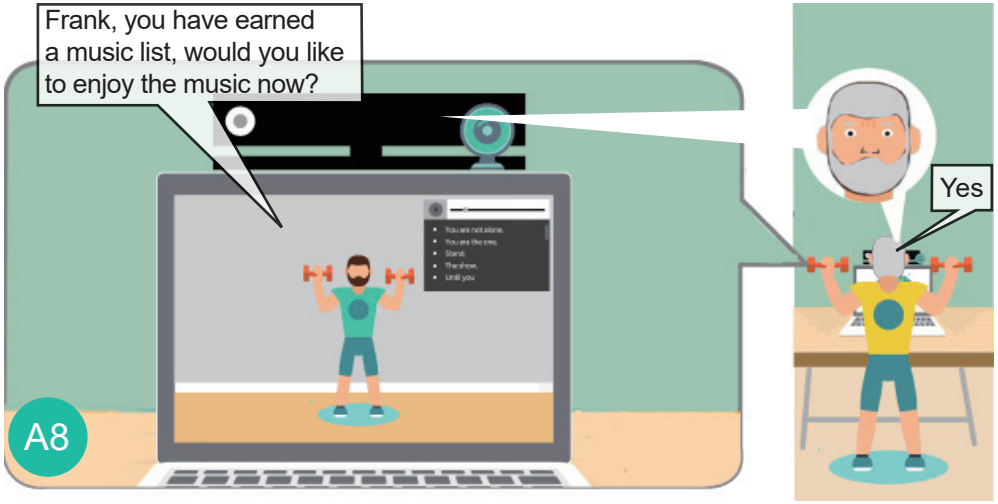
A5. When Frank is performing his second set of biceps exercise, he feels tired. So he firstly slow down, then stops. So system detected that and gives reminder: “ Frank, you still have 5 repetitions to go, would you like to continue or have a short break? Please answer “continue” or “break”. Frank answers “break”. Then the system said:” Ok, let us have a break. Please come back within 10 minutes.”



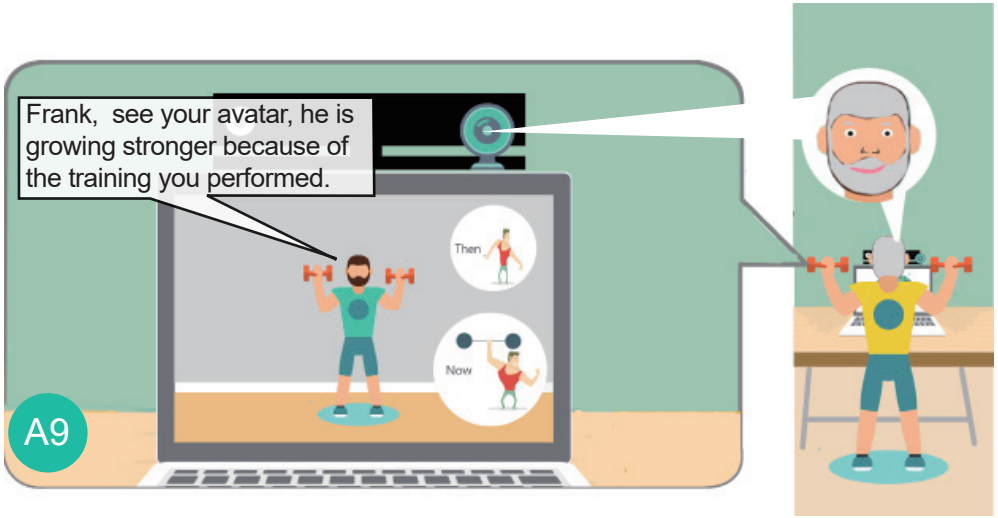
A6.10 minutes later, Frank hears the trainer says:” Frank, you can continue now.



A7. Frank continues his training. 20 minutes later, Frank gradually gets bored. The system detects his boredom and says that “Frank, I think you are bored, we can play the lastest album of “Boyz ii man” on your listening history for you, but you have to lift 3 more repetitions to earn it.



A8. Then Frank lifts 3 more repeititions. The virtual trainer says" well, you have earned a music list, we choose 5 musics from your listening history. Would you like enjoy the music now? Frank answers "Yes"



A9-When all the 5 musics have played, the KINECT still can detected the boredom on Frank's face. So the system shows Frank's character on the screen. Frank's training amount could lead to the growth of the character. So once Frank sees the grown character, the boredom disappears.

B. Relevance to CPSs

B1-Network integration

"Your training manager" integrated the KINCET V2, webcam as well as the software installed on service computer to holistically address the issues of training management, enjoyment enhancement.

B2-Sensing-data acquiring

In this concept, users' trajectory of joints, movement of facial muscle as well as the repetitions are captured.

B3-Reasoning sitations and actions

The situations in this concept are quite simple: elderly's moods and motions quality in the process of the training. The moods is reasoned based on movement of facial muscle and the motion quality is assessed based on trajectory of joints.

In order to correct wrong motions, the system pauses the training and reasoned the guidance to correct motions.

In order to reduce users' boredom, the system selects preferred album and asks users to earn the album by doing extra repetitions.

B4-Learning capabilities

Two things are learned. The one is the music which is useful for increasing enjoyment. Another is the training plan which is suitable for user to perform.

3.4.2 Concept two--Your joyful trainer

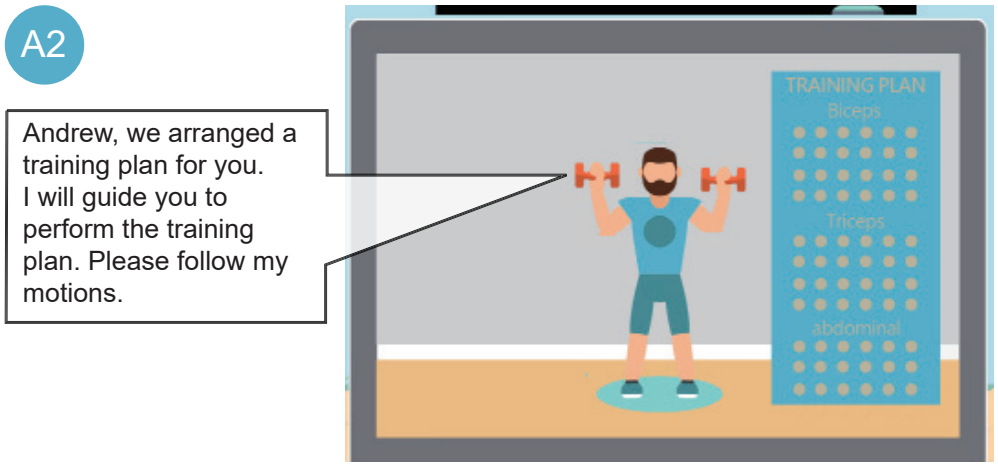
As mentioned in 3.3, The focus of this direction is on delivering training guidance, motivational message as well as the interventions for increasing enjoyment in a joyful and unintrusive way, so the concept is shown as follows

A. Scenario

A1

A1-Andrew selects his objective through an APP named “Your joyful trainers. His objective is “ I want to hold my grandson easily than now”, “ I want to play table tennis with my friends”, “I want to step out of my bathtub easily and safely.”

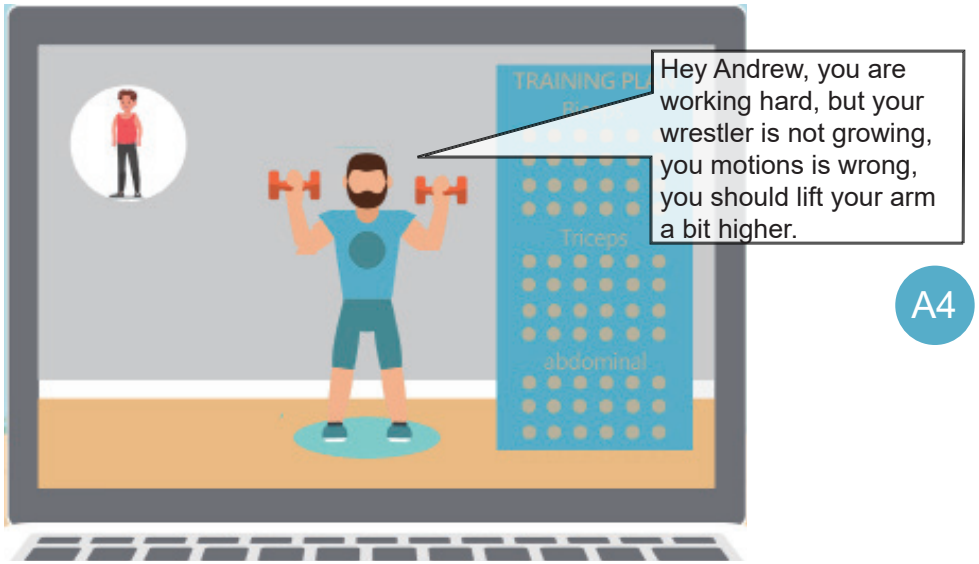
A2



A2-On the basis of the selected objectives, the system arranges Andrew a training plan and show it on the screen of elderly’s laptop.

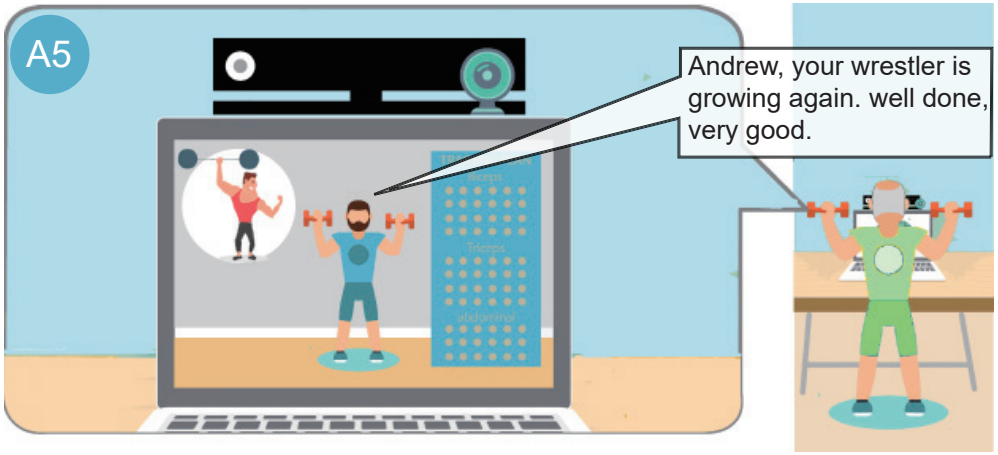
A3

A3-Andrew starts to perform his training plan following the virtual trainers shown on the laptop screen.

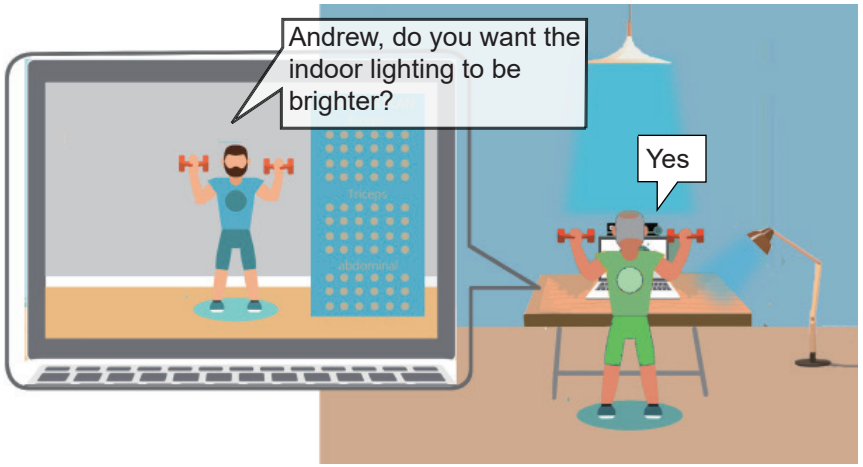


A4

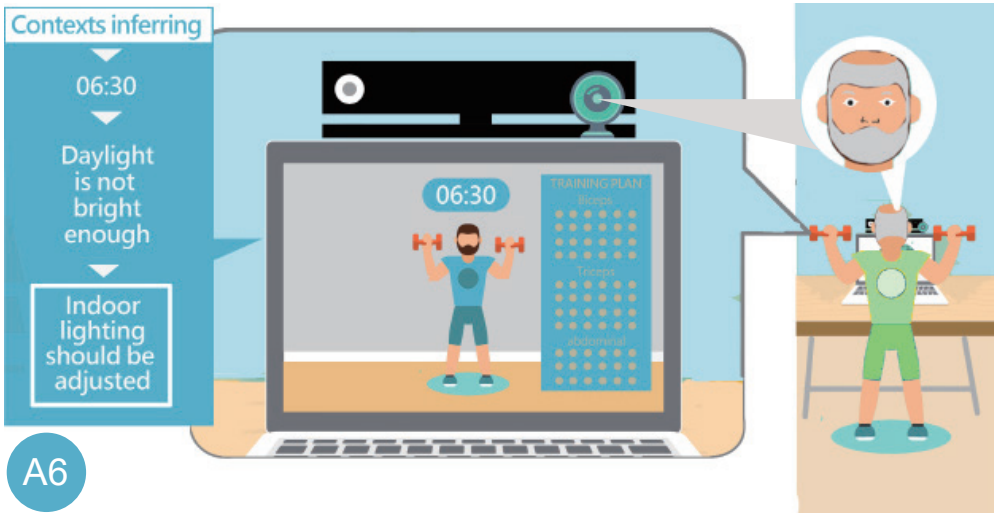
A4-Andrew’s motions are found to be wrong, so the system shows Andrew his surrogate role (a wrestler) on the screen and says:” Hey Andrew, your are working hard, but your wrestler is not growing. You should try to lift your arm a bit higher.



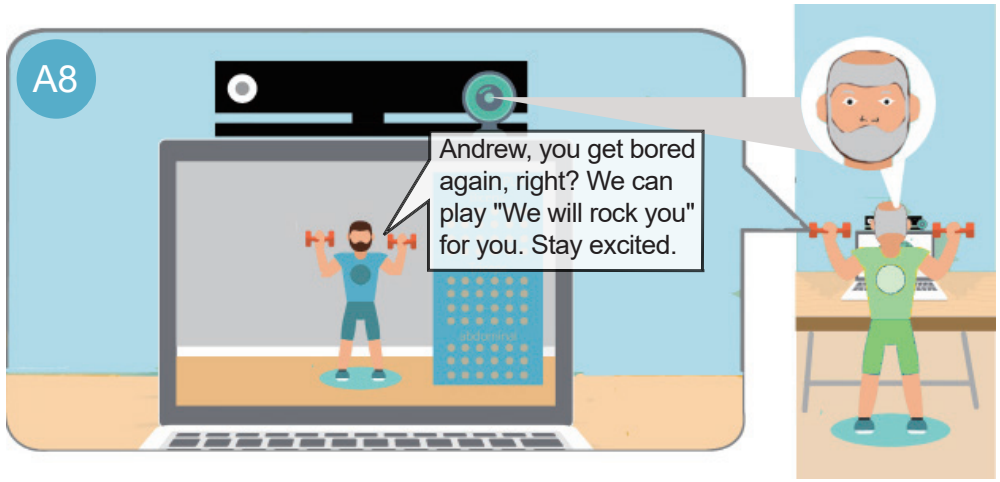
A5-Andrew lifts his arm then and the system says, see. your wrestler starts to grow again, well done, very good.



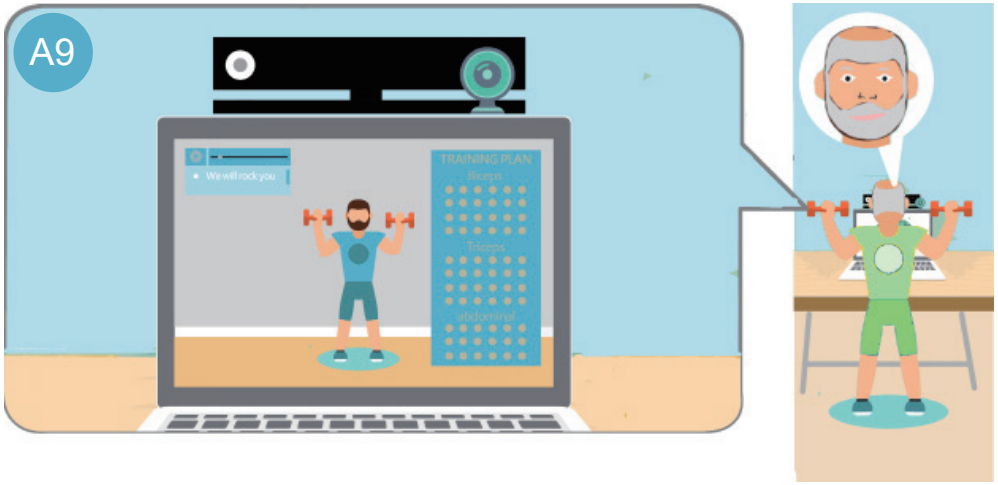
A7-Before lighting adjustment, the trainers in the screen asked" Andrew, do you want the indoor lighting to be brighter?" Andrew says" Yes". When the lighting adjustment is done, the system asks Andrew:" Are you comfortable with the lighting now?. Andrew responds "Yes".



A6-Andrew has worked on his training for 30 minutes and get bored. The system detected the boredom and figures that the indoor lighting has to be adjusted because the time is 06:30 P.M and the daylight is getting darker.



A8-Andrew continues to perform his resistance training and he seemingly gets bored again 15 minutes later. So the digital trainers asks: "Perhaps we can play “we will rock you" for you. Please answer Yes if you are interested. Andrew says “Yes”.



A9-The system then plays “we will rock you” and other five similar musics in turn. Then boredom disappears from Andrew’s face

B.Relevance to CPSs

B1-Network integration

Besides Kinect V2, Webcam which were mentioned in concept one, in concept two, more components were integrated in order to aggregate extra informations, such as: personal objective, brightness of daylight, weather condition, etc. It worth to mention that the number of components in concept two are not fixed. Some components are included only when they are needed, such as the components for capturing weather conditions.

B2 -Sensing-data acquiring

In concept two, the movement of facial muscle and trajectory of joints are also acquired during training. As mentioned in B1, more sensors are used to sense brightness of daylight, weather conditions, etc.

B3-Reasoning sitations and actions

Same as concept one, users’ moods are still considered as the indicator of level of enjoyment while motions are expected to reflect people’s training quality. The two are respectively reasoned based on facial muscle movement and trajectory of joints. Most of the actons/ interventions for improving training quality and enjoyment are also similar with concept one, such as providing guidance for correcting motions, music provisioning for reducing negative moods,etc.

However, several reasoned situations and actions differentiate concept two from one. i) the training plan is provided based on objective instead of physical conditions, the objective is collected using mobile phone, ii) the lighting is provided and adjusted based on the situaions like brightness of daylight, weather conditions, time period, etc. The lighting is also for increasing level of enjoyment.

B4-Learning capabilities

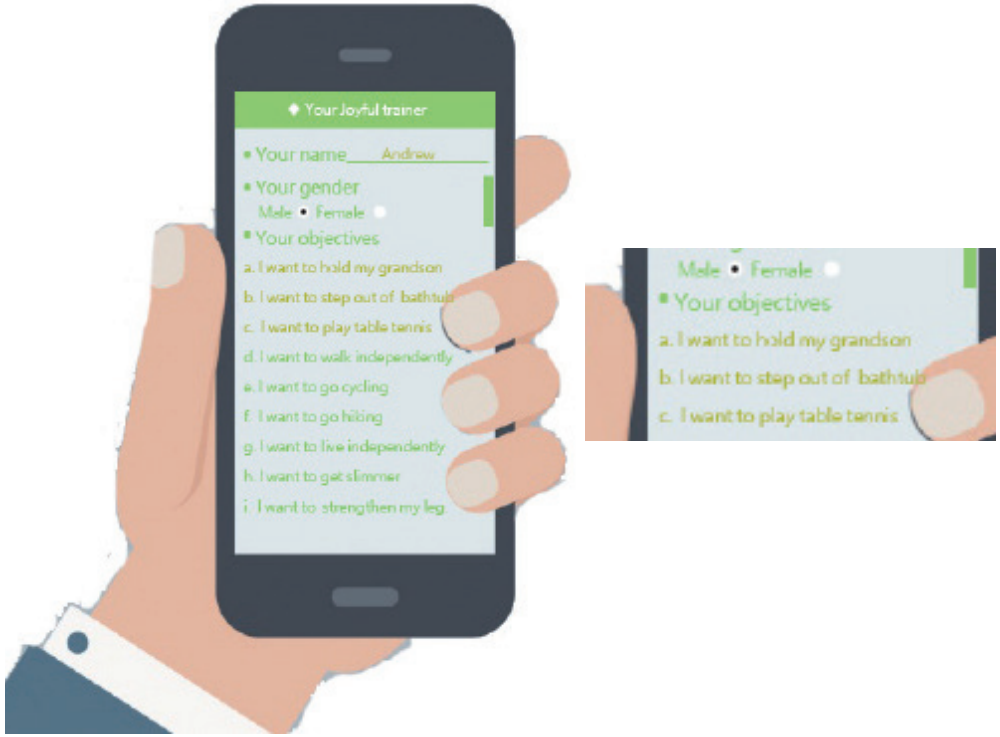
Same as concept one, the useful music for reducing negative moods can be learned in concept two.

In the meanwhile, the lighting parameters (such as: brightness, color temperature) for increasing level of enjoyment can also be learned.

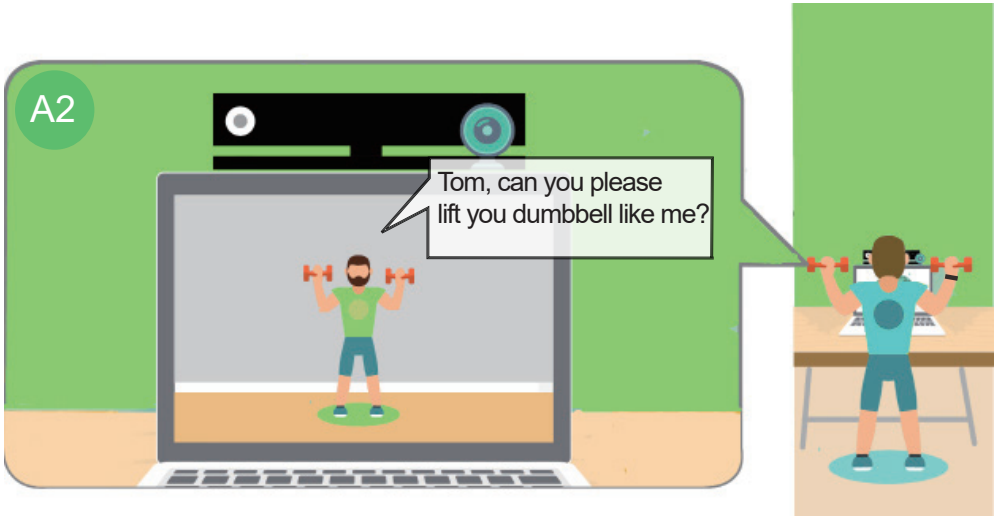
3.4.2 Concept three--Your digital trainer

As mentioned in 3.3, the focus of concept three is on creating a digital companion which gives concern and interventions in following conditions:
1) if users' motions are found to be wrong,
2) if the abonormality of users' heart rate are detected,
3) if users' negative moods are found.
The concept is shown as follows:

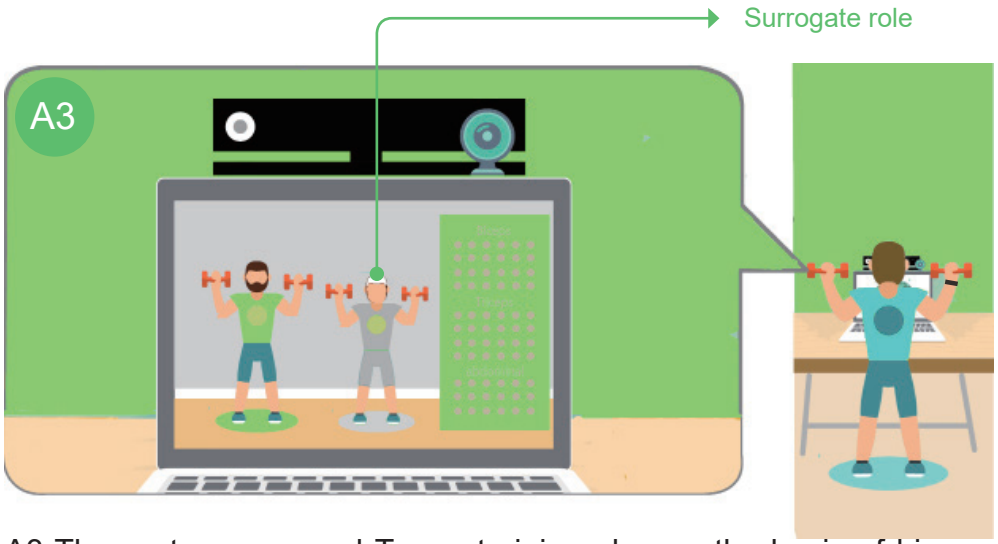
A.Scenario



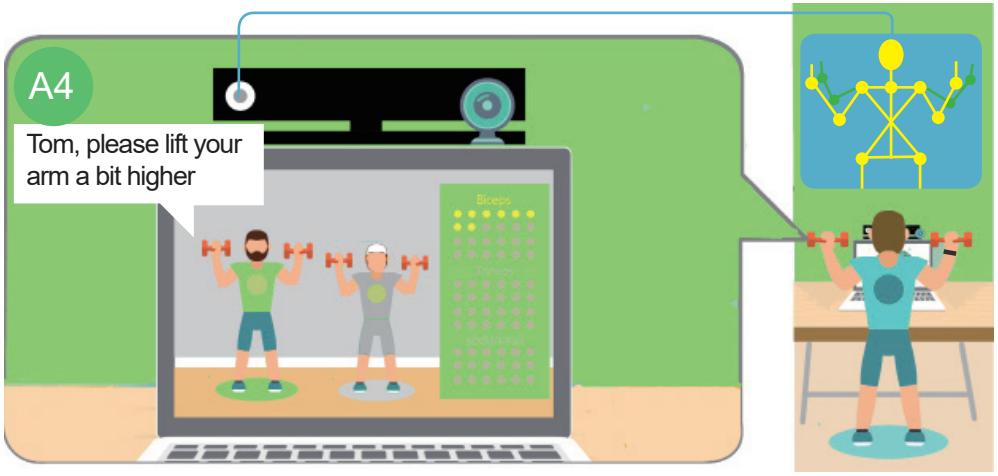
A1-Tom turns on his phone, opens the APP named "Your Fitness Companion" and selects in his objective in resistance training. His selected two following objectives:
1) I want to hold my grandson easier than now,
2) I want to step out of bathtub easily,



A2-Tom opens the same APP on his laptop and a trainers guides him to perform a set of motions which are needed for performing activities of daily living (ADLs)

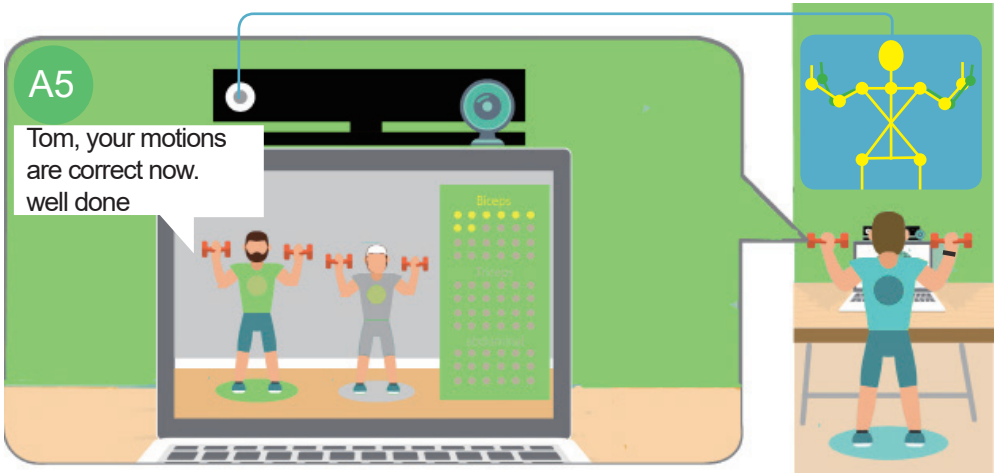


A3-The system arranged Tom a training plan on the basis of his assessed physical conditions as well as objective. Tom mimics the digital trainers' motions. It worth to stress that Tom also has a surrogate role in the virtual world.



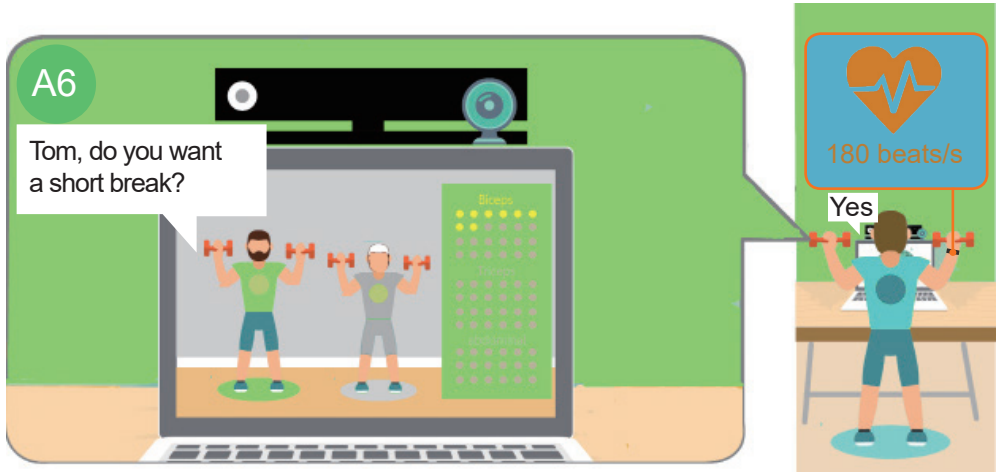
A4-In the process, Tom's motions are found to deviate from standard motions. So the virtual trainers gives reminders: "Hey Tom, please lift your arm a bit higher."

● Captured motions ● Standard motions

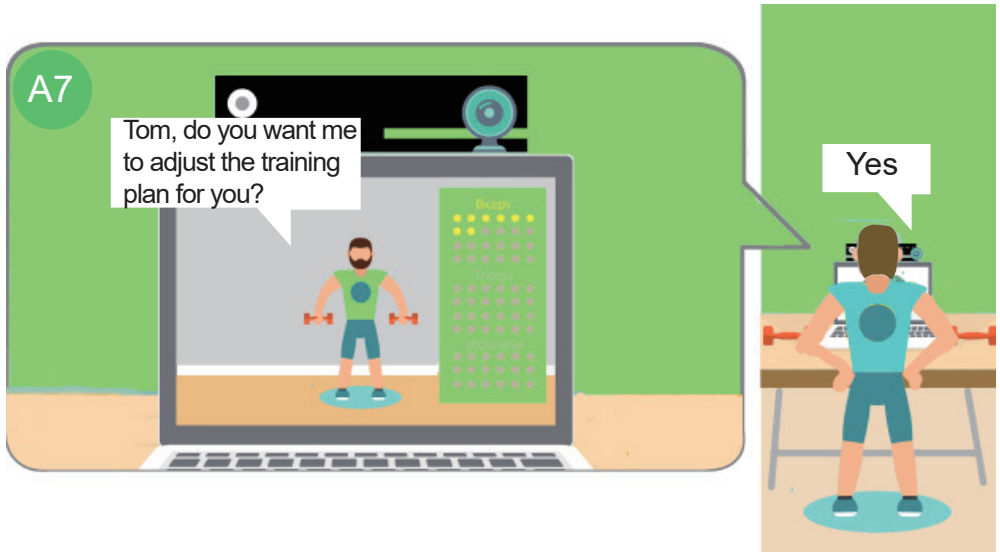


A5-Tom corrects his motions. The system says: Well done Tom. Your motions is correct now.

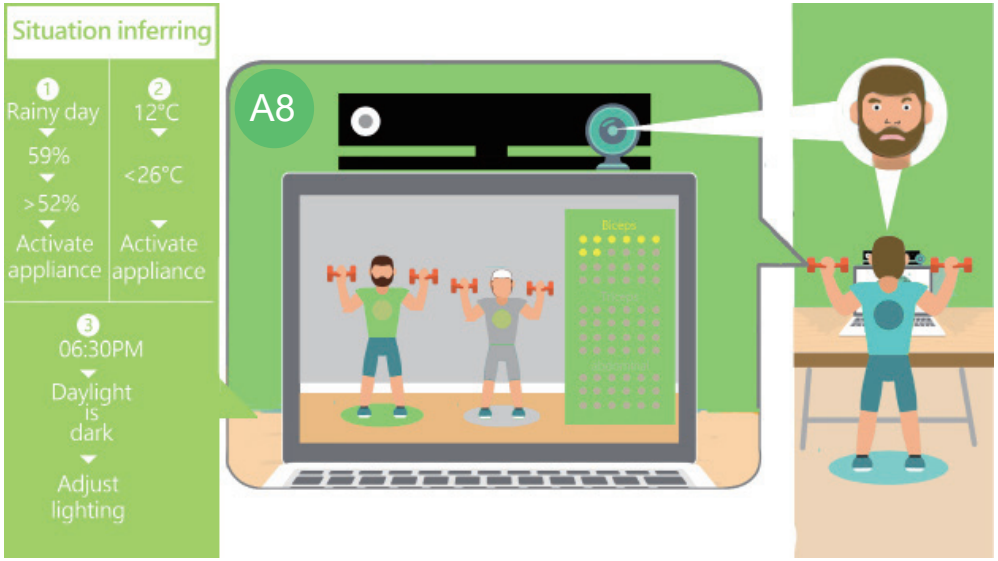
● Captured motions ● Standard motions



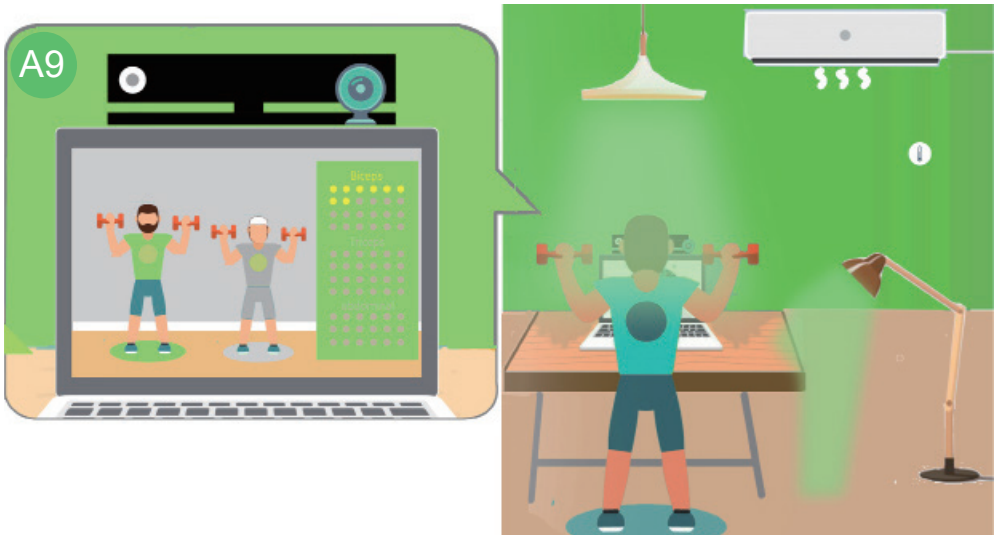
A6-When Tom is performing his triceps exercise, the system starts to give inquiry: Hey Tom, you heart rate is found to be faster than normal, do you want a short break? Please say "yes" if you want to have a short break. Tom responds "Yes".



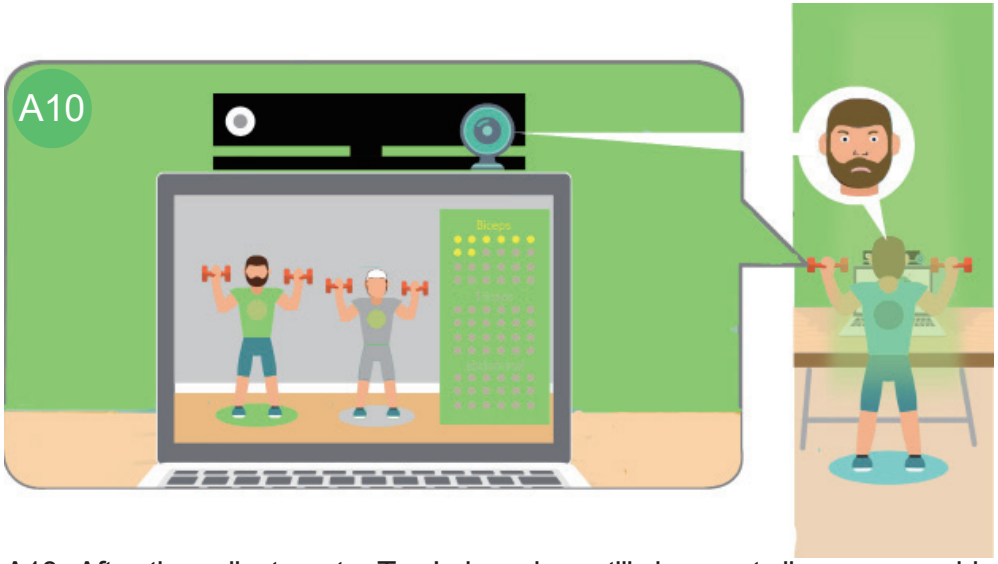
A7-During Tom's break, the trainers asks Tom if he wants his training plan to be adjusted. Tom says yes.



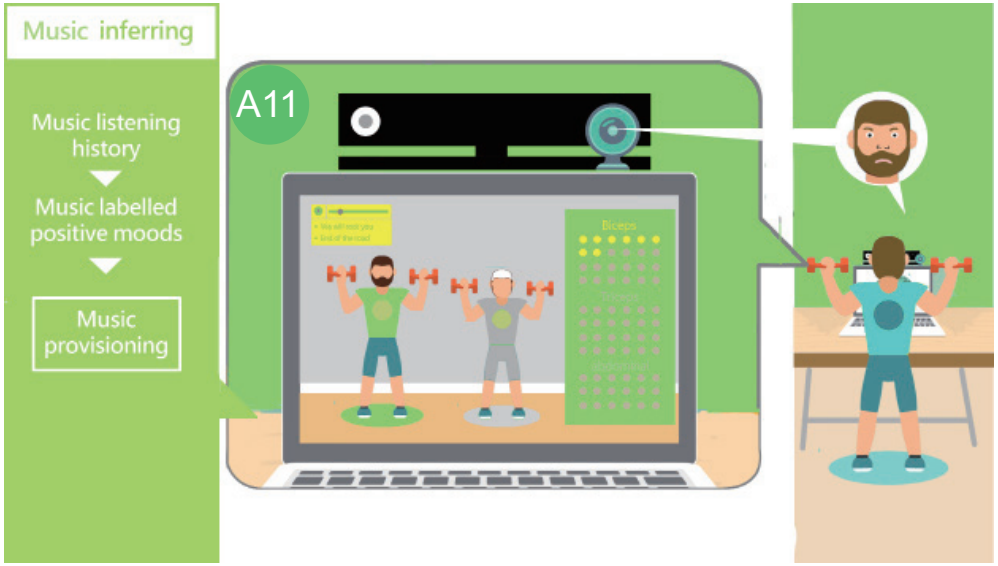
A8-After 30 minutes, Tom starts to become bored and the system detects the boredom. And system starts to infer the situations. Firstly, the time is 18:30 and the daylight is darker. Secondly, the indoor temperature is 12 °c which is lower than ideal temperature range while the rainy day makes the humidity level higher than 52%.



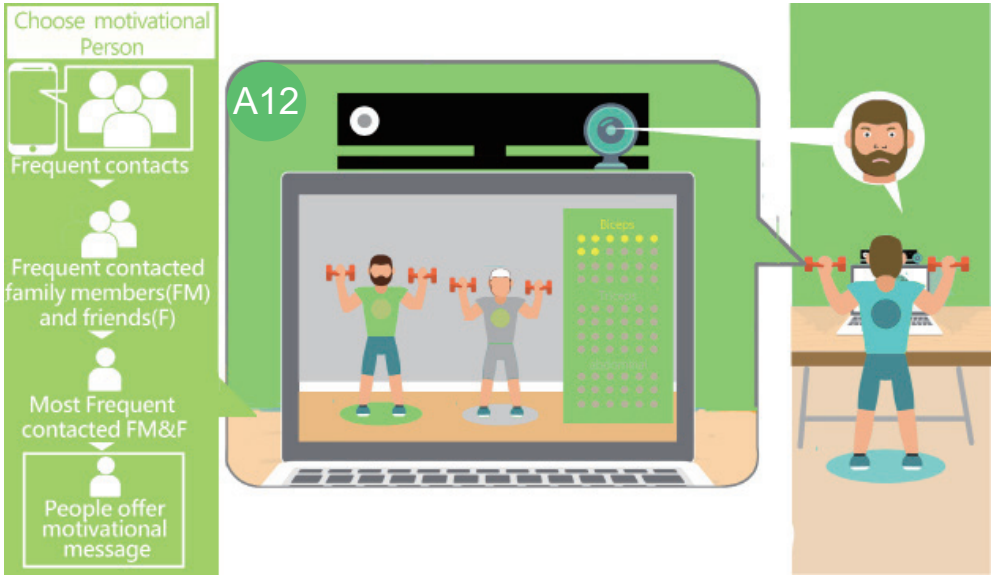
A9-The system, then, activate air conditioners, and air dryer and adjust the brightness of lighting.



A10- After the adjustments, Tom's boredom still does not disappear on his face. So the system decides to play some music for Tom.

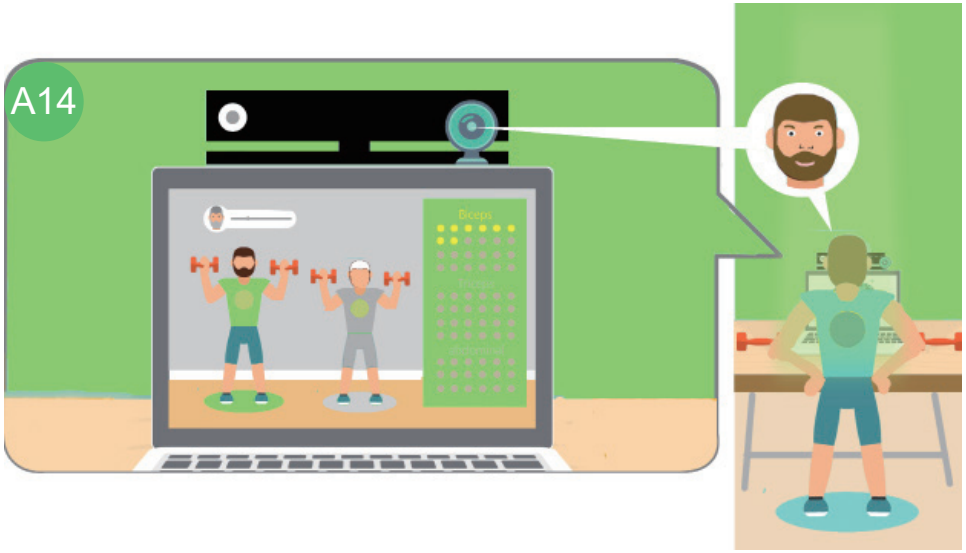


A11-The system selected 5 musics from Tom's listening history saved on his phone and plays these music in turn. When music is being played, Tom boredom gradually disappear. However, happiness still is not detected from Tom's face.

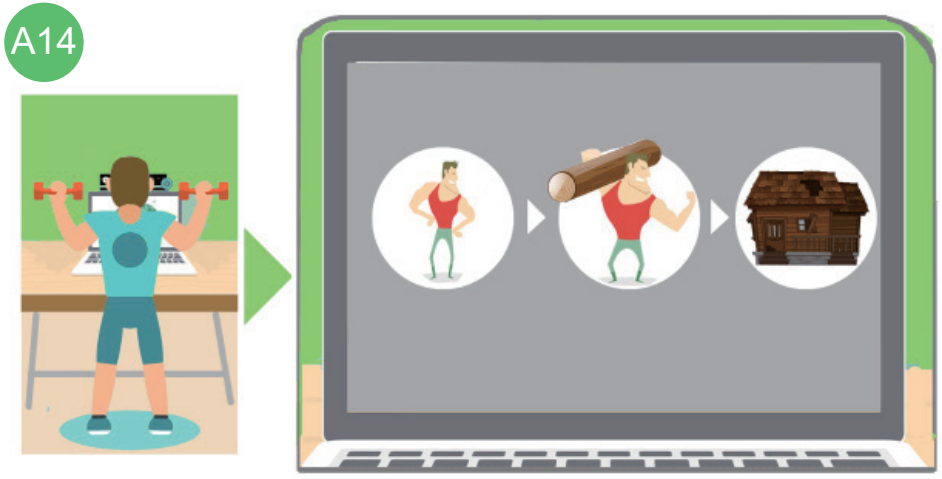


A12-So the system infers that Scott is the most frequently contacted person from Tom's contact history. On the other hand, scott's number is saved in the category of friend&family memebers. So the system decides to invite Scott to provide motivational message to Tom.

A13-System contacts Scott and invites Scott to offer motivational mesage through mobile phone.



A14- When Tom hears the message from scott, the happiness is captured on his face.



A15- In order to keep Tom motivated in a long run, Tom is allowed to choose a character in the virtual world. The character is a builder named Joe. Tom's training can make Joe stronger and stronger Joe can carry logs and build cabins, castles and skyscrapers.

B. .Relevance to CPS

B1-Network integration

Same as in concept 1 and 2, the components relevant to motion quality and moods are still included in concept 3, such as: Kinect V2, webcam. But in concept 3, more components are included in order to address the issues like: i) fatigue detection, ii) training plan adjustment as well as the actions for increasing enjoyment such as i) indoor climate adjustment, ii) social activities enabling, etc.

B2 -Data acquiring

Same as in concept 1 and 2, the trajectory of joints and the movement of facial muscle are still the most important data to capture.

The unique data captured in concept 3 are indoor humidity&temperature measured by Xiaomi mijia sensor and heart rate measured by smart bracelet. The former data is relevant to level of enjoyment while the latter is related to level of fatigue.

Additionally, the most frequent contacted person are selected from contact history somehow.

B3-Sitations and actions reasoning

Obviously, the moods and motions are the most important situations in all the three concepts. The situation which is unique in concept 3 is the level of fatigue and abnormal value of temperature and humidity.

B4-Learning capabilities

There are two main things are learned in concept 3. Firstly, the people who should be invited to provide the motivational message, secondly, the suitable training plan for specfic users. Beside the two, the useful lighting parameters and musics are also learned.

3.5 Concept selection

In 3.5, the optimal concept is selected from the three using Harris Profile. Four respondents were invited to select best concept and give their opinions to optimize the selected concept.

3.5.1 Criteria

There are several criterias(C) formulated on the basis of LoR. On the basis of these criterias, a Harris profile matrix was used to score the three concepts.

C1- Perceived usefulness

The functions of this system can effectively contribute to improve elderly's training quality, increase enjoyment as well as enhance motivation.

C2- Necessity

The problems/issues addressed by this concept can hardly be addressed by human.

C3- Originality

The services provided by the system are different from and superior to those you have seen/used before.

C4- Ease of use

The usage of the concept is easy to understand and requires only brief guidance or tutorial to handle it.

C5- User friendliness

Users can come across the system with pleasant and low pressure.

C6- Unintrusiveness

The service provided by the system is not intrusive

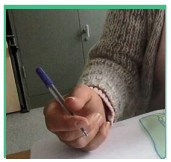
3.5.2 Concept selection session

Obviously, concept selection session aims at selecting optimal concept. At the same time, the respondents are also asked to contribute their suggestions to improve the selected concepts.

A. Participants(P)


Caregiver1


Caregiver2


Coordinator


Gerontologist

Author realized that care givers and gerontologist usually know better about elderly's needs than personal trainers. So two care givers, one coordinator of leisure activities as well as a gerontologist were invited to participate the concept selection session.

B. Harris Profile(HP) for concept selection

Harris Profile is a graphical representation of strengths and weaknesses of design concept. Harris profile can be used whenever a number of alternatives of product concepts need to be compared and consensus needs to be reached/made.
Source: http://wikid.io.tudelft.nl/WikID/index.php/Harris_profile

Criterias	Concept 1				Concept 2				Concept 3			
	1	2	3	4	1	2	3	4	1	2	3	4
Perceived usefulness												
Necessity												
Originality												
Ease of use												
User friendliness												
Unintrusive-ness												

Figure 42-The example of harris profile matrix.

C.Procedures(P) of the session

• **P1**- Author introduces the background information, objective as well as the procedures of the session,

• **P2**- Author elaborately described the three concepts and six criterias to respondents,

• **P3**- After explaining every single concept, respondent was asked to fill the six criterias in Harris Profile Matrix using the score from 1 to 4. (1 represent strongly disagree while 4 means strongly agree).

• **P4**-When filling the scores, respondents have to explain why do they give the score to the criteria of this concept.

• **P5**-When all of the scores are filled, author added the scores of each concept and selected the concept scored the highest.

• **P6**-In the meanwhile, author also asked the following questions in order to get suggestions for further improvement of selected concept.

• What suggestions do you have to make the functions of selected concept more useful for target group?

• What functions in selected concept are redundant/useless for target group?

• What functions in unselected concept can be included in the selected concept?

• Do you have something else to add?

It worth to mention that two respondents did the session together because they are couple. Another two respondents do the session separately.

D. Evaluation

• The evaluation aims at finding out the answer for further improving the selected concept. Due to the time constrain, the evaluation is based on the notes taken during the concept selection session.

E.Findings

Three out of four respondents gave highest overall score to concept three. One respondent gave highest overall score to concept two but this respondent still held positive opinion towards concept three. So author identified concept three as the best concept.

In the meanwhile, respondents also contribute some suggestions to improve concept three. These opinions are shown as follows:

E1-Suggestions for making concept more useful

• In concept three, digital trainer is shown on the screen of laptop, however, one respondent reflected that elderly do not necessarily have laptop, but most of them have TV at home. So TV should be used to display the digital trainer.

E2-Redundant functions

• None of the four respondents pointed out redundant functions. However, two respondents suggested that adjustment on lighting should be optional instead of the basic functions while one respondent reflected that air-conditions are rarely used in Northern and western Europe and installing air-conditioners or other appliances may increase the cost.

E3-Good functions/features from unselected concepts

• One respondent reflected that she preferred the guidance in concept 2 which tells users that his/her character is not growing due to his wrong motions. This guidance sounds more acceptable for users than directly telling users that their motions are wrong.

• In concept 2, system asking users if he/she wants music before playing music. One respondent suggested that this feature is necessary because she can imagine that users would feel uncomfortable and strange when music are played without asking whether they really need music.

E4-Other suggestions

• One respondent mentioned that music should not just selected from users' listening history. Music can also be provided based on users' preferred music category.

F. Summary

3 out of 4 respondents gave highest overall scores to concept three, so concept three is selected as the final concept. In the meanwhile, several suggestion on improving the final concept are also shown as follows:

• Visual content should be shown on users' available appliance. (Most elderly have TV at home, so the content should be displayed on TV in this case)

• Adjustment on temperature and lighting should be optional functions.

• The musics should be provided based on users' preferred music category instead of listening history.

• The way of conveying guidance should be more inviting instead of directly telling users that their motions are wrong.

• Before providing music, system should ask users if he/she wants the music. If users said "yes", then the music can be provided.

More relevant information about concept selection can be found in APPENDIX C

Based on the suggestions, concept 3 will be further optimized. In the meanwhile, in order to implement the concept 3 by technologies in detailing phase, we need to know all of the functions constitute concept 3. So the overview of the functions are mapped out in 3.5.3.

3.5.3 The function overview of optimized concept

The aim of 3.5.3 is to show the overview of functions of optimized concept 3. As mentioned in analysis part, network integration of functions, products and systems enables CP-DTS to address multi-faceted issues, hence, the functions are categorized in terms of the issues mentioned at the end of analysis part. Additionally, due to the importance of sensing and monitoring, so the relevant functions about the two are also listed.

A. Functions for managing training

• A1- Training plan are reasoned based on both objective and users' physical conditions. (Training plan is composed of type of exercises, loads, repetitions as well as sets).

• A2- When users' motions are found to be deviated from standard motions, guidance content are reasoned to correct wrong motions.

• A3- When users' abnormal heart rate and negative moods are detected simultaneously, the inquiry content are reasoned in order to get users' feedback about their feeling.

• A4- On the basis of users' feedback to inquiry, the adjusted training plan is reasoned.

B. Functions for motivation enhancement

• B1- The content of motivational message is reasoned when users' negative moods are detected.

• B2- The suitable person is invited to provide motivational message. The suitable person is reasoned based on most frequently contacted person.

C. Functions for enjoyment enhancement (optional)

• C1-When negative moods are detected, the music is reasoned based on users' listening history and music preference. (Author assumes that music preference can be filled through mobile phone)

• C2-When daylight and weather conditions are not as ideal as expected, the parameters of indoor lighting like brightness and color temperature are adjusted.

• C3-When indoor temperature and humidity is deviated too much from standard value, the appliance like air-conditioners, air dryer are activated.

D. Functions about exergaming elements

• D1- Users' amount of training lead to the transformation of the his/her characters in virtual world.

• D2- The character can cooperate and compete with each other by taking advantage the transformation.

E. Functions for sensing and monitoring

• E1- The trajectory of joints is monitored using Kinect while the movement of facial muscle is monitored using webcam.

• E2- Hear rate is the indicator of fatigue level, it was monitored using smart bracelet.

• E3- Other indicators of indoor climate and environment have to be monitored as well, such as indoor temperature and humidity. They can be monitored using xiaomi mijia sensor.

E. Five subsystems of CP-DTS

Cyber-Physical system is the system of systems. Hence CP-DTS should be composed of multiple subsystems. Author believes that the functions mentioned above can constitute multiple subsystems like: i) training management subsystem, ii) motivation enhancing subsystem, iii) exergaming subsystem, vi) monitoring subsystem. In addition, author assume that users need interfaces to input information and to get the services from system. So an interface subsystem is also needed.

3.5.4 Expectations towards detailing

In 3.5.3, we have already known the functions and five subsystems that constitute concept 3 (CP-DTS). 3.5.4 aims at bridge the output from conceptualisation phase with subsequent detailing phase. So we have to find out what aspects of concept 3 should be detailed and what deliverables are expected in detailing phase based on the detailed aspects. So some expectations are shown as follows:

A. Services provided CP-DTS

Obviously, concept three only shows a scenario which includes some possible examples of services provided by CP-DTS. For example, the system shows growing avatar to users in order to motivate them. However, the technical servicing is much more than that. When the growing avatar can not motivate users, system would choose another message content. Hence, it would be necessary to find a way to clearly describe the technical services provided by CP-DTS in detailing phase.

B. Technologies for function implementation

Although some functions have been proven to be implementable by technologies, some others still requires further exploration. For example, we should figure out i) what technologies can be used to reason the training plan based on personal objective and physical conditions? ii) what technologies can be used to select and recommend music? etc. So the function implementation have to be further explored in detailing phase.

C. Technologies for integrating functions

Obviously, CP-DTS is the integration of the functions mentioned in 3.5.3. However, how these functions are integrated or networked? What technologies are used? In detailing phase the two questions have to be answered.

D. The architecture of the five subsystems

When relevant technologies functions are ready, it is necessary to explore how can these technologies constitute the architecture of the five subsystems and the CP-DTS?

E. The work flow of the five subsystems and self-learning functions

When all of the achitectures, services and technologies are ready, it would be necessary to tell audiences the general work flow of the five subsystems as well as the self-learning mechanism.

F. Ways to demonstrate the detailed concept

Obviously, the detailed concept have to be demonstrated to potential users in a proper way which facilitate them to understand the functions, services and the advantage of CP-DTS. So the final use case scenario and a prototype have to be developed at the end of detailing phase.

G. Summary

Generally speaking, exploring the technologies for implementing fucntions and subsystems proposed in conceptualisation session are the primary task in detailing phase. In the meanwhile, architecture can tell people how the technologies constitute the subsystems, workflow can demonstrate how the system normally work. Finally, the implemented concept have to be demonstrated to users using scenario and prototype in order to facilitate users to understand the functions, services as well as the benefits from CP-DTS.

4.1 Short Introduction

Conceptualisation was ended up with an overview of functions and some expectations towards detailing and prototyping phase. Based on the findings from conceptualisation phase, we can clearly know that the main tasks of detailing phase is to explore:

i) what services can be provided by CP-DTS, ii) what technologies [1]can be used to implement the CP-DTS, iii) how these technologies constitute CP-DTS, vi) what are the workflow of CP-DTS, v) how can the detailed CP-DTS be demonstrated to potential users.

In order to get answers for above mentioned questions, the following approach is used.

A. Overall approach and specific methods

On the basis of the expectations proposed in 3.5.4, the approach can be described as follows:

• A1- Service units description: The service units provided by CP-DTS have to be described on the basis of the functions of concept 3.

• A2- Technologies for implementing functions: The overview of the technologies for implementing CP-DTS have to demonstrated. The technologies include cyberware, software, hardware and network componens.

• A3- Architecture of CP-DTS: The architecture is made to present how the cyberware, software, hardware constitute subsystems. The achitecture is visualized using flowchart.

• A4- The flow of operations: The flow of operations (workflow) can reflect how the subsystems and self-learning functions work. The flow is also visualized using flowchart.

• A5-The scenario and prototype: Finally, some relevant technologies, flow of operations as well as the services are demontrated using scenairo and prototype.

B. Reflection on the tasks related to the selected concepts

In chapter three, the best concept has been chosen. In order to detail this concept and make it feasible and credible, several following factors have to be taken into consideration:

• B1-The number of in-home hardware of this system should strictly be controlled, the indispensable hardware (e.i sensors for capture motions) and alternative hardware (e.i actuators have to be installed by specific person) should be highlighted.

• B2- Elderly users should not be required to install more than one software themselves. On the other hand, most of the application software should be installed on one device instead of multiple devices and they should ideally operate on the same operation system.

• B3-The device for data and information storage should ideally from third party instead of in-home device. (Elderly do not have to rent it or buy it)

C. Principle of detailing the solution elements

At first, all of the technical servicing are specifies in 4.2 by texts which is followed by the layer model (4.3) which consists of all the cyberware, software, hardware and network layers components of CP-DTS. The different combinations of these components constitute five different subsystems of CP-DTS namely: i) interface subsystem, ii) monitoring subsystem, iii) training management subsystem, iv) motivation enhancing subsystem and v) exergame subsystem (Figure 43). The five subsystems are the enabler of CP-DTS and the operation of these subsystem are manifested as the technical services.

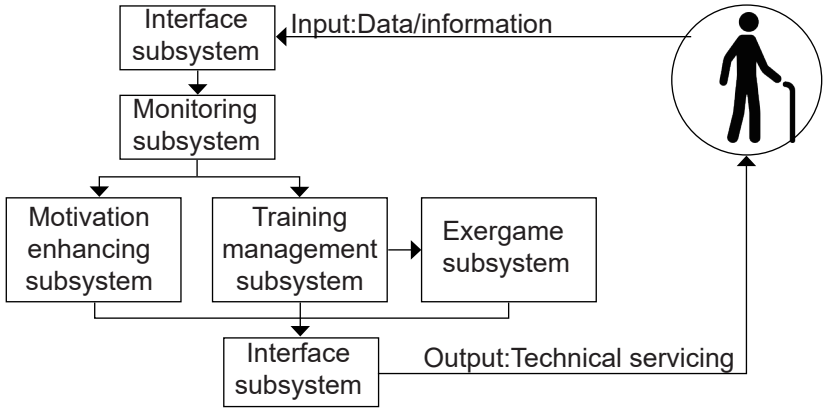


Figure 43-Overall concepts of the Cyber-physical digital trainers system (CP-DTS)

[1] Technologies include cyberware, software, hardware and network

4.2 Sevice Units

As mentioned in 3.5.4, technical servicing are expected to be shown in detailing phase. Technical servicing shows not only the output of CP-DTS, but also how the output appear to end users. In 4.2, these technical servicing are categorized in terms of several issues mentioned at the end of exploration phase. So each category of technical servicing is considered as a service unit. These services are formulated based on the functions mentioned in 3.5.3.

A. Services for managing resistance training

• **A1-**CP-DTS provides personalized training plan on the basis of users' physical conditions and objectives. The training plan is shown as the visual content on the screen of TV or laptop,

• **A2-**CP-DTS provides guidance information to correct his/her wrong motions in the process of training, the informations could be conveyed through screens and speakers,

• **A3-**CP-DTS gives inquiry about users' feeling when their negative moods and abnormal heart rate are monitored simultenously. The inquiry are given to ask about users' feeling. Users have to react "Yes/No ". Based on users' feedback, CP-DTS adjust exercise type, repetitions, sets which constitute the training plan.

B. Services for enhancing motivation

• **B1-**CP-DTS provides motivational message when users' negative moods are found. Motivational message has both visual and audio version. Hence the content can be shown through both screen and speakers. *(In this case, the message contents are selected from database)*

• **B2-** CP-DTS changes content of motivational message if the negative moods are still detected.

• **B3-** CP-DTS invites suitable people to provide motivational message, *(The people are selected from " Most frequent contacts" save in users' phone)* The message is delivered through speaker.

• **B4-** CP-DTS also adjusts the visual contents to the position of gaze in order to attract users' focus attentions. (The gaze is captured by Kinect V2)

C. Services for enhancing enjoyment (Optional)

• **C1-**CP-DTS provides music when users' negative moods are detected. Before music provisioning, users are asked if he/she wants music. If "Yes" the music will be provided. The music are selected based on either user's listening history or users' music preference,

• **C2-**CP-DTS provides lighting or adjustment on the brightness/color temperature of indoor lightings when situations like negative moods, dark daylight are detected,

• **C3-**CP-DTS adjusted indoor temperature and humidity(T&H) when indoor T&H are found to be deviated from normal standard.

D. Services for keeping long-term motivation

• **D1-** CP-DTS arranges competitiors and competitions for users based on the his/her preference in number of competitiors and type of competitions as well as the transformation of his avatar in virtual world. The tranformation happens when users' perform certain amount of training. For example, the avatar is a rally car, users' training amount is converted into oil while training quality is converted into score which can be used to purchase engine. The rally car with engine and oil can compete with other cars in virtual world.

• **D2-** CP-DTS arranges team members and cooperative tasks for users based on number of team members and type of cooperative tasks. More information about cooperative tasks will be shown in user case scenario.

In 4.3, the needed resources for implementing the above mentioned services are explored and mapped out.

4.3 Overall organization of the system

Obviously, different resources are needed to enable the technical service provisioning. These resources are categorized in terms of four layers: cyberware, software, hardware layer as well as the network layer which enable the connection and data transferring between various software and hardware. So in 4.3.1-4.3.4 the needed resources are elaborated. At the end of 4.3, there is a diagram which shows a clear overview of the four layers of components belong to CP-DTS. Additionally, the inter-connection between these components are also shown in this diagram. (Only part of the components are elaborated below due to the concern of report length).

4.3.1 Cyberware Layer components

According to Jože Tavčar and Imre Horváth (2018), cyberware is usable knowledge, information which are converted from data using sets of inferences and reasoning strategies. So in 4.3.1, the useful data, information, and knowledge for technical servicing provisioning are elaborated as follows:

A. D, I, K for resistance training management

• A1- Trajectory of joints(D) is captured. Users' physical conditions and motion quality (I) can be reasoned based on trajectory of joints. It worth to mention that physical conditions is manifested as the *"weak muscle groups"* which have to be enhanced. Motion quality can be manifested as *"Mistakes of motions"*

• A2- Type of exercises, repetitions, loads as well as sets (K) are arranged for enhancing weak muscle groups (I).

• A3- *Guidance contents(K)* are given to correct motion mistakes(I),

• A4- Heart rate (D) is captured. Abnormalty of heart rate (I) is reasoned by comparing captured heart rate with standard value . Based on the abnormal of heart rate (I), the level of fatigue (I) is reasoned,

• A5- The content of inquiry (K) is given when fatigue is detected,

• A6- On the basis of users' feedback (I) towards inquiry(K), the adjustment on repetitions, sets and loads (K) are reasoned.

• A7- Additionally, users' personal training objective(I) is an important information based on the exercise (K) can be recommended to help user to achieve his/her goal.

B. D, I, K for enhancing motivation and enjoyment

• B1-Facial muscle movement (D) is captured. Based on the movement, various negative moods(I) can be reasoned. (e.i: Boredom)

• B2-The indoor temperature and humidity(D) is captured. The indoor climate(I) can be assessed by comparing captured T&H with standard value,

• B3-Other information considering the situations which may lead to negative moods are also needed, such as the brightness of daylight(I), bad weather (I), etc. *(Situational information is too broad, so author decides to not make it too specific)*

• B4-The motivational message contents (K) which are proven to be effective in motivating other people is matched with negative moods..

• B5-People (K) who provide motivational message are chosen based on frequent contacts (I) preserve in the phone.

• B6-Users' personal music preference (I) and the music(I) from listening history is needed for reasoning the music (K) recommended for

D=Data, I=Information, K=Knowledge

reducing negative moods, such as boredom.

• B7-The lighting parameters (K) (e.i: brightness, color temperatures) which can reduce negative moods in various situations(i) (e.i: skylig-ting is not bright enough) is needed.

C. D,I and K for arranging competitors and cooperators.

• C1-Users' preference(I) in number of competitiors, type of competitions is needed for CP-DTS to arrange competitors and competitions.

• C2-Users' preference(I) in number of cooperative partners, type of cooper-ative tasks is needed for CP-DTS to arrange partners and cooperative tasks.

4.3.2 Software Layer components

Software is a key component of any CPS. The software can basically be categorized into i) application software(AS) , ii) control software(CS) and iii) basic software. In 4.3.2, only application and control software will be discussed.

According to Wikipedia, An application software is computer software de-signed to perform a group of coordinated functions, tasks, or activities for the benefit of the user. AS can aggregate real-time data, convert the data into useful information and preserve the information in the machine learning library. Additionally AS can be used as the interface concerning the users and system. CS, on the other hand, is responsible for driving the device and application software.

In 4.3.2, the application and control software belongs to the systems are elaborated.

A. AS-The APP on mobile device as data aggregator and interface.

• A1-The APP on the mobile device should be considered as the personal information aggregator. It allows users to fill in the information like: i) pref-erence in color and music, ii) preference in competition/cooperation, iii) preferred competitors, iv) preferred role in the game world, etc

• A2-The APP can also be used as the interface through which elderly can play exergame after their training.

B. AS-The App on LCD as interface

B1-Unlike the APP on mobile phone, the APP on LCD TV play a role as the pure interface which conveys the content like: i) Interactive video for instructing elderly to perform training, ii) the motivational message, iii) the feedback towards elderly's performance in resistance training, etc. Elderly users only interact with the APP in the process of resistance training.

C.AS-Kinect Studio, and Insight SDK for data translation

C1-The Kinect studio can be used to translate and assess the posture and motion (Data) captured by Kinect V2. The output from Kinect stu-dio are considered as context information based on which the person-alized training plan are inferred using context dependent reasoning.

C2-Insight SDK can be used to translate the movement of the face muscle (Data) captured by webcam into certain mood. The output from Insight SDK are considered as the context information based on which the system can recognize the effectiveness of the interventions in mo-tivation enhancement and motivational message.

C3-Wang, K., & Ji, Q(2016) proposed a 3D eye model to estimate the gaze output from Kinect V2. The estimation can reflect elderly's atten-tion and interest.

D. AS-MATLAB for case-based reasoning (CBR) and learning

D1-According to Wikipedia, MATLAB is a multi-paradigm numerical com-puting environment and proprietary programming language developed by MathWorks. It usually used for case-based reasoning and deep learning, that is why MATLAB is choosed to do the computation in CP-DTS.

Source: https://en.wikipedia.org/wiki/MATLAB

E.AS-Message broker for information collection and transfering

According to Wikipedia, a message broker is an intermediate program module that translate a message from the formal messaging protocol of the sender to the formal messaging protocol of the receiver.

In CP-DTS, message broker(MB) are used to collect profile information from mobile phone / LCD-TV and send these information to context-dependent reasoning components (Service computer). At the same time, MB also send the i)motivational message, ii) guidance message and iii) suggestive message from service computer to mobile device and LCD-TV.

F.CS-Software for the operation of the above mentioned software

Obviously the APP on mobile phone and LCD-TV can operate on Android while the Kinect studio, Insight SDK and MATLAB can operate on Windows 10. It worth to stress that the operation of Kinect studio requires a driver named Kinect SDK.The application server has its own operational system.

4.3.3 Hardware Layer and network layer components

A. Kinect V2, Webcam, Smart bracelet and Mijia sensor for data capturing

Kinect V2(a) is used to capture elderly's motion and gaze position while webcam(b) is used to capture the movement of facial muscle. Smart bracelet is used to collect elderly's heart rate. Xiaomi mijia sensor can be used to sense the indoor temperature and humidity.

B. Service computer(c) for application software installation

There are some software are installed on the service software, such as kinect studio, Insight SDK, MATLAB are installed on service computer.

C.The screen and speaker of LCD-TV&Mobile device as actuator

The screen of LCD can be used to display the motivational message, guidance message and instructive video while the speaker can be used to play music and convey the inquiry.

The screen of mobile phone not only allows elderly to fill their personal information,such as: various preference in the phone, but also can be used as the interface for exergame.

D. PHILIP Hue and air conditioner as actuator

PHILIP hue can be used to change the indoor light includes color, brightness and color temperature, etc.
Source: https://www.youtube.com/watch?v=h1falu7l8bg

Air conditioners can be used to control the indoor temperature and humidity.Obviously, both Philip hue and air conditioners are the extra in-home hardware which cost extra money to install them, so in this case, both of this two hardware should be treated as a "optional hardware" instead of the "indispensable hardware". In Figure 44, the optional hardware are marked by orange.

E. Network layer components

The way of connection between different software and hardware are visualized in Figure 44. Other overview of components can also be found in this diagram.

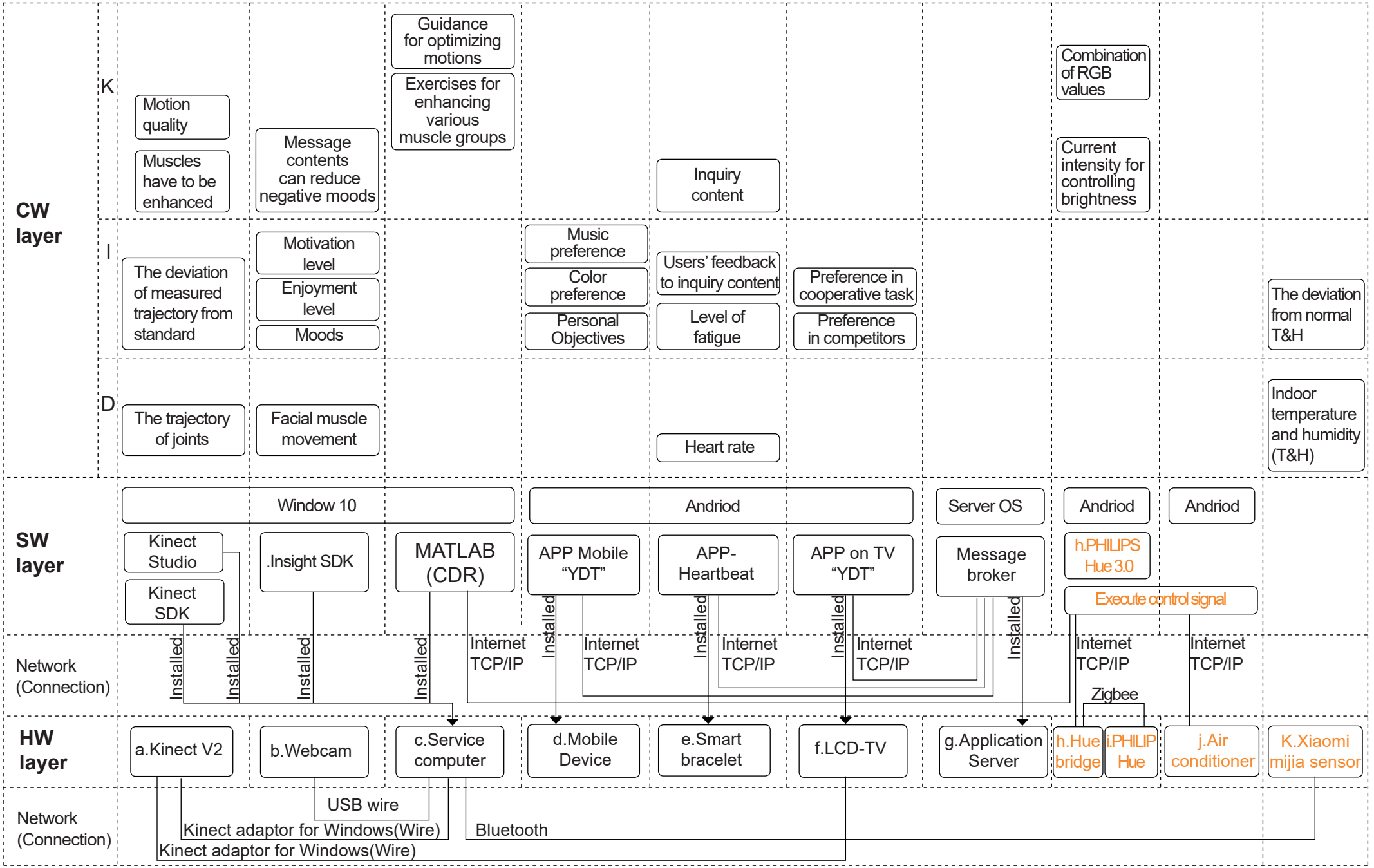


Figure 44-The Cyberware, Software, Hardware and Network components.(The components marked by orange is alternative components)

4.4 Architectural embodiment of components

As mentioned in 4.1, CP-DTS is composed of five subsystems and these subsystems are the enablers of the technical servicing mentioned in 4.2. The components mentioned in 4.3 constitute these subsystems. So in 4.4, the architectures which illustrate how these cyberware, software and hardware components constitute each subsystem.

4.4.1 Interface subsystem

According to wikipedia, in the context of computing, interface is a shared boundary across which two or more separate components of computer system exchange information. The exchange can be between software, computer hardware, humans. Obviously, in interface subsystem, we should explain what informations are input/output and how. As we see, the subsystem is composed of four lines. They will be explained one by one.

Line 1: Kinect V2 captures the trajectory of joints (D). On the basis of this data, the motion quality (I) can be reasoned using KINECT Studio. On the basis of the reasoned motion quality, MATLAB matches guidance contents(K) which ams at correct the motion quality. The guidance is displayed using LCD-TV.

Line 2: The trajectory of joints(D) captured by Kinect V2 can also indicate which muscle group should be enhanced or in another words-" target muscle" (I). MATLAB can match exercises(K) with the target muscles which constitute exercise package/training plan. The training plan is displayed using LCD-TV.

Line 3: Heart rate (D) is captured using smart Smart bracelet and processed using an APP named "Heart beat". The abnormalty of heart rate(D) can indicate "level of fatigue (I)". MATLAB can match inquiry content (K) with leve of fatigue. The inquiry is displayed using LCD-TV.

Line 4: Webcam is used to capture the facial muscle movement(D) based on which the negative moods (I) can be reasoned using Insight SDK. On the basis the negative moods, MABTLAB can match motivational message, music as well as lighting parameters (e.i: brightness, color temperature, etc) with specific negative moods. The motivational message and music are output using LCD-TV while lighting is adjusted using Philip hue.

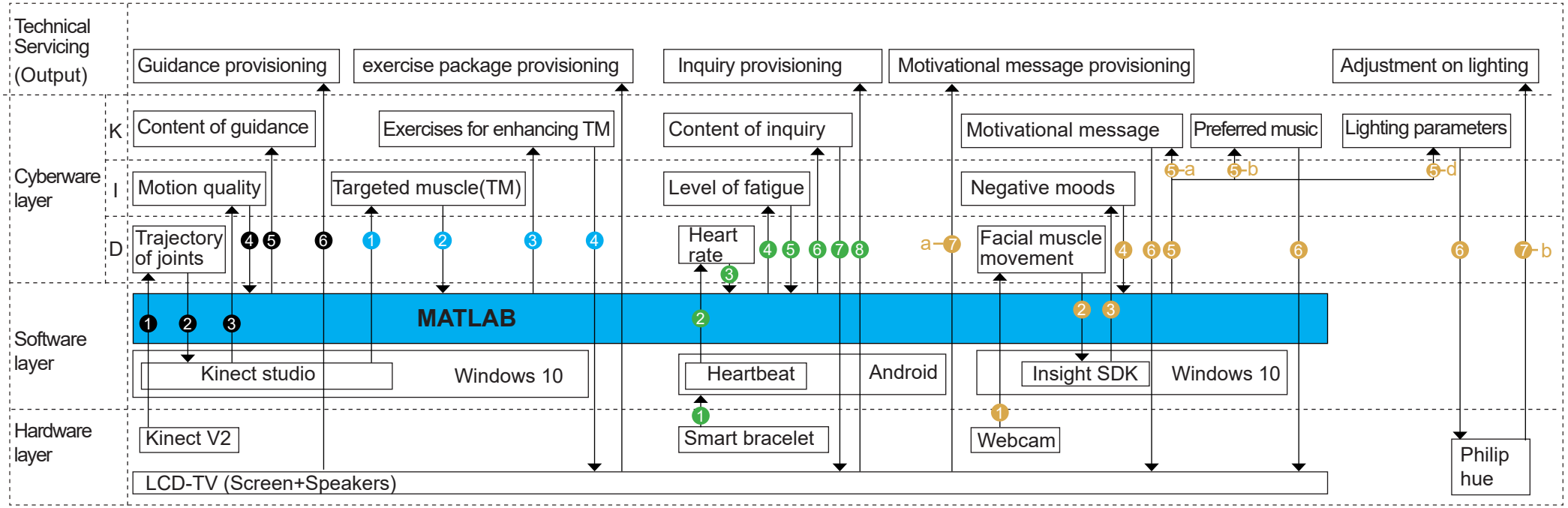


Figure 45-Architecture of interface subsystem

D=Data, I=Information, K=Knowledge

4.4.2 Monitoring subsystem

The monitoring subsystem is composed of four parts which are represented by four colors. So the four parts are elaboratedly explained as follows:

Line 1: Users' gaze coordinate is always monitored using KINECT V2. Gaze coordinate is the indicator of the position of users' focus attention.

Line 2: The trajectory of joints (D) is monitored in the process of resistance training. the Kinect Studio is used to assess users' motion quality(I) by comparing monitored trajectory with standard trajectory.

Line 3: Heart rate is also monitored in the process of resistance training using smart bracelet and processed using the APP named heart beat. Abnormalty of heart rate is the indicator of level of fatigue(LoF). On the basis of LoF, MATLAB can reason whether the load is too heavy or the repetitions, sets are too much for users or not.

Line 4: Facial muscle movement (D) is monitored using webcam and processed using Insight SDK. Insight SDK compare the moods change (I) before and after: i) the motivational message is provided, ii) the in-door lighting is adjusted, iii) the music is provided. The moods change can indiate the following three aspects:

a. Whether the content of the motivational message is effective or not,

b. Whether the brightness and the color temperature can contribute to increase the level of enjoyment or not,

c. Whether the provided music is enjoyable or not.

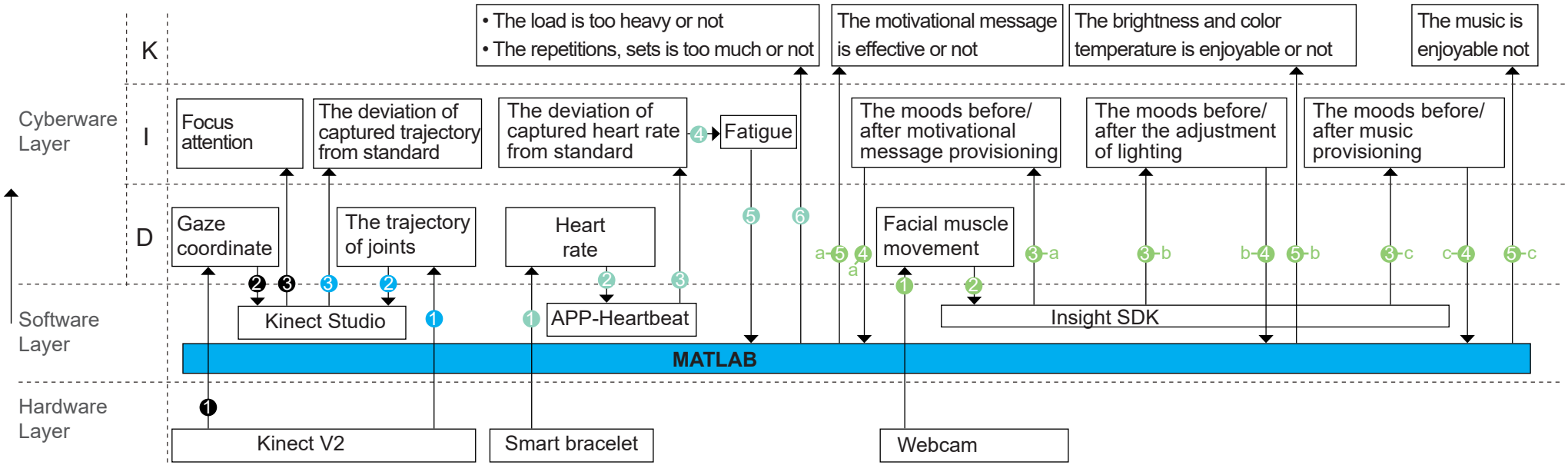


Figure 46-The architecture of monitoring subsystem

4.4.3 Training management subsystem

The training management subsystem is composed of three parts. Three colors are used to represent the three parts. The three parts are explained as follows:

Line 1: Exercise package provisioning are on the basis of two factors: The one is target muscles (I) and the other one is objective (I) filled by users through an APP named “Your digital trainer”. The target muscles are found out using KINECT Studio based on the comparison between trajectory of joints (D) captured by Kinect V2 and standard trajectory.

Line 2: As mentioned in 4.4.2, the deviation of captured trajectory of joints can also indicate wrong motions in the process of training. MATLAB can used to match the specfic guidance contents with the wrong motions in order to correct his/her motions.

Line 3: Heart rate(D) can be captured using smart bracelet and processed using the APP called “heart beat”. “Heart beat” can reason the abnormality of heart rate which is the indicator of fatigue(I). In the meawhile, the negative moods (I) are reasoned using insight SDK based on facial muscle movement(D). Based on both negative moods(I) and abnormality of heart rate(I), MATLAB can choose inquiry content (K) which are displayed through LCD-TV screen and users have to give “Yes/No” feedback towards the inquiry. Based on the feedback, MATLAB adjusts the loads, repetitions as well as the sets of the exercises.

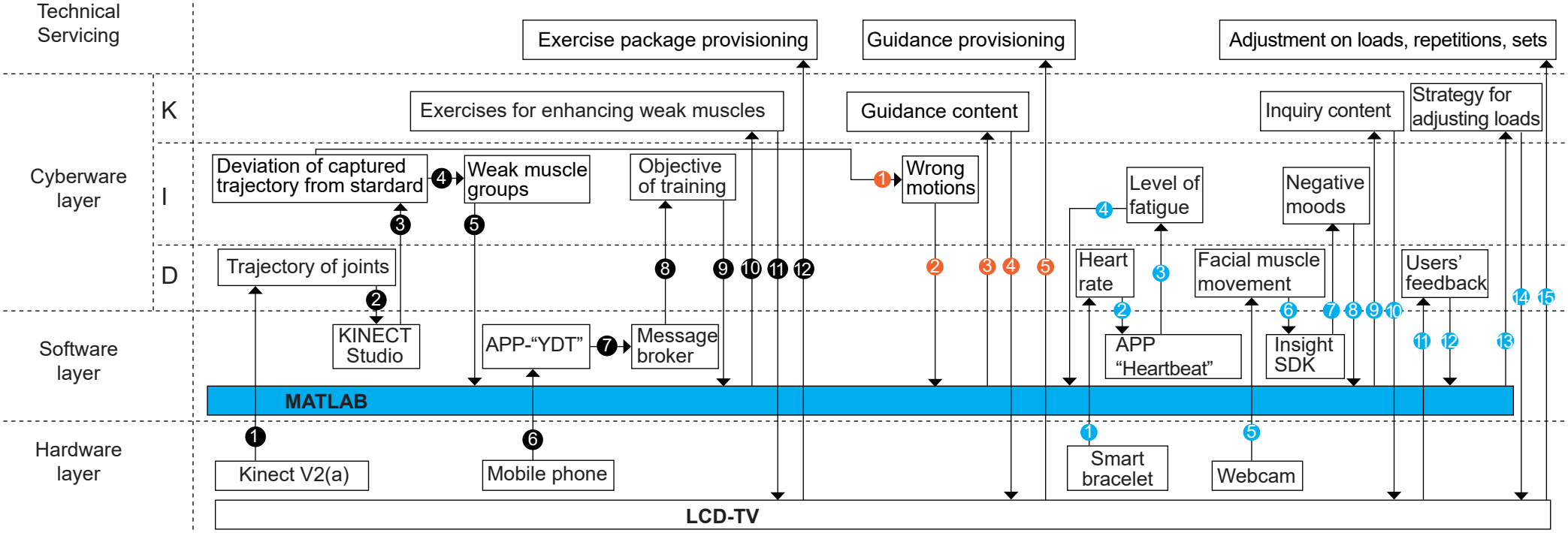


Figure 47-The architecture of training management subsystem

4.4.4 Motivation and enjoyment enhancing subsystem

The motivation and enjoyment enhancing subsystem is composed of six parts. The six parts are explained as follows:

Line 1: The negative moods are reasoned based on the movement of facial muscle captured by webcam and processed by insight SDK. MATLAB matches motivational message content with negative moods. The motivational message are proven to be effective for other people. The message are displayed on the screen and conveyed using speaker of LCD-TV.

Line 2: The people who provides motivational message are selected from "Frequent contacts"(I) saved in the phone. Once the people are selected, the invitation message are sent to his/her phone. The invited people send the motivational message to message broker and message broker send message to LCD-TV. The message is finally presented through the screen and speaker of LCD-TV.

Line 3: The coordinate of gaze (d) can be captured by KINECT V2. Based on the coordinate of gaze, KINECT Studio reasons users' focus attention. CP-DTS adjusts the visual message to the position of focus attention.

Line 4: Desktop APP "Accuweather" installed on laptop can provide weather related information, such as cloud cover, time of sunset, etc. (Other situational information can also be included, weather is just one of them). Based on the information, MATLAB reasons the value of RGB combition(Color of lighting) and current intensity(Brightness). PHILIP Hue is used to provide lighting.

Line 5: Music is provided on the basis of user's music preference(I). The preference is input by users through the APP named "Your digital trainer (YDT)" installed on both LCD-TV and mobile device. MATLAB can reason the enjoyable music (K) based on the preference. The speaker of LCD-TV is used to play music(K).

Line 6: Temperature and humidity(T&H) is measured using Xiaomi Mijia sensor. MATLAB is used to compare the measured T&H with standard value. Air-conditioner and other appliances are used to change indoor T&H.

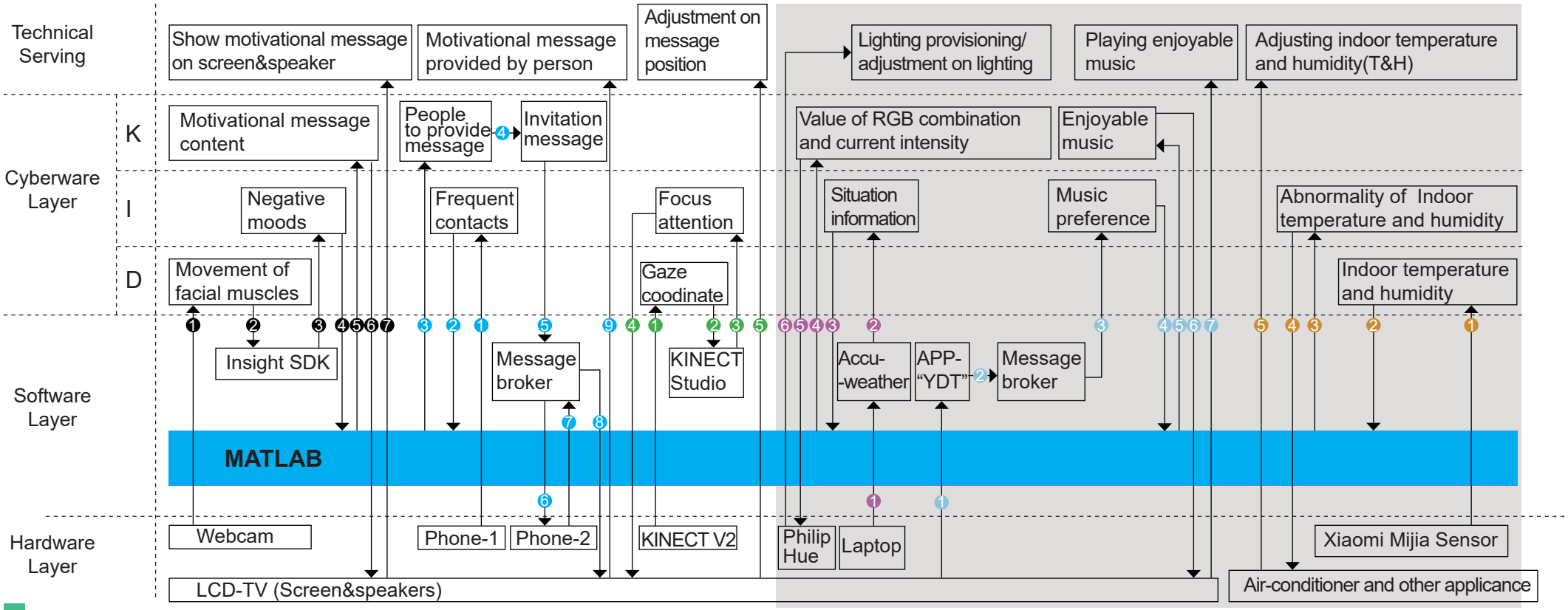


Figure 48-The architecture of motivation enhancing subsystem

4.4.5 Exergame subsystem

The exergame subsystem is composed of three parts. The three parts are represented by black, blue and yellow. They are elaborated as follows:

Line 1: The system starts with **blue** line because it relates both black and yellow line. The line starts with trajectory of joints capturing. Based on the captured trajectory of joints, KINECT Studio is used to reason i) the accuracy of motions and ii) repetition and sets of motions. MATLAB can translate the two into the transformation in game world. The typical example of transformation is the growth of users' avatar in the game world due to the amount of training performed by users.

Line 2: Users' preference in competition type and competitors are input by users using APP named "Your digital trainer" installed on LCD-TV. MATLAB arranges proper competitors and type of competition on the the basis of transformation and users' preference. The arrangement of competitors and competitions are shown through mobile devices. For example, if the preferred character in virtual world is a rally car. The possible fruit of training could be "scores" earned through performing accurate motions and "oil" earned through performing certain amount of training. Score is used to purchase engine and oil is used to fuel the rally car. In this case, MATLAB arranges rally competitions in which the user can compete with competitors who earned similar scores and oils. The game can be shown and played on mobile device.

Line 3: Users' preference in type of cooperative task and type of members (e.i: aquitance or new friends) can also be input through the APP named "Your digital trainer" on LCD-TV. The team members and tasks are also arranged based on users' preference and the fruit of training in game world. The arrangement can also be shown on mobile phone.

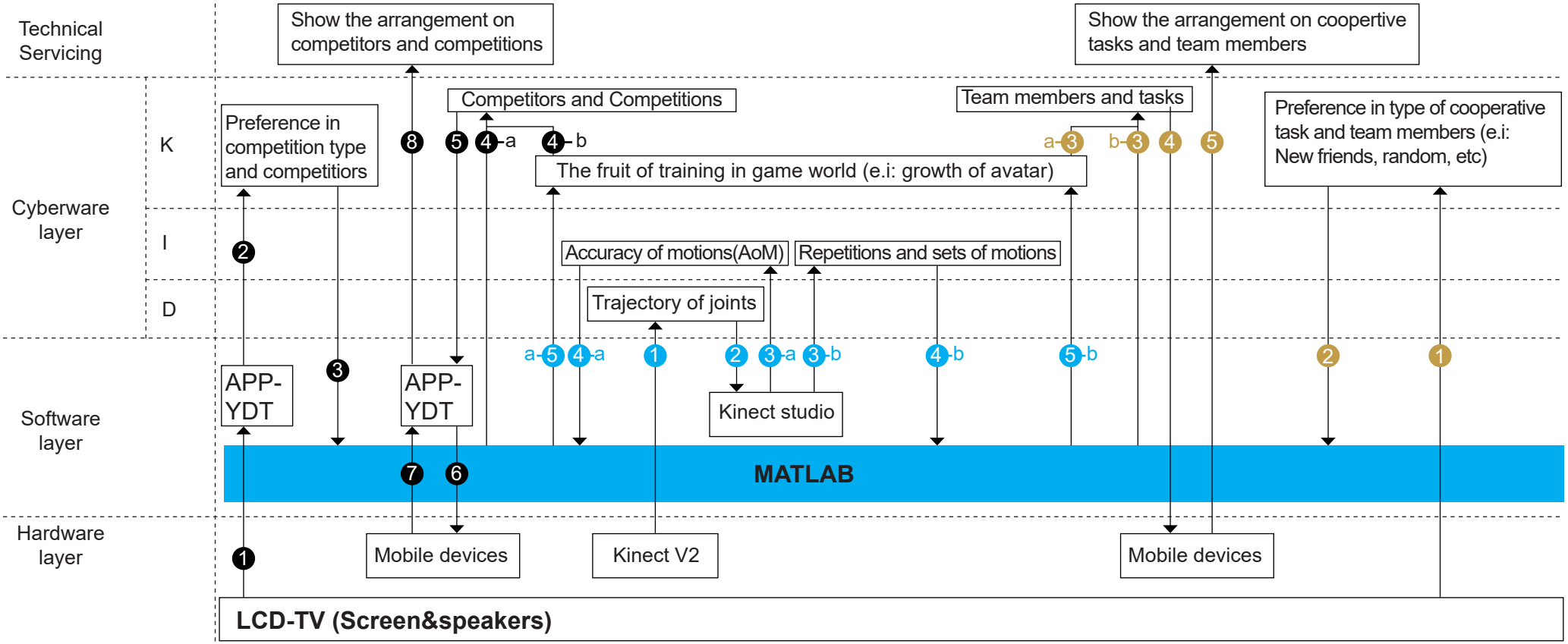


Figure 48-The architecture of exergame subsystem

4.5 Operational detailing of the subsystem

In 4.4, the architecture of the five subsystems have already been elaborated which allows people to know how the components in different layers collaborate with each other and enable the five subsystems. In 4.5, the operation of the five subsystems will be explained by texts and visualized in terms of five flowcharts. In addition, the learning mechanism will also be visualized.

4.5.1 Flow of interaction operations

The operation flow of interaction starts with the aggregation of personal information before training. Users can input personal information through the APP either on mobile device or on a LCD-TV. On the other hand, users motions are captured and assessed.On the basis of the assessment, the CP-DTS provides an interactive tutorial video. Elderly can follow the video and perform resistance training plan. Inthe process of training, three data of elderly are captured by subsystem: i) motion, ii) face muscle movement (indicator of mood) and iii) heart rate.

Based on the three data, the subsystem provides i) guidance to correct elderly's motion, ii) motivational message to keep elderly motivated, iii) inquiry to learn elderly's feeling. and iv) the updated training plan based on elderly's response to inquiry. All of the four are conveyed through LCD-TV screen. Based on the training amount and quality, CP-DTS recommends competition and cooperative tasks to elderly and allows elderly to interact with the exergame through the screen of mobile device. After the game, CP-DTS aggregates the result of elderly's level of satisfaction towards the result of competition or elderly's completion in cooperative tasks. On the basis of the result, CP-DTS gives suggestions for next exergame.

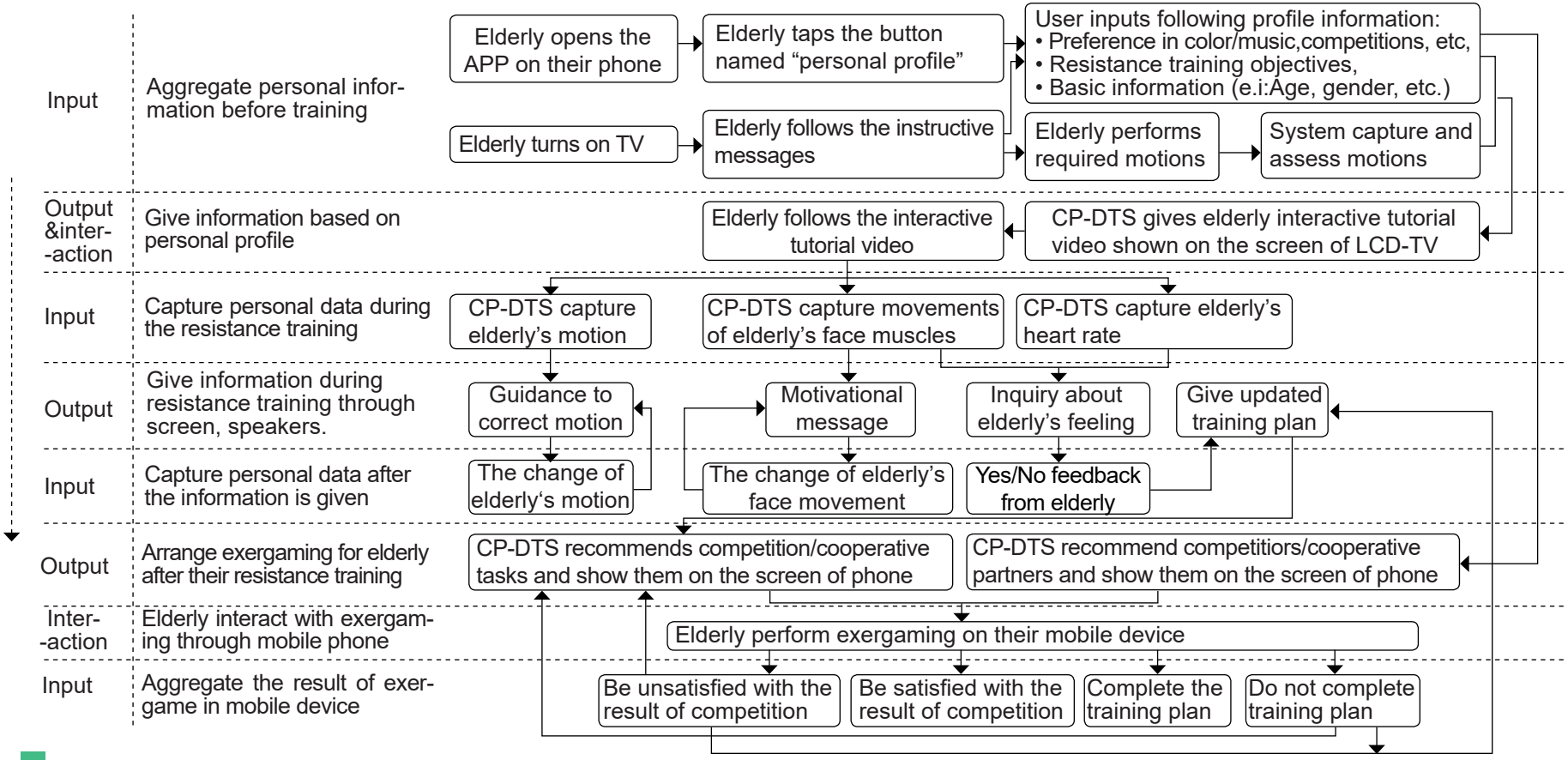


Figure 49-
Flow of interaction operations

4.5.2 Flow of monitoring operations

The operation flow of the monitoring subsystem consists of six activities. The operation flow begins with initial monitoring of elderly's mood, heart rate during the exercises.

When negative mood is observed, CP-DTS provides initial multisensory interventions and motivational message. When negative moods and abnormal heart rate is simultaneously observed, CP-DTS starts an inquiry and adjusts the parameters of exercise package.

After the initial multisensory interventions (e.i: music, lighting and indoor temperature changing) are provided, CP-DTS continues to monitor elderly's mood. If expected mood is not monitored, the parameters of interventions will continuously adjusted. In the meanwhile, the content of motivational message. The adjustment will continuously underway until the expected mood are monitored. Additionally, when visual version of messages are provided. Elderly's gaze is monitored in order to learn elderly's attention. If his/her gaze is not on the message, CP-DTS has to adjust either the position or size of the message.

After the adjustment of exercise package, elderly's heart rate and mood are also continuously monitored. The adjustment on exercise package will be continued until expected mood and heart rate are monitored.

Finally, If elderly's motions are found to be incorrect, the guidance is provided to correct his/her motions.

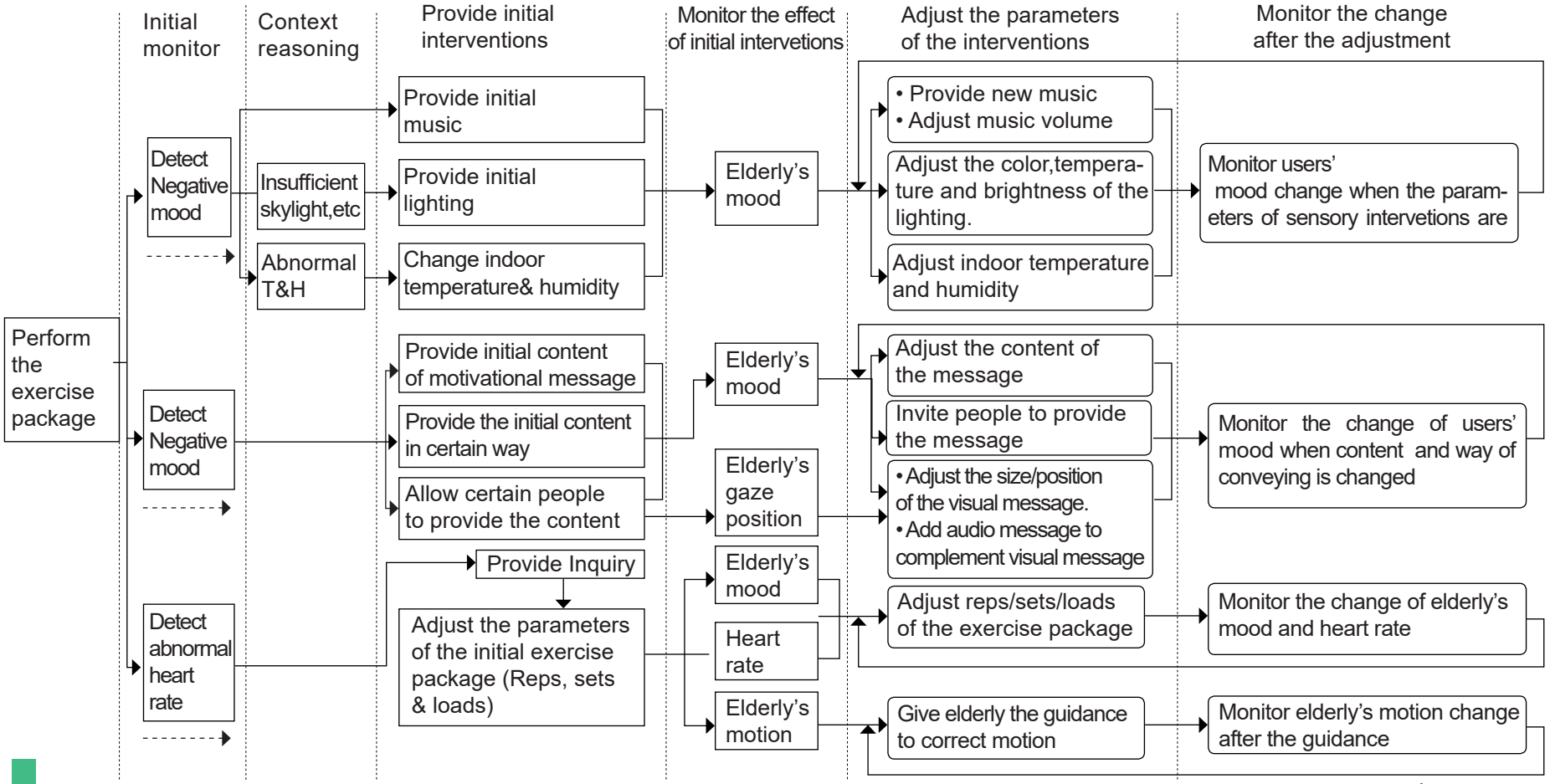


Figure 50-The flow of monitoring operations

4.5.3 Flow of training management operations

Training management operations are composed of six activities. The flow begins with elderly's personal objective collection and physical condition assessment.

On the basis of personal objective and physical condition, an initial exercise package was recommended to elderly in the form of an interactive tutorial appear on the screen of LCD-TV and elderly is required to follow the tutorial video.

In the process of the training, the subsystem i) assesses the deviation of elderly's motion from standard motion, ii) compares elderly's heart rate with normal heart rate and iii) monitor elderly's negative moods.

When the subsystem finds that elderly's motion deviates too much from the standard, the subsystem provides guidance in order to improve elderly's training quality.

When the subsystem monitors that elderly's heart rate deviates too much from normal standard, in the meanwhile elderly's negative mood is also monitored, the subsystem provides inquiry to learn elderly's feeling (e.i Do you want to stop and have a short break?). Elderly respond to the inquiry through giving Yes/No answer.

On the basis eldlery's answer, the subsystem provides suggestion on adjusting the parameters (e.i: Reps, sets and loads) of the initial exercise package. The adjustment may not be necessarily effective in one go, so the continuous adjustments are needed until the desired heart rate and moods are detected.

The visualized operation flow of training management subsystem can be found in Figure51 shown below:

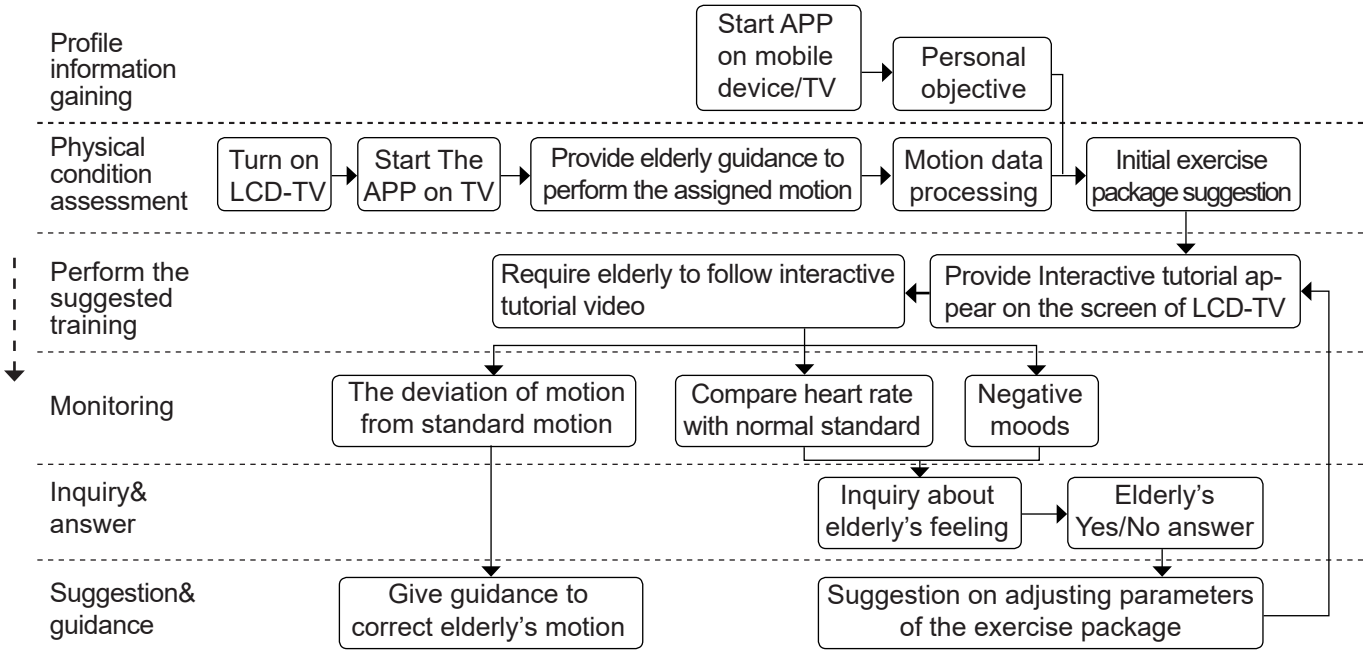


Figure 51-The flow of training management operations

4.5.4 Flow of motivation enhancing operations

The operation flow of motivation enhancing subsystem consists of four phases. The flow begins with guiding elderly to follow the tutorial video. During the process, the subsystem are firstly responsible for monitoring elderly's negative moods.

Once elderly's negative mood is monitored, two kinds of initial interventions are provided. The one is multisensory interventions while another is motivational message. The multisensory interventions include the music, lighing provisioning and temperature/humidity changing. (Music provisioning is on the basis of elderly's preference in music genre while lighting provisioning is related to elderly's preference in color. Both of the two preferences are input by elderly through the APP on either mobile devices or LCD-TV.)

Once the initial sensory interventions are provided, elderly's mood changing is monitored. If a desired mood is observed, the parameter of initial interventions do not have to be changed. But the parameters of multisensory interventions *(e.i: volume, rhythm, tempo of music or color temperature, brightness of the lighting)* have to be adjusted if desired mood is not monitored.

On the other hand, the effect of motivational message on mood is also monitored. The initial messages are visual version and shown on LCD-TV screen. If the desired mood are not monitored, the content of the message will be adjusted or changed. In the meanwhile, if elderly's gaze is not on the message, the position of the visual message on the screen will be adjusted. If adjustment of position does not lead to a desired mood, audio message will be provided. (The motivational message mentioned above are rechieved from database).

If the content and position adjustment still do not elicit elderly's positive mood, the subsystem would invite people from elderly's social network to provide motivational message.

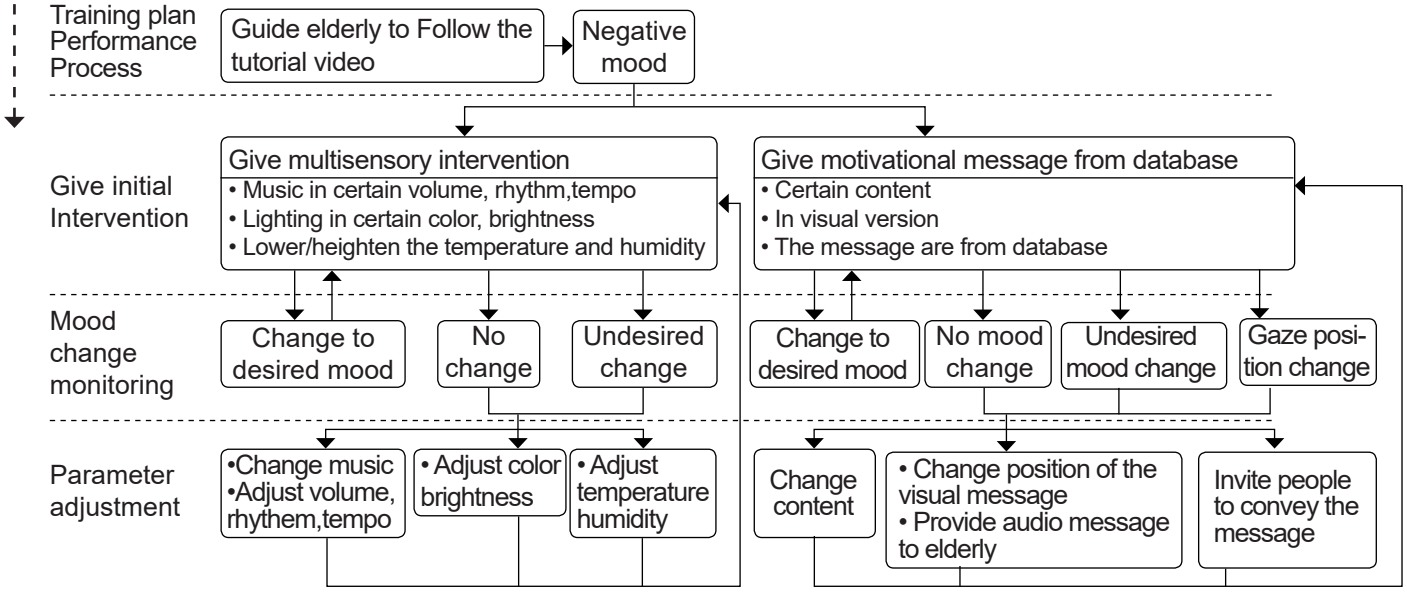


Figure 52-Flow of motivation enhancing operations

4.5.5 Flow of exergaming operations

The operation flow of exergaming consists of six phases. The flow starts from “preparation” which consists of two parts. The one is guiding elderly to follow the arranged exercise package while another is filling the personal preference through the APP.

The second phase is aggregating personal capabilities and preferences. The subsystem can convert elderly’s fruit of exercises into character’s transformation in game world. *(e.i: Users’ character in virutal world is a builder, the training amount performed by users’ can make the builder stronger which allows the builder to carry log and build a house along with other builders in the virtual world)*

In third and fourth phase, the subsystem allows elderly to perform competitions/cooperative tasks on mobile phone which is followed by results aggregation (fifth phase). The results include i) whether elderly are satisfied with the results of the competition, ii) whether elderly have completed the cooperative tasks.

If elderly are unsatisfied with the result of competition, the subsystem will either adjust the parameters of exercise package or change the competitors, level of difficulties, agenda for the next competition. If elderly have not completed the cooperative tasks within given time, the subsystem will either adjust the exercise package or provide less challenging task next time. (Adjusted exercise package allows elderly to make more transformation of character)The visualized operation flow of exergaming subsystem can be found in Figure 53 shown below:

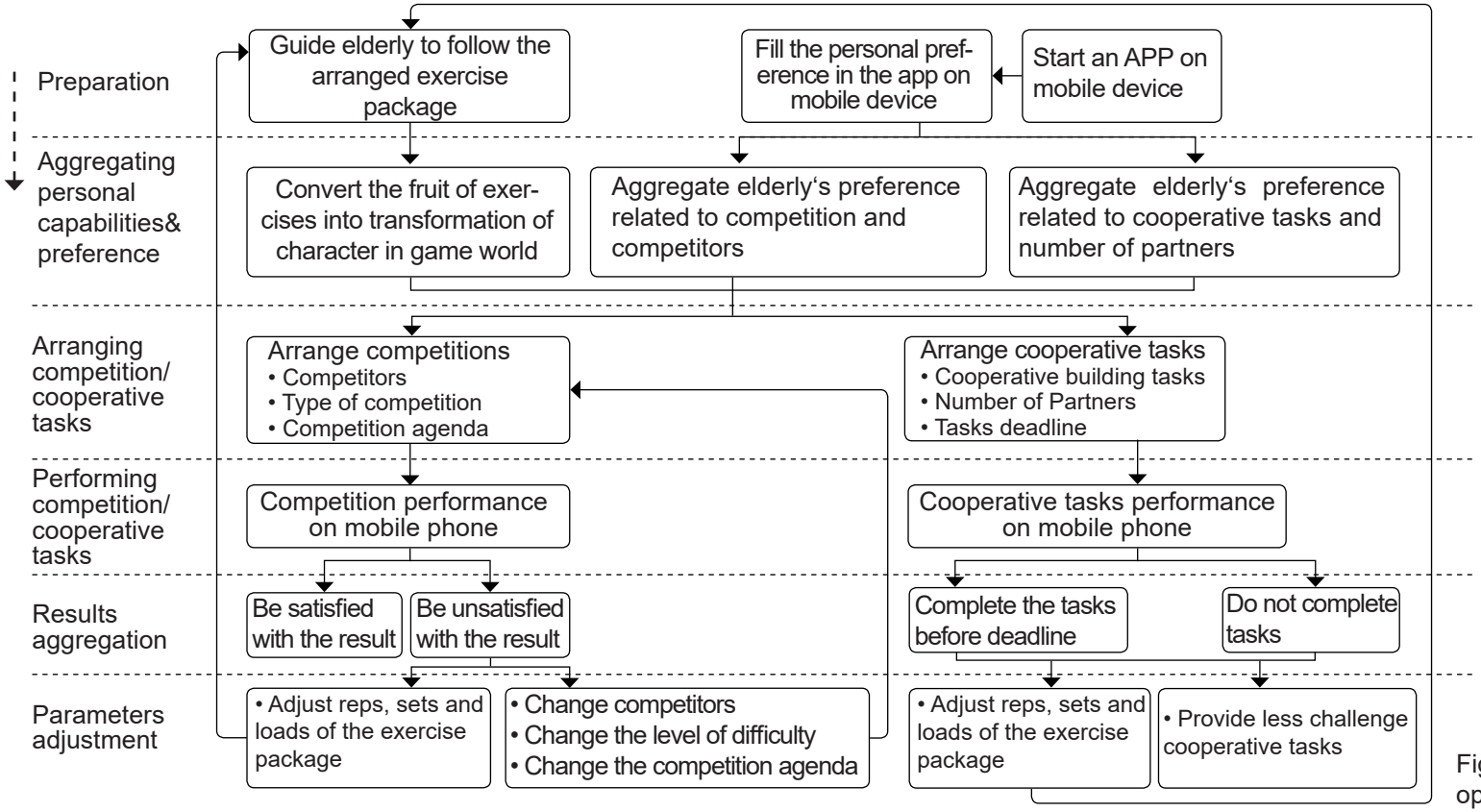


Figure 53-Flow of exergaming operations

4.5.6 Flow of self learning operations

The operation flow of self learning mechanism begins with aggregation personal information. The information includes i) elderly's ADL capabilities. ii) Personal objectives and iii) personal preference in color, music.

On the basis of ADL capabilities and objective, the training management subsystem provides an initial exercise package. Once the initial exercise package is provided, elderly's heart rate and mood are monitored

If the monitored heart rate and mood simultenously deviate from the standard, the training management subsystem(TMS) gives inquiry and user responds to the inquiry using Yes/No feedback. On the basis of the feedback,TMS adjusts the parameters of exercise package. If the mood and heart rate does not change to desired state, the adjustment of the exercise package are still needed. If the desired mood is observed, the parameters are saved in self-learning mechanism (SLM).

On the basis of personal preference in color and music, the motivation enhancing subsystem provides initial interventions (music, lighting). The effect of the initial music and lighting is continuously monitored. The parameters of music (e.i: loudiness, tempo, etc) and lighting (e.i: color temperature, brightness, etc) is continuously adjusted until the neutral or positive mood are monitored. The effective parameters are saved in SLM. Additionally, the indoor temperature and humidity is also controlled.

Motivation enhancing subsystem (MES) also provides motivational message retrieved from database. Once the message is provided, elderly's mood and gaze are monitored. Mood indicates the effectiveness of the message content while gaze reflects whehter the visual message attract elderly's attention. The subsystem adjusts the message content if the desired moods are not monitored. The subsystem adjusts the size, position of the visual message on the screen of LCD-TV if elderly's gaze is not on the message. Additionally, audio message can also be provided if visual message can not attract elderly's gaze. (The size, position and the format of the message are considered as "way of conveying) So the effective content and the proper way of conveying the content are saved in SLM. If the motivational message from database can not change elderly's mood, MES invites the people from elderly's social network to encourage them. Then SLM can learn that the proper people who can offer the effective motivational message.

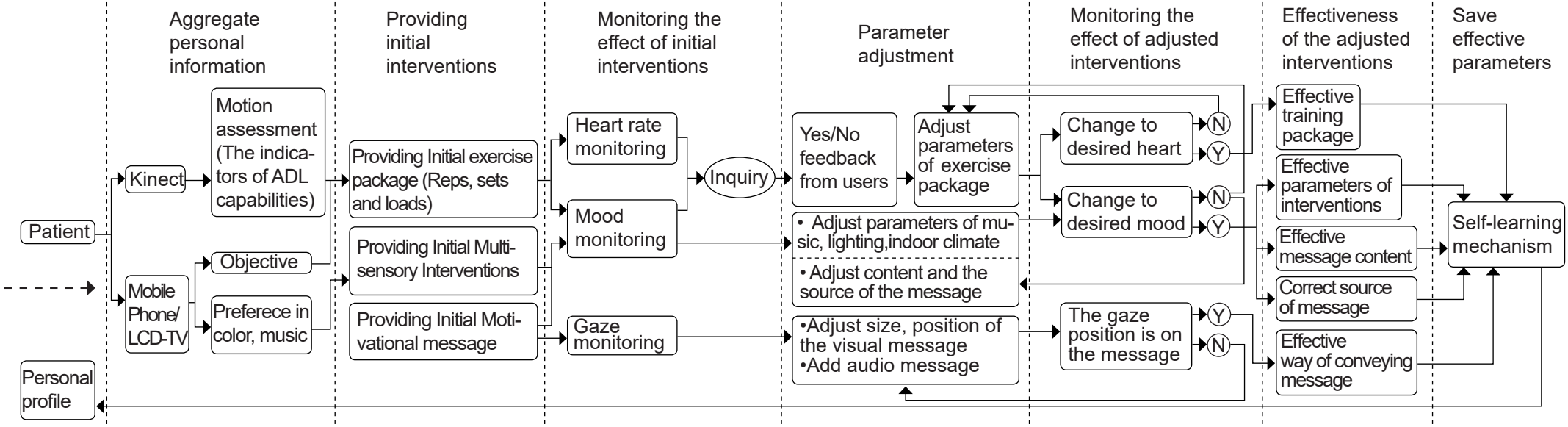


Figure 54-Flow of self learning operations

4.6 Demonstrative prototyping of the system

In 4.6, a use case scenario and a demonstrative prototype are created. Prototype aims at demonstrating the functions, services as well as the benefits of CP-DTS to potential users. Before developing the scenairo and demonstrative prototype, the architectural embodiment model and operational embodiment model is created. In 4.6.1 and 4.6.2, the role of the two models in prototype and scenario development will be explained.

4.6.1 Architectural embodiment model

Architectural embodiment model provides an overview of components which enables techincal servicing of CP-DTS. The overview facilitate us to choose the components which should be included in use case scenario and demonstrative prototype. 4.6.1 is composed of two parts, Part A is the visualized services and components. Part B is considering components selection for use case scenario and prototyping.

A. Overview of services and components

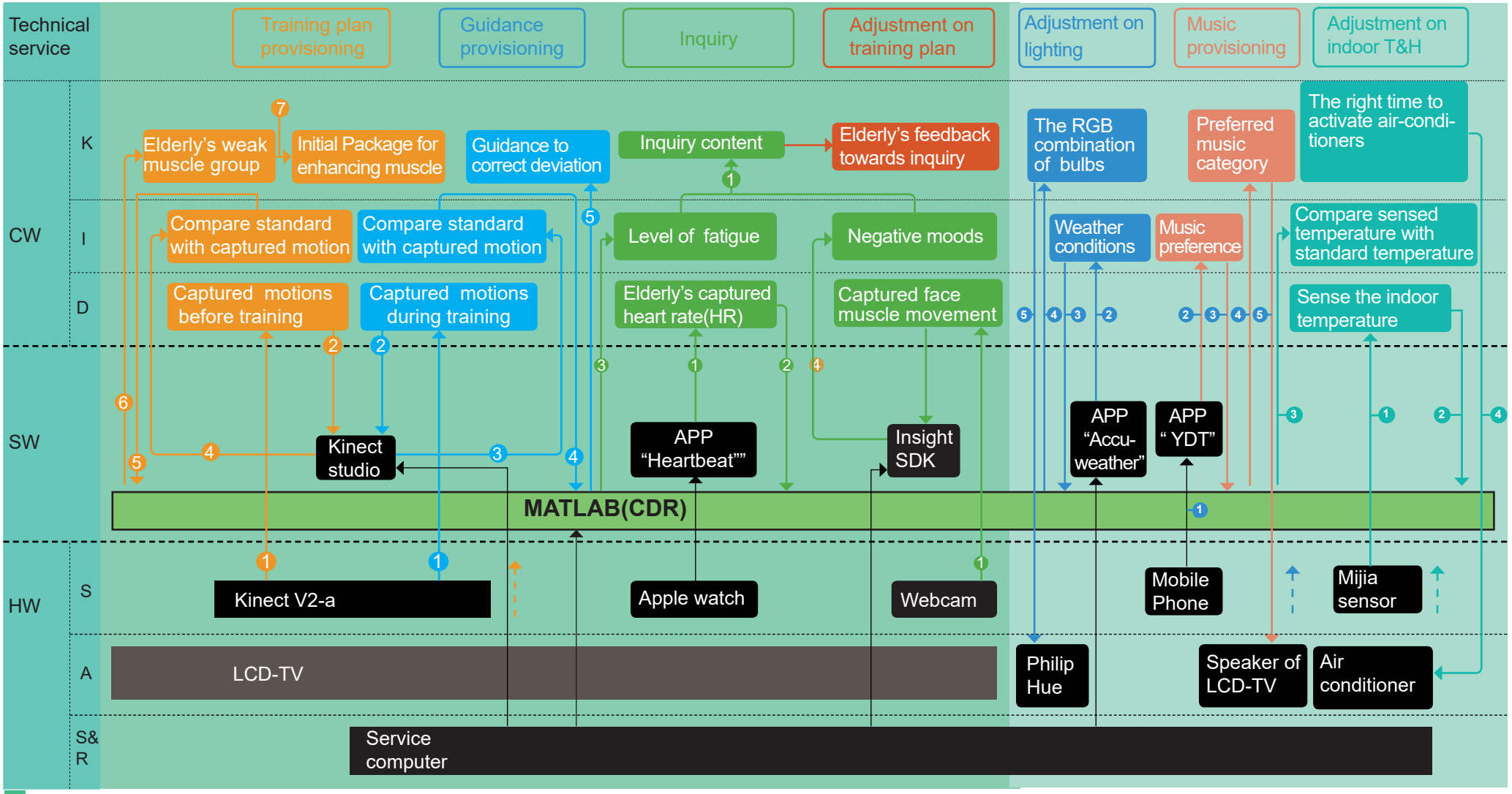


Figure 65- Architectural embodiment model-a

S=Sensing, A=Actuating, S&R=Storing and reasoning

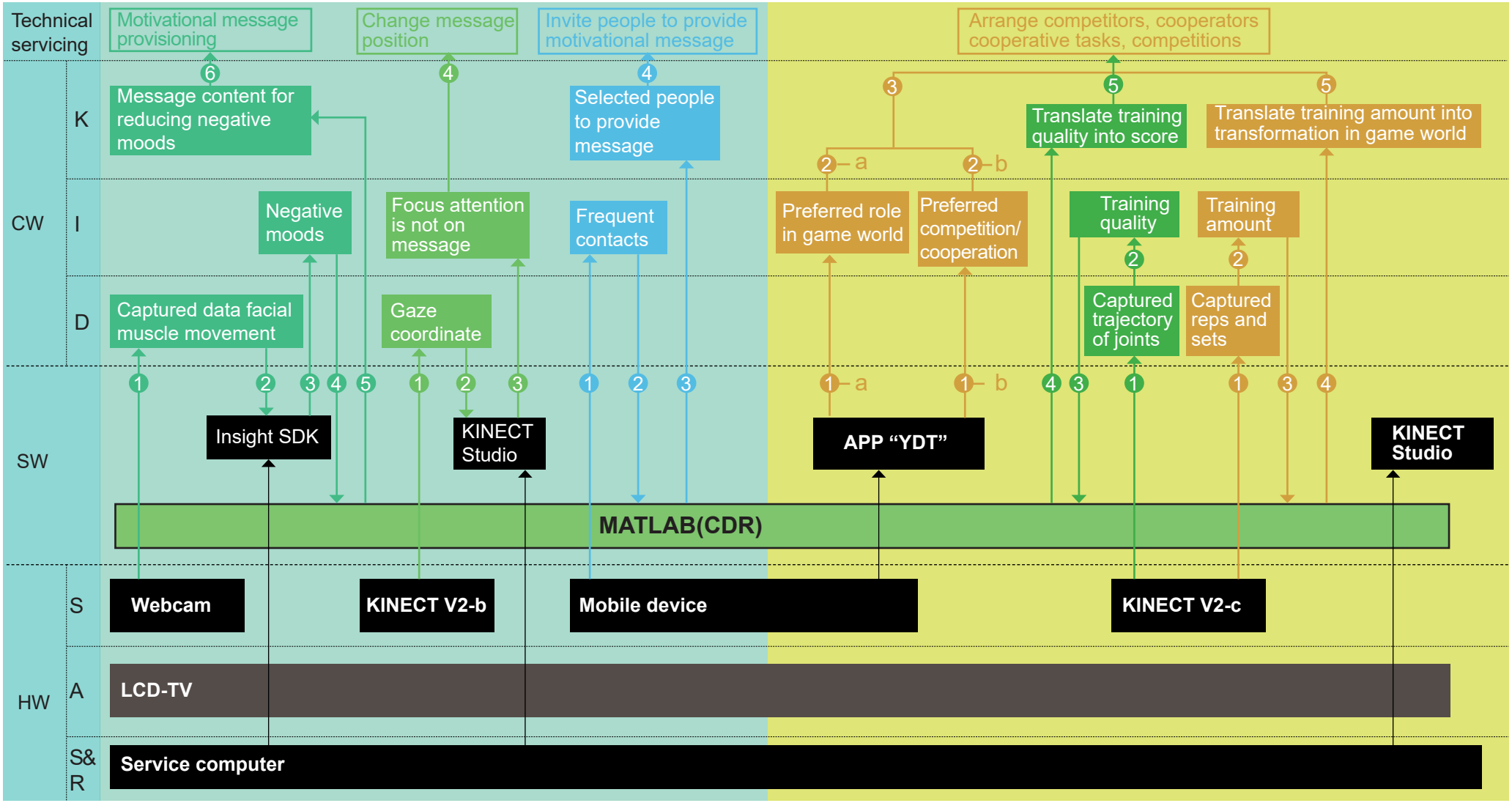


Figure 65- Architectural embodiment model-b

Obviously the figure above clearly show the components which enables techincal services of CP-DTS. Obviously, some components are more visible than others because they either have direct or indirect interaction with users or they deliver services. Author assume that the visible components should be included in both use case scenario and prototype which can intuitively show users what the system look like. Hence, in Part B, the specific components which should appear in scenario and prototype are selected.

B. The components included in scenario and prototype

In part A, all of the techincal services and components are shown. Obviously, only part of the components (normally hardware and software) will appear in scenario and prototype. Author assumed that the components which are relevant to user interfaces have to appear in scenario, such as LCD-TV. In the meawhile, some home-based components should also appear because the CP-DTS is used in home-based environment. Additionally, the price of the components have to be calculate, so as to enable users to judge if the cost is acceptable for them. Finally, it would be necessary to find out i) which components are specific for CP-DTS, ii) which components are optional in order to allow users to choose the most desirable and affordable functions. The relevant components are shown as follows:

Components	Home-based	Type	Necessity/ optional	Specific to the CP-DTS	Price
KINECT V2	Yes	Hardware	Necessary	Yes	€30,00
Webcam	Yes	Hardware	Necessary	Yes	€25,00
Bracelet	Yes	Hardware	Necessary	Yes	€18,00
Mijia sensor	Yes	Hardware	Optional	Yes	€16,00
LCD-TV	Yes	Hardware	Necessary	No	€155,00
Philip hue	Yes	Hardware	Optional	Not necessarily	€155,00
Air-conditioner	Yes	Hardware	Optional	Not necessarily	€288,00
Service computer	Not necessarily	Hardware	Optional	No	>€900,00
Insight SDK	Not necessarily	Software	Optional	Yes	/
APP-Heartbeat	Yes	Software	Necessary	Yes	/
MATLAB	Not necessarily	Software	Necessary	Yes	/
APP-YDT	Yes	Software	Necessary	Yes	/

Table 1-Components (Necessary components are marked by yellow)

As shown in Table 1, the necessary hardwares are: i) KINECT V2, ii) Webcam, iii) bracelet, The three hardwares are specific to CP-DTS. LCD-TV and service computer are also important, but users are expected to have them already before using CP-DTS. Service computer can also be public computational infrastructure because the operation of MATLAB requires a high performance laptop which can hardly be possessed by elderly, especially those above 75 years.

Philip Hue and air-conditioners are specific for CP-DTS, but author assumes that they should be optional instead of necessary components, because they may significantly increase the cost.

There are some software which are for data processing and reasoning. Such as KINECT Studio, Insight SDK, MATLAB. The first two are matched with KINECT V2 and webcam. The price of MATLAB ranges from €45,00 to €2000,00. So it is hard to decide the cost on software.

So the basic price of CP-DTS should be €30+€25+€18=€73. When philip hue and Air-conditioners are included in CP-DTS, the lowest price should be €155+€288= €443, As mentioned above, users are not expected to purchase LCD-TV and service computer for CP-DTS. So the totall cost for hardware is €443+ €73= €516.

Obviously, in scenario and prototype, the functions of Kinect V2, webcam, smart bracelet as well as LCD-TV have to be elaborated because they are relevant to most of the functions of CP-DTS. In the meanwhile, the functions of Philip Hue and air-conditions should also be explained even if they are just relevant to optional function.

The functions of the APP named Your digital trainer (YDT) should be elborated as well because it is not only very important information aggregator, but also related to the interface of CP-DTS. Other software are not necessary to be elaborated because their functions are not very visible for end users.

Scenario and prototype aims at showing the services of CP-DTS. Services is the result of the operation of functions. Hence, in 4.6.2, the operational embodiment model of CP-DTS are presented.

4.6.2 Operational embodiment model

As mentioned in 4.6.1, services happens when users come across the operation of functions. Obviously, operational model is the key when it comes to develop use case scenario and prototype.

Same as in 4.6.1, 4.6.2 is also composed of two parts. Part A shows an overview of CP-DTS operation. The operation is composed of five phases and a self-learning mechanism. Part B aims at selecting what details of the operation should be included in use case scenario and prototype.

A. Overview of operational model

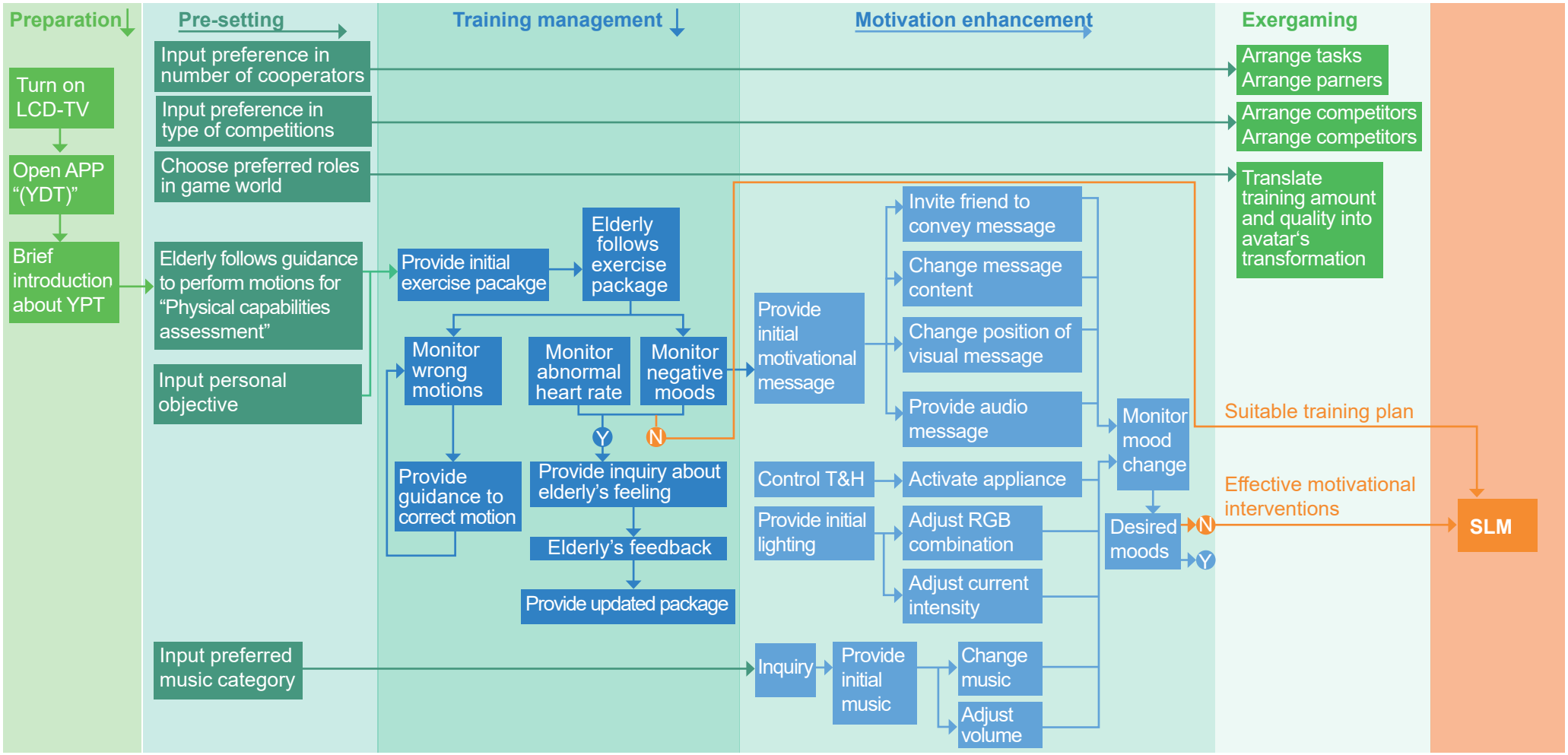


Figure 66-Operational embodiment model

B. The detail of operation included in use-case scenario

In Part A, we can clearly see the five phases of the operation flow. Part B aims at selecting the phase and details which should be included in use case scenario and prototype. Obviously, the audience of use-case scenario and prototype are potential users and other stakeholders, so scenario and prototype should demonstrate how the operation affect and interact with users. Hence the following phase and detail will be shown in scenario and prototype.

B1-Preparation(Introduction)

Obviously, potential users and other stakeholders have very little knowledge about the system. So a brief introduction should be needed in order to allow users' know i) why do they need the system, ii) how to set up the system as a new user.

B2- Presetting

Presetting is as important as sensing because some technical services are provided based on the informations obtained in presetting session. So the scenario should show i) what informations are obtained, ii) how users input these informations.

B3-Training management

In training management, several services of CP-DTSs should be shown, such as: i) giving training plan, ii) providing guidance to correct motions, iii) inquiry as well as iii) adjusting training plan. As shown in operation embodiment model, some of these services are provided based on monitored situations, such as: wrong motions, abnormal heart rate, etc. Hence in both scenario and prototype, the above mentioned services and the corresponding monitored situations have to be included.

B4-Motivation enhancing

The indispensable functions is motivational message provisioning. So this part should be the focus in both scenario and prototype. As shown in operation flow, motivational message provisioning are composed of three parts: i) providing visual and audio message, ii)adjusting the position of visual message as well as inviting friends to provide motivational message. Obviously, the provisioning of motivational message is based on monitored moods and the adjustment on visual message position is based on monitored gaze. Hence, in scenario and prototype, the three services and two monitored situations should be included. In the meanwhile, it worth to mention that the example of motivational message content should also be specified.

The music provisioning and the adjustment on lighting, temperature, humidity should also be mentioned, but it is not necessary to elborately explain them because they are optional functions.

B5-Exergaming

As mentioned in exploration part, most elderly incline to be contributor instead of competitor. So the exergaming should be relevant to cooperation between avatars. In the scenairo and prototype, three things have to be explained: i) how CP-DTS arrange team members to users, ii) how CP-DTS arrange cooperative task to users, iii) how do users manipulate the avatar and complete the cooperative task.

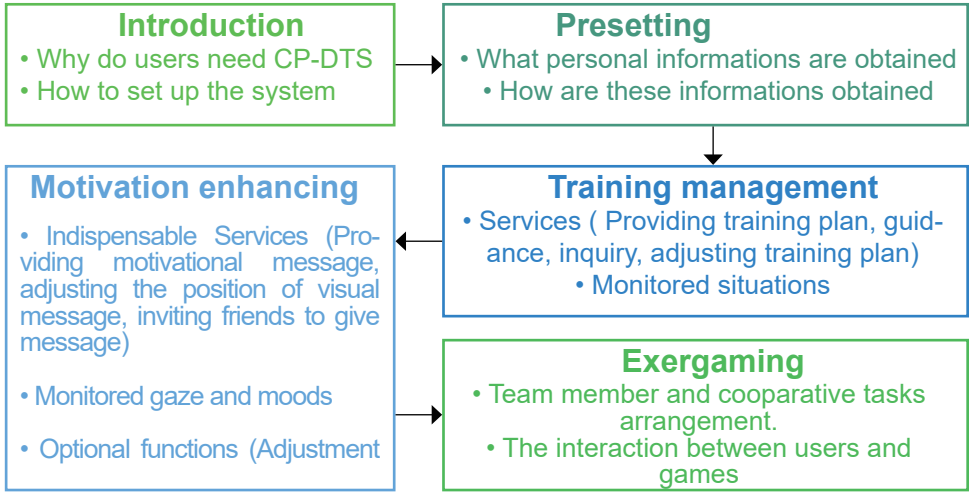


Figure 67- Content of use case scenario

On the basis the contents mentioned above and the components found in 4.6.1, use case scenario is developed.

USER CASE SCENARIO

This picture shows how the sensors and actuators are positioned according to the user case scenario.

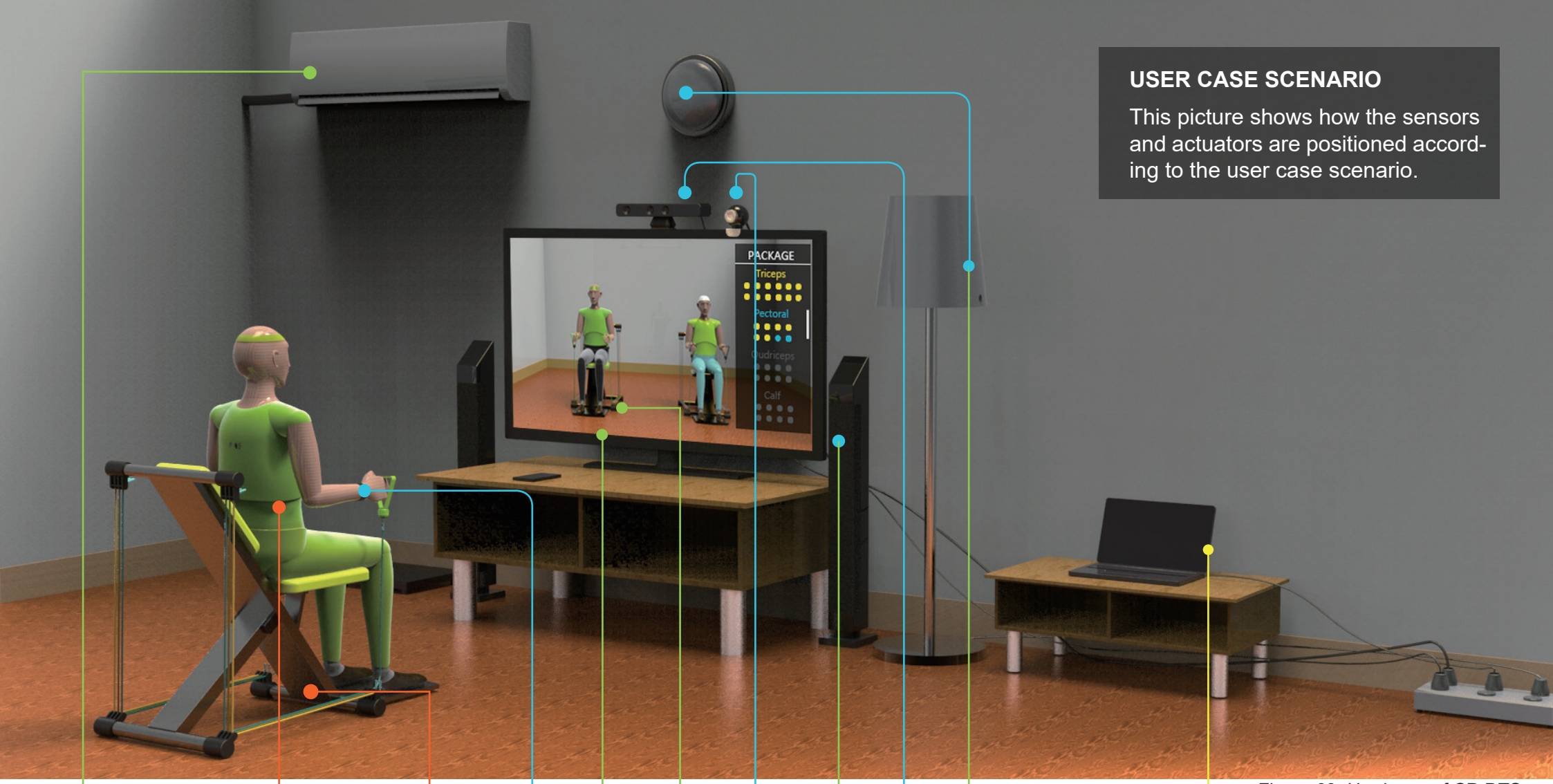


Figure 68- Hardware of CP-DTS

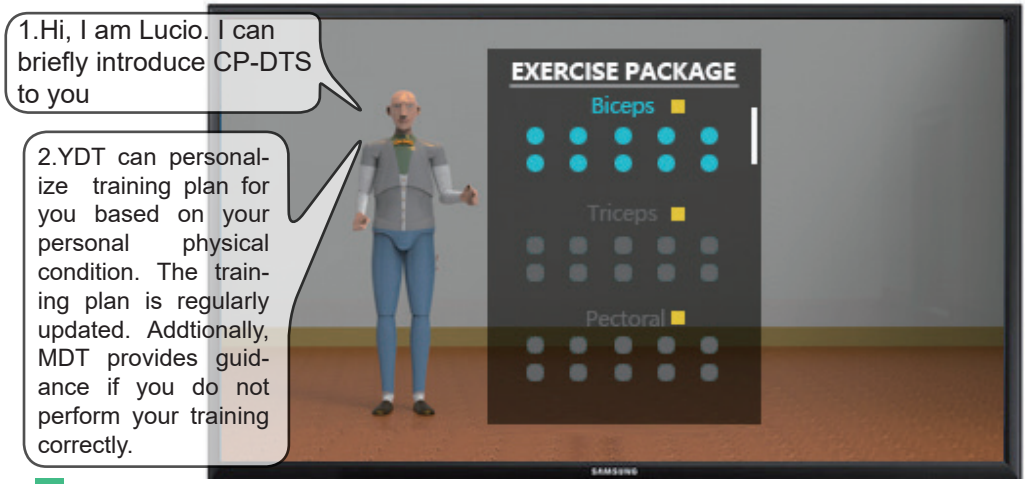
4.6.3 Use case scenario

On the basis of the components found in 4.6.1 and the detail of operation mentioned in 4.6.2 the use case scenario is developed. The scenario is demonstrated using pictures and illustrative texts. The user appears in this scenario named Tom.

A. Kick-off session

A1. This is Tom's first time to try out CP-DTS. Tom turns on the LCD-TV and initiates the APP named "Your digital trainer" (YDT).

A2. An avatar appears on the screen. He elaborately introduces the functions about training management and enjoyment enhancing.



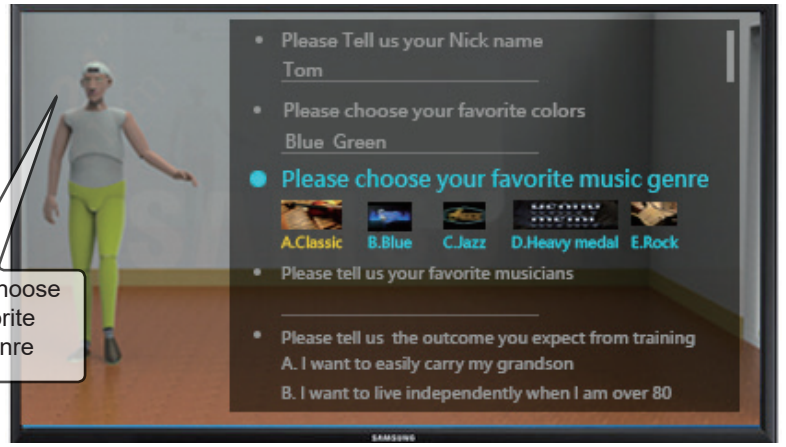
A3. The avatar also introduces how the exergame work.

A4. The avatar finally asks if Tom wants to formally experience "My digital trainer". Tom answers "Yes".

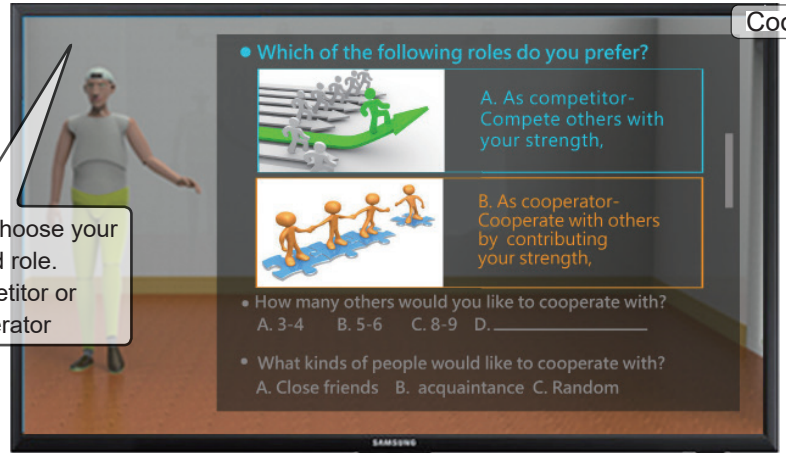
B.Pre-setting before training

B1.Before starting resistance training, users have to input personal information through the APP either on the mobile device or LCD-TV. In 4.6.3, only the interaction with LCD-TV is elaborated.

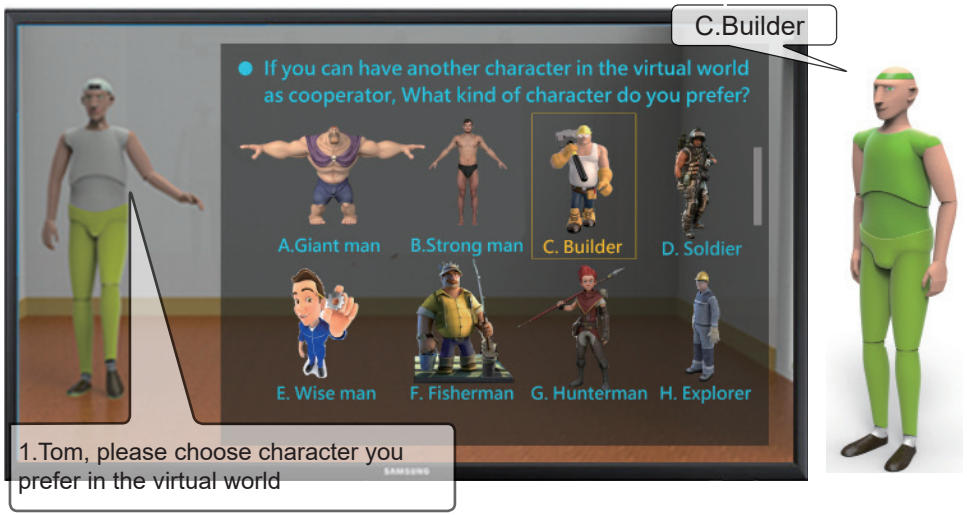
B1-1. Training assistant briefly introduces himself to Tom.



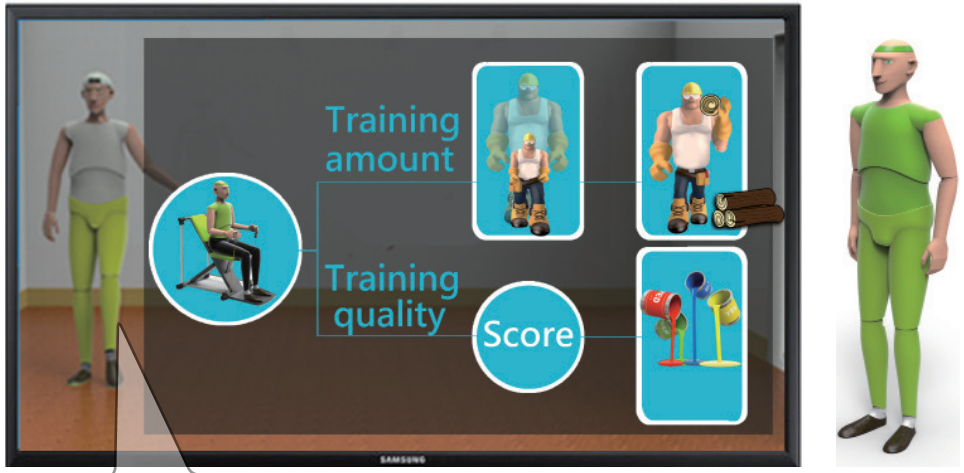
B1-2. The avatar asks Tom to input his color/music preference and other informaion,



B1-3. Avatar asks Tom to choose his prefered role in game world.(Competitor/ cooperator) Tom chooses cooperators as his preferred role.



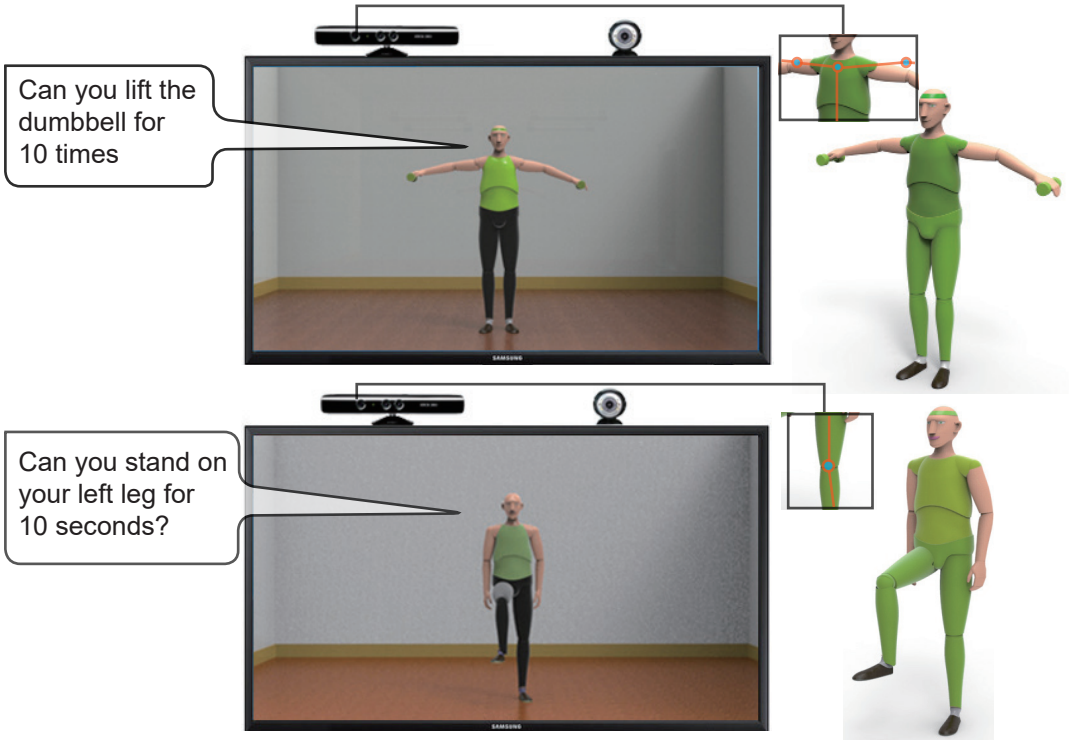
B1-4. Avatar asks Tom to choose his prefered character in virtual world, Tom chooses builder as his preferred character.



B1-5. Avatar explains Tom i) the possible cooperative tasks for his character Joe. ii) the possible influence of Tom's training on his character and the cooperative task.

B2.After inputting initial personal information, Tom is asked to perform a set of motions following the guidance shown on the screen of LCD-

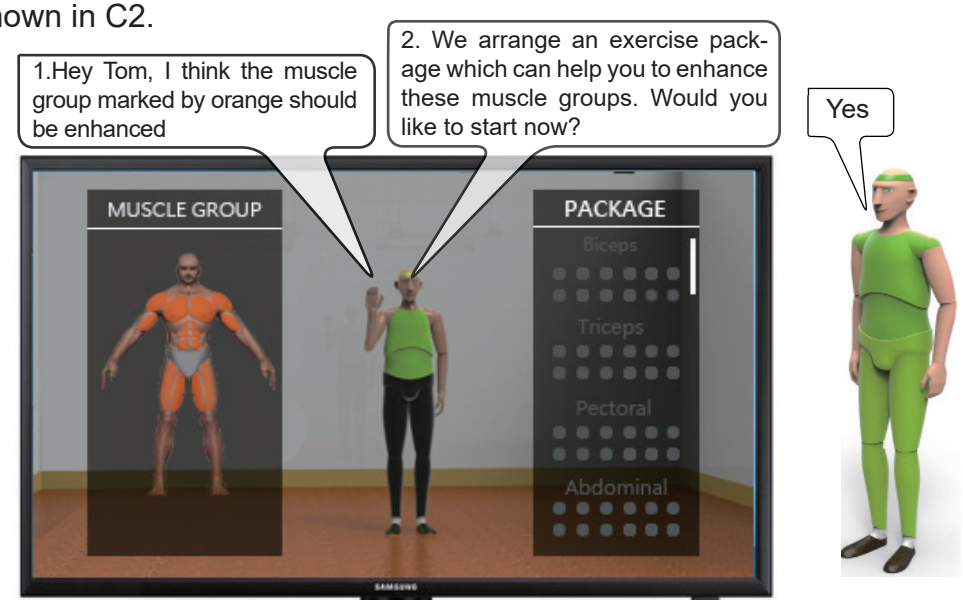
B2-1. The avatar introduces Tom his personal trainer and the personal trainer starts to take over.



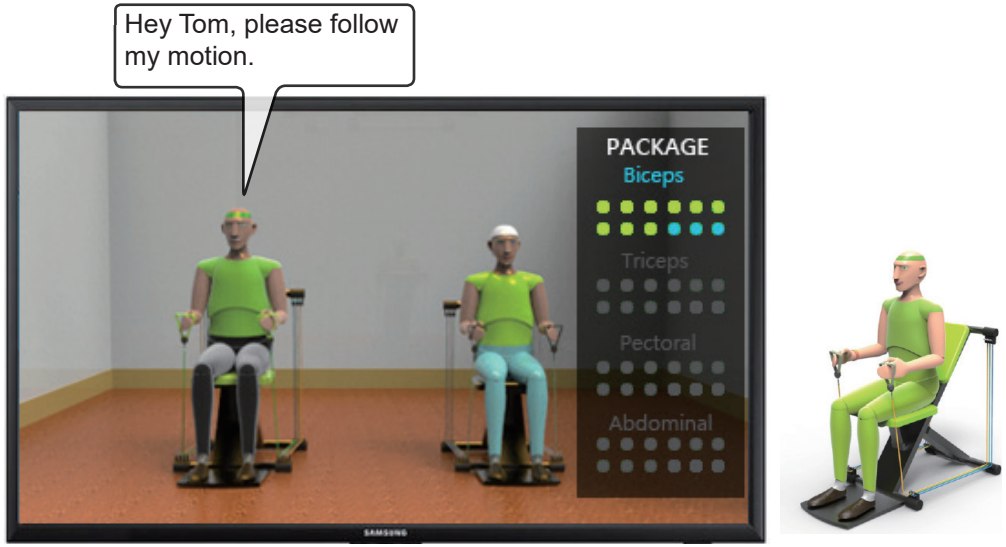
B2-2. The personal trainer guides Tom to perform a set of motions. These motions are essential for performing activities of daily living(ADL). By comparing their motions with standard motions, CP-DTS can assess which muscle groups have to be enhanced.

C.Training management

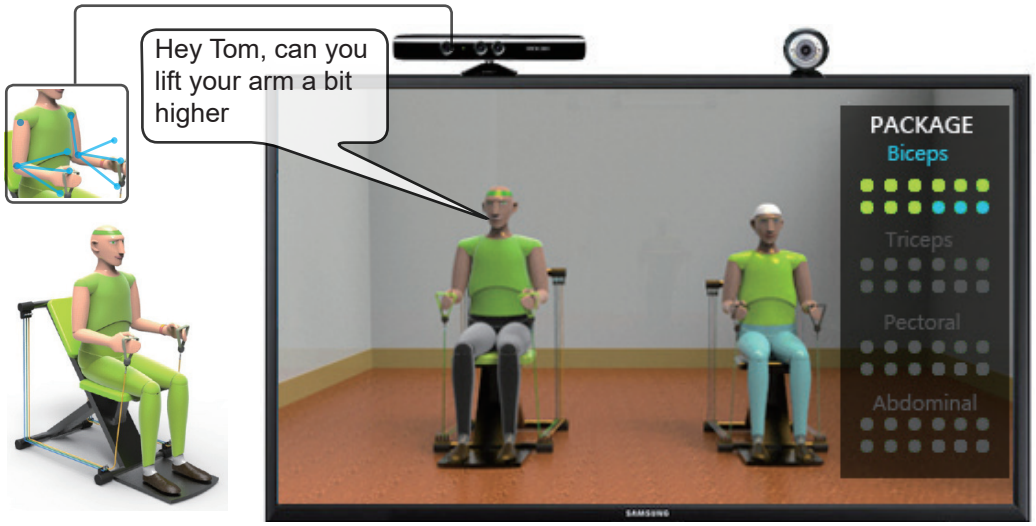
C1.On the basis of the motions, Joe offers Tom an exercise package. The exercise package are provided in the form of an interactive video shown in C2.



C2.Tom follows the motions of digital trainer in the instructive video shown on the screen of LCD-TV.

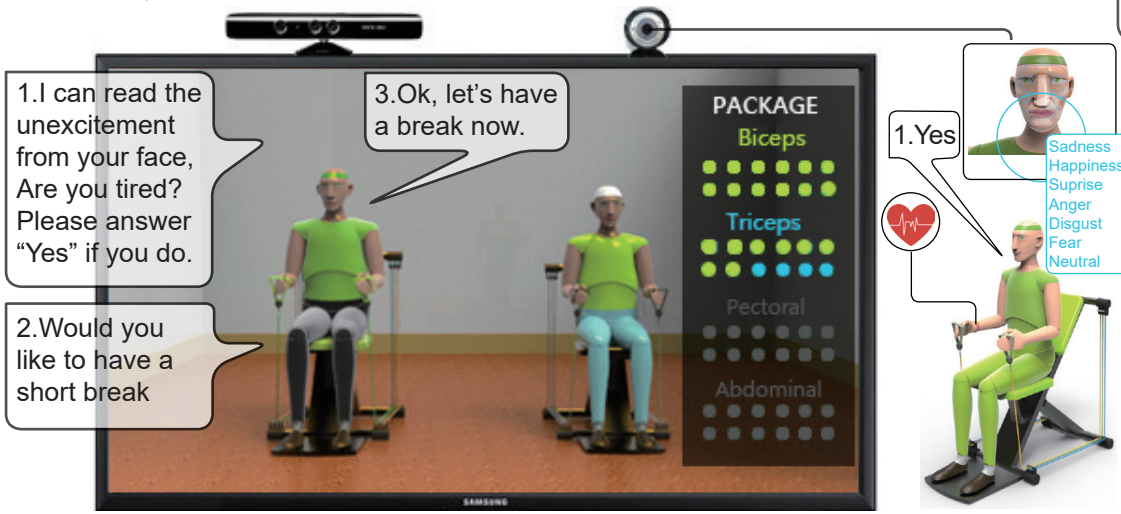


C3. Tom's motion is found to be inaccurate by CP-DTS, so the personal trainer provides the guidance message to correct Tom's motion.



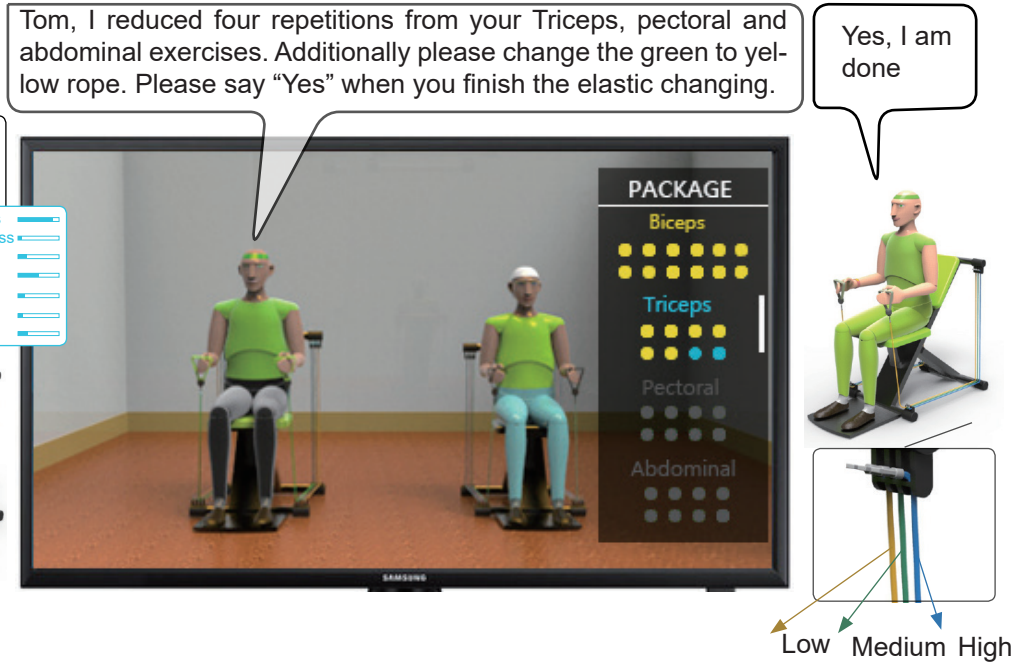
C5.During the break, personal trainers asks the Tom if he wantS to adjust the exercise package or not. And Tom says: "Yes".

C4. When Tom is performing his second sets of Tricep exercise, he hears the personal trainer inquires him that if he feels tired. Tom says" Yes" . Then the trainer asks" if you want to have a short break at once or not?" Tom also says "Yes". So the CP-DTS finally says:" Ok, let's have a break."



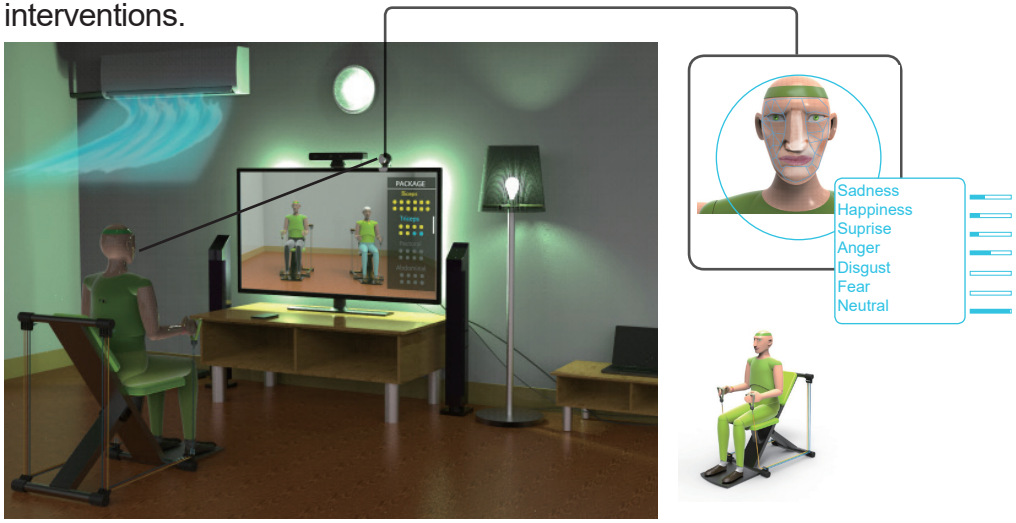
C4-1 CP-DPS recognize Tom's unenjoyment through his abnormality of heart rate and movement of face muscle.

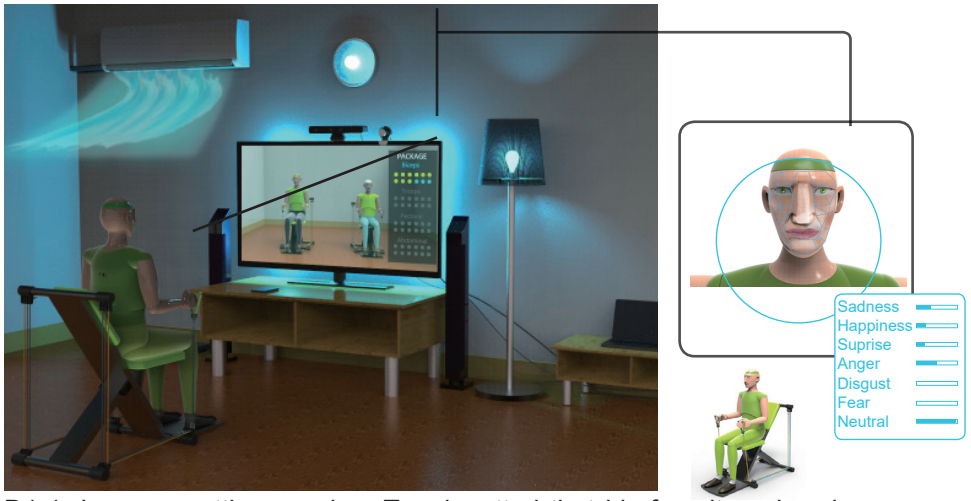
C6. The personal trainer recommends Tom to reduce a set from the biceps and tricep exercise. In the meanwhile, change from medium resistance to low resistance.



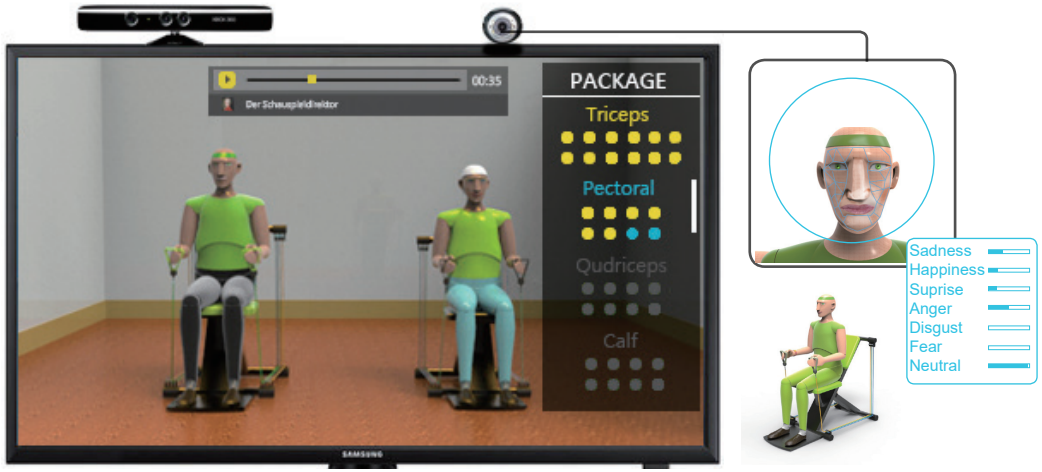
D.Motivation enhancement

D1. The season is summer and the indoor temperature is above 26. In the meanwhile, the weather is cloudy. Tom has performed the resistance training for 10 minutes under such an unenjoyable environment. CP-DTS observes the Tom's unhappiness through webcam and provides some interventions.





D1-1. In a pre-setting session, Tom inputted that his favorite colour is green and blue. He would enjoy himself to be immersed in greenish and bluish environment. Hence, CP-DTS turns the indoor lighting into green and adjust the color temperature as well as brightness of the lighting. Additionally, CP-DTSs also lower the temperature by activating the air conditioner. Webcam observed the subtle mood change.

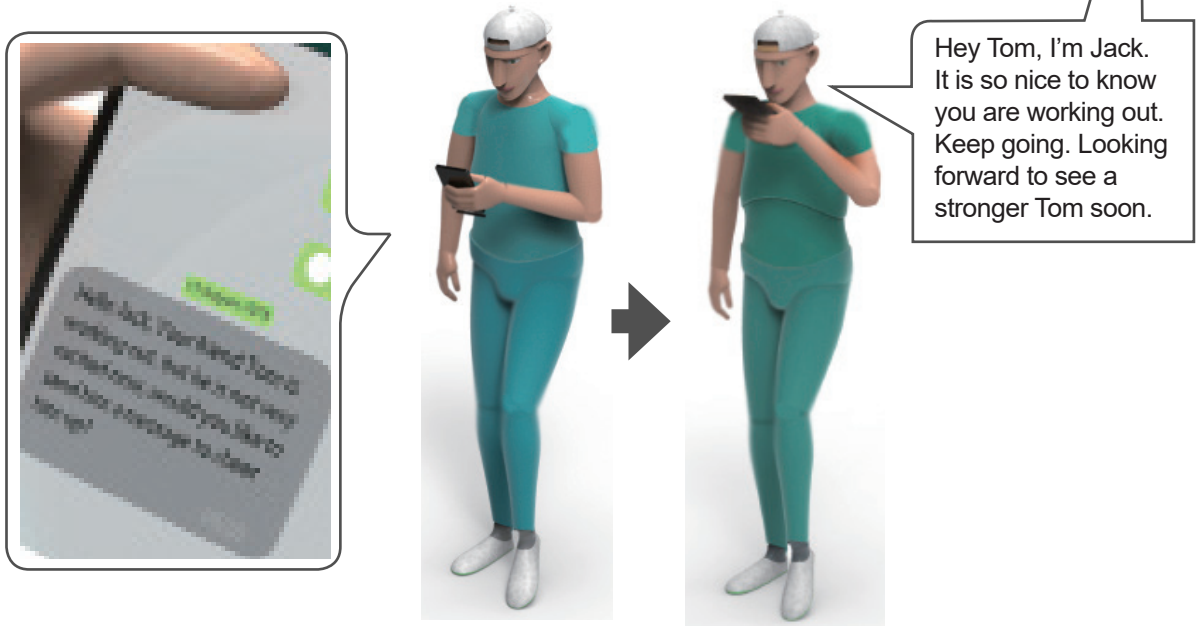


D1-2. Tom also inputted that his favorite music genre is classic music and his favorite musician is mozart. So CP-DTS plays "Der Schauspieldirektor". In order to avoid the intrusiveness, the music starts in a small volume and system gradually increase the volume of the music. CP-DTS observed the mood change on Tom's face.

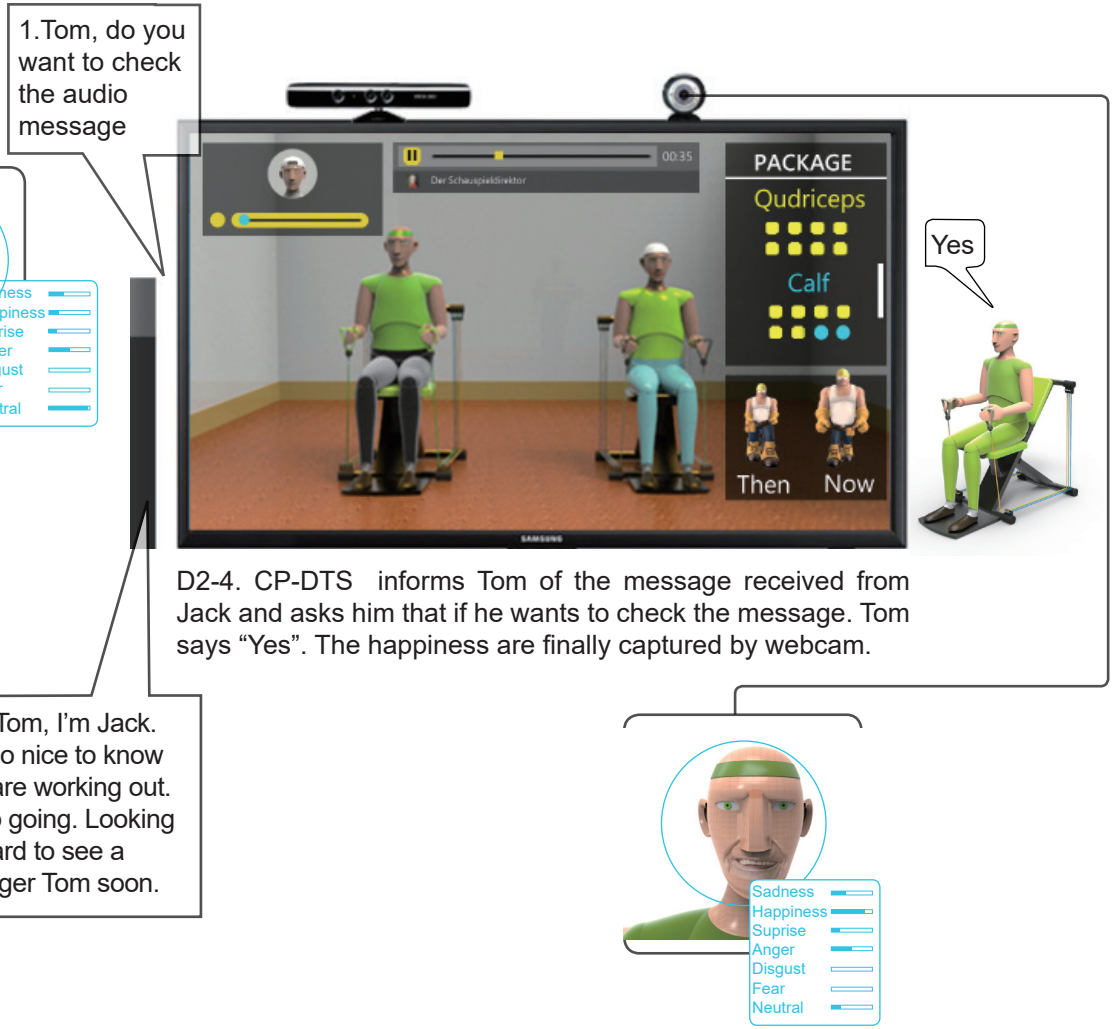
D2. Although the mood change is captured by webcam after the provisioning of the interventions, it has not turned into desired mood. So CP-DTS starts to provide motivational message.

D2-1. CP-DTS presents Tom's character(Joe) on the left side of the screen. But no mood change is captured. In the meanwhile, Tom's gaze is found to be on the right side of screen.(Gaze is captured by Kinect). This may indicate that i) message content should be changed, ii) the message should be adjusted to the position which is more likely to attract Tom's attention.

D2-2. CP-DTS shows the comparison between the current state of character(Now) and the state at the start of Tom's training(Then). In the meanwhile, this visual information is adjusted to the right side. The mood change is finally observed. However, the observed mood is still not happiness (Desired mood).



D2-3. CP-DTS contacts Tom's close friend Jack to invite him to send motivational message. Once Jack receives the message, he immediately sends an audio message to Tom.

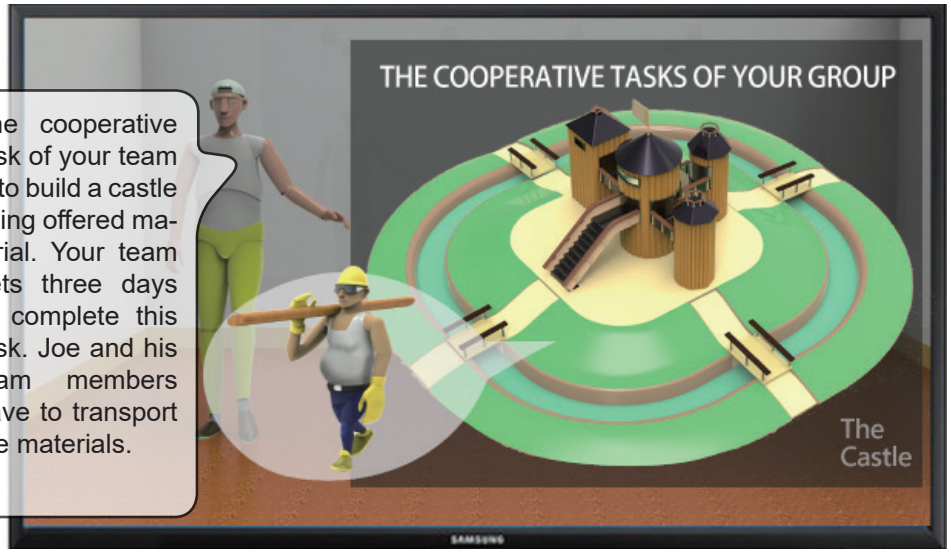


D2-4. CP-DTS informs Tom of the message received from Jack and asks him that if he wants to check the message. Tom says "Yes". The happiness are finally captured by webcam.

E. Exergame

E1. 2 weeks later, CP-DTS arranged cooperative partners. Now a task for Tom is based on the result of his 2 weeks training and the information given by Tom.

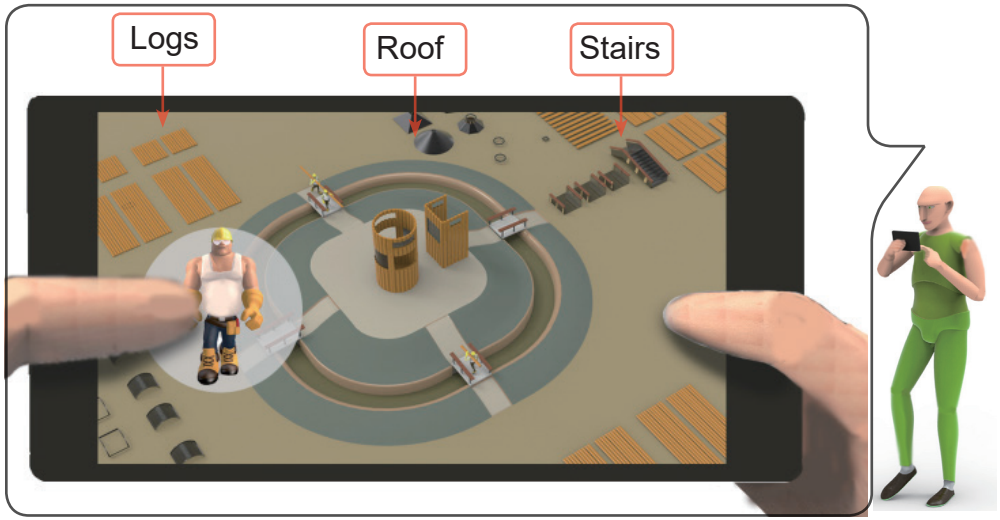
E1-1. In pre-setting, Tom filled that he likes work in the Group of 8-10 and he enjoys to cooperate with new people. So the CP-DTS arranged nine team mates for Tom. Avatar sam conveys this arrangement to Tom.



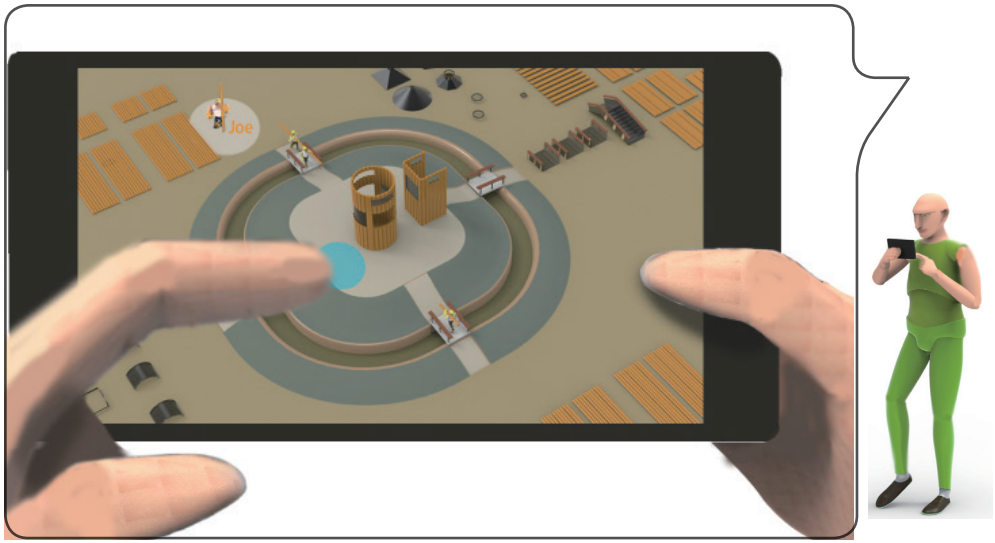
E1-2. The avatar explains Tom that their cooperative task is to build a castle using Joe's to carry the materials and accumulate them. The transportation and accumulation requires the energy of Joe earned by Tom through performing two weeks of resistance training.

E1-3.Sam also explains that the decorative materials can be purchased using the score they earned.

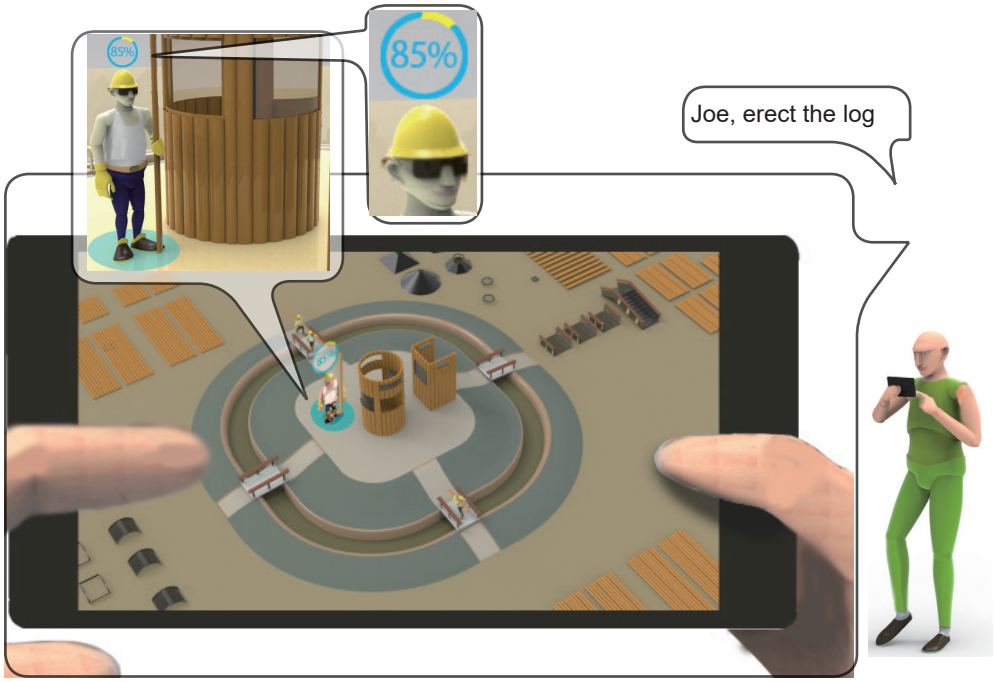
E2- In this two days, there is no other training plan. So Tom got the chance to focus on his cooperative task. The following screenshots can indicate how the game works.



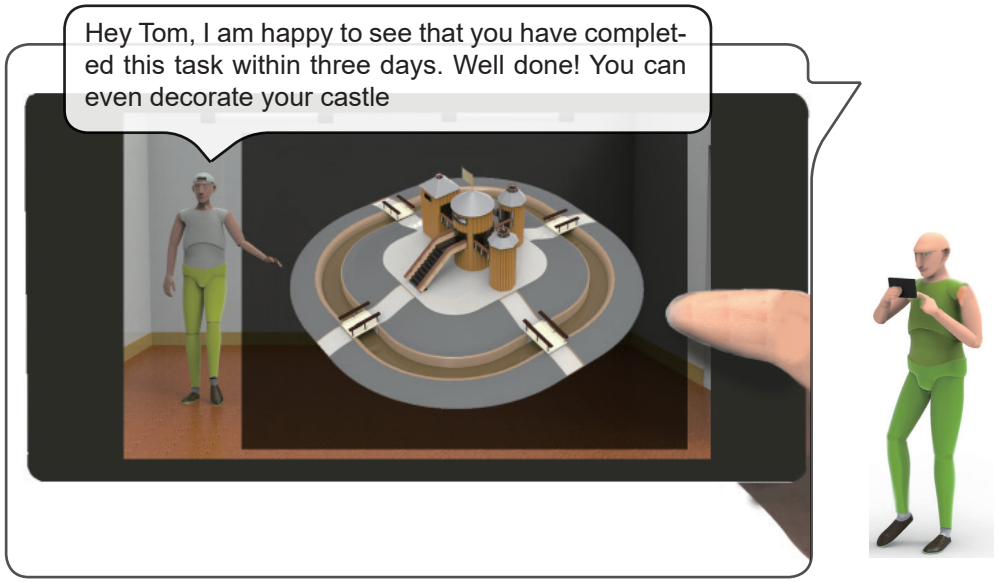
E2-1 Tom moves his character Joe towards the materials and Tom will automatically pick up the material.



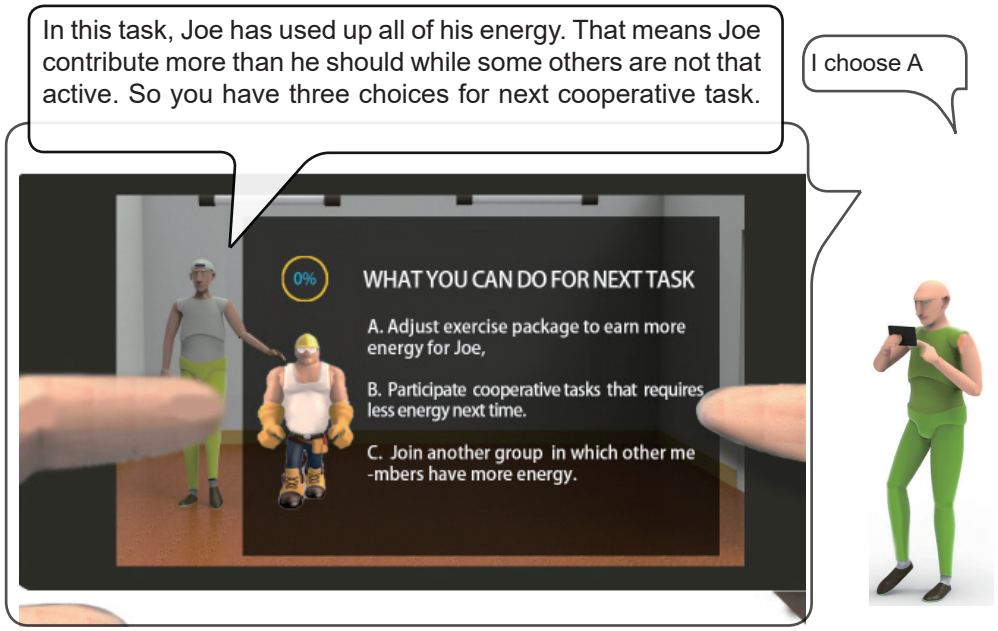
E2-2 Tom uses his finger to point at the location where Joe has to move the material to.



E2-3 After Joe reaches the location, Tom gives Joe a command:“ Joe, erect the log”. The Joe erect the log. In the meanwhile, a blue circle appears on top of Joe’s head. The blue circle indicates the percentage of Joe’s the energy consumed in the process.



E2-4 Joe and other group members finally complete the castle within three days. Sam appears again and says congratulations



E2-5 Sam also reflected the percentage of energy used in this cooperative task and explains Tom that the three choices for next cooperative tasks.

E2-6 Tom and his cooperative partners also got to purchase the needed paint, plants and other decorative materials using the score they have earned in resistance training.

As mentioned at the beginning of 4.6.3, use case scenario is to explain functions,service of CP-DTS and how potential users benefit from the functions of CP-DTS using pictures and illustrative texts. In this case, readers or audiences can hardly have immersive experience because they have to read the texts and figure out the meaning of pictures.

Obviously in testing phase, respondents should have immersive feeling about the CP-DTS, otherwise they can hardly judge the concept in the aspects of usability, desirability and satisfaction. Hence, we need a demonstrative prototype to present how the real life users would experience the CP-DTS. So in 4.6.4, the demonstrative prototype will be explained.

4.6.4 Demonstrative prototype

Demonstrative prototype is expected to allow potential users to have immersive feeling about CP-DTS. Hence, the prototype should be interactive which allows users to understand CP-DTS with low effort. 4.6.4 is composed of two parts. Part A aims at explaining the main contents of the prototype. Part B is considering how author expect the prototype to be demonstrated.

A. The main contents of demonstrative prototype

Demonstrative prototype is developed on the basis of use case scenario. Demonstrative prototype is composed of four parts: preparation, training process, motivation enhancement as well as exergaming. In meanwhile, several components are included in the four parts. These components are elabroated in 5.1.2

B. The way of demonstrating prototype

Demonstrative prototype is developed on the basis of use case scenairo (UCS). But demonstrative prototype is a slide which is composed of 352 pages. Author aims at creating an effect of interactive animation by playing this slide page by page. Each page of the slide is one frame of the animation. As shown in Figure 70, the demonstrative prototype is shown through laptop.

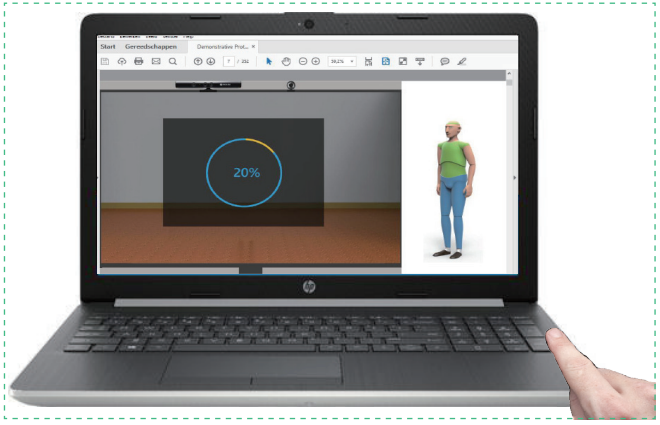


Figure 70- Demonstrating the prototype using laptop.

When demonstrative prototype is ready, the testing of the prototype (validation session) is conducted in order to allow users to score the concept in the aspects of satisfaction, usability and desirability. In the meanwhile, respondents can also give their comments about future's enhancement of this concept. So in validation session, the testing process and the finding from the testing will be introduced.

5.1 Short introduction

The main objective of prototype testing is to collect respondents' feedback in desirability, usability as well as satisfaction of the concept detailed in Part 4.

In the meanwhile, respondents were also encouraged to contribute their suggestions on improving the concept in the future. More detail about this testing are elaborated below:

5.1.1 Approach of testing

A.Respondents

Six respondents were invited to do the prototype testing.More information about respondents are elaboarted in 5.2.1.The procedures of this testing are shown as in Part B.

B. Procedures

• Respondents did their testing separately because their diiferent time slot. The prototype testing starts from a brief introduction which includes i) main objective, ii) background informantion as well as iii) main procedures of the testing.

• Brief introduction was followed by a prototype demonstration during which users present the prototype (a slide) to respondent and give brief oral explaination at the same time in order to help respondents to fully understand this concept.

• When the demonstration is done, the respondent was asked to fill a matrix for assessing the *desirability*, *satisfaction* as well as *usability* of the concept. The three aspects are composed of several criterias. Respondents have to fill every criterias using the scale of 1-4. 1 represents strongly disagree while 4 represents strongly agree. *(The example of the matrix is shown in Figure 71)* In the meanwhile, respondents were also asked to give feedback for why they fill the score and contribute their suggestions on improving the concept.

Usability

	1	2	3	4
You can fill in your personal information without tutorial				
You can set up this program independently,				
The functions for training management is not confusing				
You can notice and react to the inquiry				
The functions for motivation enhancement is understandable				
You can understand and play the game				

1 Strongly disagree
2 Disagree
3 Agree
4 Strongly agree

Figure 71- Matrix for testing prototype (More metrix about desirability and satisfaction can be found in APPEDNDICE D).

• After the respondent has input their opinions, author concludes the session and gives gift to respondent. (The respondent did the session separately)

C. Evaluation

• The score given by different participants(P) to every criterias are added up using the following formula. *(The overall value is Y)*

$$Y=\sqrt{\frac{P1^2+P2^2+P3^2\cdots\cdots Pn^2}{n}}$$

• If Y is lower than 3, author has to find out the reasons from the feedback given by respondents during the sessions. In the meanwhile, the suggestion on improving the concept have to be collected as well.

More information about the testing (validation) can be found in APPENDIX D

5.1.2 Specific component scenario and demonstration

A. Specfic components

As mentioned in 4.6.4, the prototype are composed of four parts:Preparation, training process, motivation enhancement, as well as exergaming. Each part is composed of several components. These components are shown as follows:

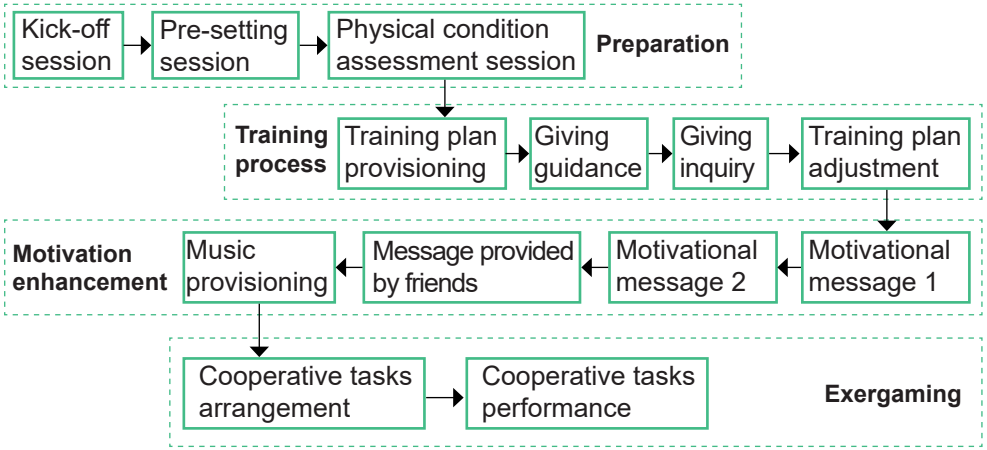


Figure 72-Visualized components of prototype

Adjustment on lighting, temperature and humidity can hardly be expressed using prototype, so author gives extra explaination.

B. Demonstration

As mentioned in 4.6.4, the prototype is a slide which is composed of 352 pages. Author gives slideshow on one hand, and explain the slide on the other hand. For instance, the capturing of negative moods, motions have to be explained by author, otherwise respondent can hardly observe these information from prototype. In the meanwhile. author play a role as user and demonstrate the interaction between user and CP-DTS. More details about prototype demonstration can be found in 5.2.2.

5.2 Evaluation with users/stakeholders

5.2.1 Sampling users/stakeholders

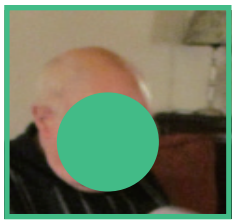
As mentioned in 5.1.1, six respondents were invited to participate the prototype testing. The six respondents are shown as follows:

P1

• 74 years
• Prefer home-based exercise

P2

• 80 years
• Yoga enthusiasts
• Spend much time at home



P3

• 75 years
• Volunteer in the church

P4

• 83 years
• Informal caregiver
• prefer home-based exercise

P5

• 86 years
• Informal caregiver
• Prefer social activities with friends

P6

• 75 years
• Start to do exercise recently

All of the respondents mentioned above have experience in resistance training, in the meanwhile they also observed the situations of their friends/peers at their age.

5.2.2 Set up the demonstration

As mentioned at the end of 4.6.4, the demonstrative prototype is a slide and is shown through the screen of laptop. In the process of demonstration, author plays a role as the potential user to demonstrate how users come across the presetting session, physical condition assessment session, as well as the training session. During the training session, author reads the content of audio messages, such as guidance, motivational message, etc. Then respondents do not have to read any texts.

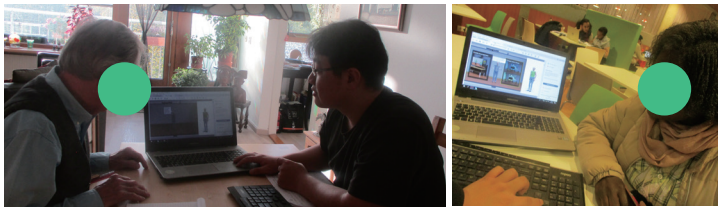


Figure 73-Author was demonstrating the prototype through laptop.

Besides the demonstration of prototype, author also demonstrated the necessary components which have to be purchased by users. In the meanwhile, the cost of these components are also presented. The home-based components and price were mentioned in Part B of 4.6.1. *(Author believe that the components and price influence the desirability of the concept.)*

5.2.3 Questions for feedbacks collection

Obviously, feedbacks should be composed of three parts: i) the scores filled by respondents in three matrix (Desirability, usability and satisfaction). ii) the respondents' feedback considering why they fill the score have to be gathered . iii) respondents' suggestion on concept improvement. In order to collect respondents' suggestions, some of the following questions were asked:

A. Questions considering satisfaction

Obviously, in the context of this thesis, satisfaction refers to "whether users believe that the functions of CP-DTS can effectively address the issues that the system are aiming to address". So the questions are shown as follows:

A1- Do you think this program gives you sufficient supervision you expect? If not, what else do you expect?

A2- Do you think the motivational message can effectively get you motivated? If not, what improvement are needed? (E.i: The content of the message, the way of conveying the message or any other way of motivating people)

A3- Do you think providing music during training can effectively increase your enjoyment? If not, do you think this function necessary or something about music provisioning should be improved?

A4- Do you think adjusting your indoor lighting, temperature and humidity can increase your enjoyment? If not, do you think these functions are necessary?

A5- Do you think the exergaming can effectively keep you motivated in a long term? If not, what aspects of the exergaming should be improved or changed?

B. Questions considering usabiility

In the context of this thesis, usability refers to "whether users can understand and handle the functions independently or with limited assistance" The questions are shown as follows:

B1-Do you think you can fill your personal information yourself? If not what assistance and tutorial do you need?

B2-Do you think you can use this program independently? *(Perhaps you need tutorial the first time, but you can do it yourself afterwards)*. If not, what assistance do you expect when starting this program?

B3-Do you think you can come across the functions for training management with zero/low confusion? If not, what functions are confusing for you?

B4-Do you think you can notice and react to the inquiry? (e.i: Do you want to have a short break? Please answer "Yes" if you do.) If not, what aspects do you think should be improved?

B5-Do you think you can understand the intention of the function for enhancing your motivation? If not, what aspects are not understandable?

B6-Do you think you can understand and play the game yourself? If not what aspects of the game do you think should be changed to make it more understandable and usable for you?

In this thesis, "program" is equivalent with "system". The "program" is more comprehensible for elderly respondents.

C. Questions considering desirability

In the context of this thesis, desirability refers to "users would like to try or even pay for some functions or even the whole system." So the questions are shown as follows:

C1- Do you think you are willing to try/pay for the whole program? Do you think you are willing to try/pay for some of the functions? If yes, what functions are willing to pay for? Why?

C2- Do you think you are willing to pay the price for the necessary components of this program? Do you think you are willing to pay the price for the extra/optional components of this program? If not, how can I change your mind?

Obviously, the questions above were asked only when users gave the score lower than 3 which means therer are something users disagree or hold negative attitude.

5.2.4 Evaluation of feedbacks & main findings

As mentioned in 5.2.3, feedback is composed of three parts: i) The score from matrix, ii) feedbacks for why filling the score, iii) suggestions on improving the concept. So firstly, the overview of filled scores are shown as follows:

A. The scores from matrix

As mentioned in 5.1.1, the scores filled by different users in each criteria have to be added up in order to assess the overall attitude of respondents towards each criteria. Higher score indicate more positive attitude. Author have to figure out the reason for the relative low score. The overview of scores can be found as follows:

Satisfaction	R1	R2	R3	R4	R5	R6	Score
This program gives you satisfactory supervision	4	4	4	3.5	3.5	4	3.8
The motivational message can effectively get you motivated	3	3	3	3	2.5	2.5	2.8
Providing the music you like can increase your enjoyment	4	4	4	4	4	4	4
The adjustment on indoor lighting, T&H can increase your enjoyment	3	2.5	2	2	2	3	2.5
Exergaming can keep you motivated in a long term	3.5	4	4	4	4	4	3.9

Usability	R1	R2	R3	R4	R5	R6	Score
You can fill your personal information yourself	3.5	4	4	4	4	4	3.9
You can use this program independently	3	3.5	4	4	4	4	3.8
You can come across the functions for training manage ment with low confusion	3	3.5	3.5	4	4	4	3.6
You can notice and react to the inquiry.	4	4	4	4	4	4	4
The intention of the motivational message, music and adjustment on lighting, T&H is understandable	4	4	4	4	4	4	4
You can understand and play the game yourself	2.5	2.5	3	3.5	3.5	4	2.8

Desirability	R1	R2	R3	R4	R5	R6	Score
You are willing to try the whole program.	3.5	4	3.5	4	4	4	3.8
You are willing to pay for the whole program.	2.5	2	2	2.5	2	2	2.2
You are willing to pay for some of the functions,	4	4	4	4	4	4	4
You are willing to pay for the necessary components of this program	4	4	4	4	4	4	4
you are willing to pay the price for the extra/optional components of this program	1	1.5	2	2	1	2	1.6

Figure 74- The overview of the score for Satisfaction, Usability and Desirablity

Obviously, in the matrix of satisfaction, motivational message provisioning and the adjustment on lighting, temperature/humidity get the lowest score. In the matrix of usability, exergaming get the lowest score. In the matrix of desirability, two criterias get the score lower than 3. In order to know the reasons for these low score, the

feedbacks are evaluated and shown in part B.

B. The feedback for low scores

In part B, the reasons for low scores are extracted from the respondents' feedbacks:

B1- Low satisfaction on Motivational message: 4 respondents (R) reflected that the contents of motivational messages shown in prototype can hardly motivate them. R4, R5 reflected that doing exercise with friends might be more motivational, especially when users see their friends' progress. Motivational messages might be useful in some cases, but the content could be relevant to friends' activities and progress. P6 reflected that inviting friends to provide message could be motivational, but if friends always give similar message, the message can hardly be motivational.

B2-Low satisfaction on Adjustment on lighting T&H: 3 respondents reflected that they can hardly imagine or judge the effect of the adjustment on lighting and t&h. P4 and P5 reflected that they enjoy daylight than lighting. One respondents said that they would like to try it if that does not cost too much.

B3- Low score on the usability of exergaming: All of the 6 respondents reflected that the game is totally understable after author's explaination, but R4 and R5 stressed that most of the people in their generation have limit knowledge about video game, so they may have low confidence in handling video game. But R4 and R5 also believed that the game will be promising in the people who are 15-20 years younger than them.

R1 reflected that she is not sure if she will play the game herself or not. She may try it and put it aside. R2 also held the same opinion. Interestingly R6 said that she liked the game because she tried other simpler game before, so she would like to try this game as well.

B4- Low score on the desirability of the whole program: None of the six respondents are willing to purchase the the whole program. All of the six respondents hold the opinion that the functions for increasing enjoyment should be just optional, they will not install the air conditioners, new bulbs just for enjoyable training. But all of the respondents believed that the functions for training management are useful, so they are willing to pay for it.

When the feebacks for low score are ready, the suggestions on improvement are also needed. So the improvement suggestions are shown in Part C.

C. The suggestions on concept improvement

C1-As mentioned in B1, two respondents reflected that trainng with friends or other peers can be more motivational for users in comparison with providing motivational message. The two respondents also suggested that the message content could be considering their peers' situations or progress. R6 suggested that the invited friends should provide different message every time.

C2-Respondents did not provide explicit suggestions on improving the lighting, temperature and humidity adjustment because the effect of the lighting, temperature and humidity needs to be further verified. But R4 mentioned that the specific appliances (e.i: air-conditioner, bulb) should not be needed. If the applicances are really necessary, they should be as cheap as possible. R4 agreed author's idea to change air-conditioner to fan.

C3-R 1, 4 and 5 hold the similar opinion that the game should be as simple as possible otherwise elderly people would get confused. R1 suggested that audio guidance might be useful to help users handle the game. (e.i: Please carry the log and tap here, then you avatar automatically move to here)

In addition to the feedback about improving the aspect with low score,

C4-R4 mentioned that some general exercises are needed in order to holistically improve users' physical conditions, such as balance, strength of legs, etc. (General exerise is not given based on the personal physical conditions or objective)

C5-R1 and R6 reflected that they can not fully understand trainers' motions and posture. They agreed author's opinion that they need to see the side view of trainer.

In part D, the information mentioned in Part A,B,C will be summarized.

D. Summary

D1- In matrix of satisfaction, respondents gave low score to "motivational message, the two reasons are shown as follows:

• Training with friends or peers could be more motivational compare to providing motivational message,

• If the similar messages are given repetitively, the messages will not be useful. Even if the message is provided by friends or other significant person.

Respondents suggested that training with friends could be more motivational. So the content of the message could be considering peers' or friends' progress.

D2- In matrix of safisfaction, the adjustment on lighting, temperature and humidity were also scored less than 3. The reasons is that user can hardly judge the effectiveness of the adjustment.

D3-In matrix of usability, respondents gave low score to exergames. The reasons are shown on the right:

• Older generation have limit knowledge in video game, they may only try the game once and put it aside.

• The interface of the game is still a bit complicated for some people. Some elderly needs assistance to handle it.

There are two suggestions: i) The interface should be further simplified, ii) Audio guidance could be useful to help users to handle the video game. (e.i: Please carry the log, and tap here, you avatar move the log to here)

D4-In matrix of desirability, the scores shows that respondents are not willing to pay for the whole program and the extra components. Respondent suggested that extra components like air-conditioners, philip hue should be avoided unless they are really important.

D5-Even if respondents hold positive attitude towards functions for training management, they still offers some suggestions: i) Besides the exerises tailored based on personal physical condition and objective, some general exercises are needed. ii) side view of trainers are needed in order to help some people to understand digital trainers' motions.

Besides the information related to prototyping test, respondent 4 also gave some interesting opinion. For example, he suggested that the program/system could be recommened to insurance company because if elderly clients can stay healthy through training, insurance company can save large amount of money.

On the basis of the findings from validation, the discussions can be formulated. The discussions mainly include: i) result considering satisfaction, usability as well as desirability, ii) the enhancement opportunities based on the findings from validation. So in 5.3, the discussions are presented.

5.3 Discussions, Conclusions and relevance

5.3 is the end of this thesis. 5.3 is composed of three parts:Discussions are mainly relevant to two things: i) summary of the result of validation session, ii) the enhancement opportunities for CP-DTS based on the result. Conclusions is about future's research work based on the application of S-CPSs in the domain of resistance training. However, the domain of interest in future's research work is more than just resistance training, but active leisure activities which is the starting point of this thesis. Author believed that the explored opportunities in resistance training can also reflect the opportunities for applying S-CPSs in other similar domain. 5.3 is ended up with explaination about the relevance of this thesis to "Design for interaction" and "Strategic Product Design".

5.3.1 Results from validation

In 5.2, only the aspects with low score were mentioned. In 5.3, the results from prototype testing are holistically explained.

A. Satisfaction

Respondents hold positive attitude towards the functions for training management, music provisioning and exergaming. All of respondents believed that CP-DTS can provide the supervision they expected. In the meanwhile, music provisioning was believed to be the effective way for increasing enjoyment. Finally, all of the respondents agreed that exergaming is a promising way for maintaining elderly's long-term motivation if they can get the chance to contribute their effort to the group or team in the virtual world.

The effect of motivational message should be further verified. Respondents suggested that training with friends could be more motivational in comparison with providing motivational message. In the meanwhile, if the message is about friends' training progress or enable the social interactions, it may become more motivational.

The effect of adjustment on indoor lighting, temperature and humidity can hardly be judged, so the effect of the adjustment need to be further verified.

B. Usability

Respondents reflected that they can fill their personal information independently and go through the functions with low confusion. In the meanwhile, they can understand the intention of the interventions like motivational message provisioning, the adjustment on lighting, temperature and humidity. Inquiry plays an essential role in CP-DTS. respondents reflected that they can react the inquiry properly.

Obviously, in most cases, users just have to follow the flow of CP-DTS, so they barely have confusion. They only have to do what they are told to do, such as filling needed personal information, reacting to inqury with Yes/No answer, etc. However, when it comes to exergaming, users have to initate the interaction with the avatar and finish the cooperative tasks using avatar. This process requires complicated manipulation, so users more likely get confused. Respondents suggested that the interface and the manipulation should be simplified. Audio guidance is also helpful for elderly users' to handle the game.

C.Desirability

All of the respondents reflected that they are willing to afford the program for training management which includes: physical condition assessment, training plan provisioning, guidance providing, inquiry as well as the training plan adjustment. In the meanwhile, the music provisioning is also the popular function. Even if the exergaming are considered to be unfamiliar for elderly group, respondents still believe that game is desirable because of reasons like: i) they are happy to be a contributor in the game world, ii) if they can play the game with the assistance from younger people, this would be a chance to communicate with them, etc.

Some functions are not that popular, such as: the adjustment on temperature, humidity and lighting. On one hand, the effectiveness of these functions are uncertain, on the other hand, these functions require extra components, such as: air conditioner, philip hue. So respondent

hesitated to afford these functions. Some respondents suggested that these functions could be retain, but they can hardly accept so many extra components just for increasing enjoyment.

Based on the findings from validation, the enhancement opportunities can be extracted.

5.3.2 Enhancement opportunities

Obviously, the issues and suggestions mentioned by respondents are usually very abstract or not directly relevant to S-CPSs (e.i: sensing, reasoning). So author transformed these suggestions in order to make these suggestions more relevant to S-CPSs.

A. Opportunity of enhancing satisfaction

A1-Respondents mentioned that the involvement of social activities can effectively motivate elderly users, such as training with friends or joining in a training group. Author imagined three opportunities for CP-DTS: i) figure out who the user would like to stay with, ii) organize these person to participate resistance training at the right time, these person can be connected online, iii) provide users the opportunities to motivate each other in the process of training.

CP-DTS can firstly find out users' preferred peers from his/her frequent contacts. Then CP-DTS can organize these person to do resistance training at the same time. Thirdly, when certain users' negative moods are detected, the CP-DTS invites certain peer to give motivational message. Peers are most likely give useful motivational message because they are working on their training and have emphathy for each other.

Obviously, the opportunities mentioned above are just examples. Many other ways for organizing training, enabling social interactions and mutual motivation need to be explored.

B. Opportunities for enhancing desirability

B1- Respondents reflected that they do not want to pay for the extra components like air conditioners, philip hue, etc. Obviously, for home-based system, the number and cost of the specfic components should be controlled. Ideally, the system should use the components that users already have at home. For example, in northern Europe, resident usually use cheap fan instead of air-conditioner. So it might be better to replace the air-conditioners with fan.

B2- Obviously, consumers barely pay for the function which they can hardly find it useful. The effect of lighting, temperature and humidity on enjoyment is uncertain for users unless they really experience the enjoyment. So other intuitive ways for increasing enjoyment should be explored.

Author assumed that providing pleasant sound is a cost-effective and useful way for increasing enjoyment because playing music is proven to be a popular functions. The sound is not necessarily music, it can also be sound of running water, breeze and rain, etc. Unlike adjusting temperature and lighting, playing sound requires only a speaker. Users' moods can indicate whether the sound is pleasant for the specific users or not.

C.Opportunities for enhancing usability

C1- As respondents mentioned, the interface and manipulation of exergaming should be simplified in order to avoid confusion. It seems that elderly can have a smoother user experience if they are following procedures or under someone's guidance. Perhaps more audio guidance can help elderly users to handle the exergame.

5.3.3 Future's research work

As mentioned above, the aim of this thesis is more than exploring the application of CPSs in the domain of resistance training. At the end of this thesis, the main research question should be answered: "What smart cyber-physical system can do in supporting elderly's active leisure activities(ALAs)".

Author assumed that the application of S-CPSs in resistance training can reflect the general characteristics of the contexts for applying S-CPSs. So 5.3.3 begins with the application context for S-CPSs. In the meanwhile, it is also necessary to explore how can the characteristics of S-CPSs be applied in supporting ALAs. Hence, the three points should also be figured out: i). what real-life process could be sensed and monitored, ii) what situations and actions could be reasoned, iii) what knowledge could be learned.

A. The characterisics of application conditions

A1-If multi-faceted issues have to be addressed

As mentioned in exploration part, multi-faceted issues have to be addressed in order to achieve a successful resistance training. S-CPS is a network integration of software, hardare and cyberware which allows S-CPS to address multi-faceted issues that stand alone system can hardly address.

Obviously, S-CPSs is like a company which congregates the employees with various expertise to address multiple issues happen in life, but the main objective is the same: "To achieve something good". So in future's research work, we should further explore what aspects/issues should be addressed in order to achieve successful active leisure activity

There are some examples of the issues for organizing an active leisure activity: i) the activities which match with users' personal preferences and physical conditions, ii) the peers that users would like to stay with, iii) the available timeslot of each participant. etc, vi) the distance that the users can reach, etc. Obviously, the smart CPSs have to address all of these issues for organizing a proper activity.

A2-If quick actions are need to react to dynamic situations

As mentioned in exploration part, CP-DTS have to react to dynamic situations which may suddenly happen. These situations include: changing heart rate, wrong motions and negative moods,etc. Obviously, these situations happen so sudden that people can hardly realize it, not to mention react to it. In this case, S-CPSs are needed to monitor changing situations and give quick reactions.

So in future's research work, more dynamic situations should be found from users' activity participation. For example, the situations may include i) health condition, such as, blood pressure, ii) weather conditions (e.i: elderly users may be more sensitive to the subtle weather change), etc. Obviously, when arranging leisure activities, these situations have to be taken into account.

A3-If daily monitoring and learning is needed

As mentioned in exploration part, fatigue is reasoned on the basis of the devitation of captured heart rate from normal value of heart rate. Normal heart rate may vary from person to person. So in order to obtain the value of normal heart rate, daily monitoring and learning is needed.

Obviously, many aspects considering leisure activities worth to be monitored and learned. For example, users' various preference (program, activities), frequent contacts, health conditions, etc. These aspects are quite useful for giving suggestions on suitable activity.

So in future's research work, it would be necessary to find out what aspects (e.i: behavior, vital sign, ritual, etc) should be constantly monitored and learned in users' daily life.

Obviously, the essence behind the above mentioned characteristics are sensing, monitoring, reasoning&learning. So it would be necessary to further explore what aspects could be sensed, monitored, reasoned and learned in elderly's active leisure activities. The relevant informations are distributed in Part B and C.

B. Sensed and monitored indicators (Data)

In part B, several assumed indicators were proposed. These assumptions are made based on the application of S-CPSs in assisting resistance training.

B1- Indicators of behaviors

As mentioned in A3, some of users' behaviors worth to be monitored, because behaviors can be a good reflection of people's preference, habits. The indicator of behavior could include: daily contact history, daily ritual, the information/news that the person usually keep track of. the place that the person usually visit, etc. Based on these example, author made following assumptions:

- Contact history could indicate which person the users are possibly willing to stay with,
- Daily ritual could indicate users' schedule and availability,
- The information content could indicate users' interest and hobby *(e.i: user usually watch the program considering knitting, the system may figure that this user is interested in knitting)*
- The constant visited place may indicate the distance the users can reach

On the basis of the items mentioned above, a favorable activities could be arranged.

B2- Indicators of health conditions&Moods

In the case the resistance training, health conditions and moods are always the two most important factors because health conditions decide what the user can do while moods reflects if users like to do what he/she is doing. Author believed that the two things are always important even if user is participating other leisure activities.

In future's research work, more indicators of health conditions are needed. Heart rate can hardly indicate the overall health conditions. In the meanwhile, more indicators of moods are needed. In resistance training, the moods can be indicated by facial muscle movement because face is almost static. However, when elderly users are participating activities which requires more body movement, the facial muscle movement is not easy to capture. Hence, new indicator of moods and the way of capturing are needed.

B3- Indicators of physical conditions

Obviously, physical conditions decides what activities user can perform physically. In the domain of resistance training, physical condition refers to whether the muscle groups are strong enough to perform activities of daily living. But in other active leisure activities, the definition may be different, hence more indicators of physical conditions are needed in future's research.

B4- Indicators of contexts

As mentioned in exploration phase, when negative moods are detected, system have to figure out the contexts that may lead to negative moods. Based on the contexts, interventions are provided. Obviously, the inditcators of context are very important for providing interventions. For example,when negative moods are detected, the indicators of contexts may include: low temperature, environment with high decibel, loneliness (Elderly users stay by themselves), etc. In future's research work, more indicators about context informations should be found out.

Besides the indicators (data), knowledge are also needed for achieving successful ALAs. Hence some assumed knowlege are shown in

C. Reasoned and learned knowledge

Some assumed informations and knowledges related to organizing leisure activities are shown as follows:

C1-Personal preference(PP)

The participation in active leisure activities is mainly for increasing enjoyment. Hence personal preference should be the most important factor for the arrangement of active leisure activities. Author assumed that relevant preference may include:

• i) What type of activities does the user like to do,
• ii) Who does the user like to spend time with,
• iii) When do the users want to do the activities,
• vi) Where should this activity happen.
In future's research, it might be wise to figure out how to obtain above mentioned knowledge when desigining a new S-CPS for organizing active leisure activities.

C2-Personal limitations(PL)

Personal limitations are relevant to what the specific user can/cannot do. In the domain of resistance training, health and physical conditions indicate users' limitation. Generally speaking, when arranging active leisure activities, health and physical conditions are also the primary factors to be considered.

Author assumed that based on the two conditions, the following knowledge could be reasoned: i) how far can this user reach on foot, ii) what is the proper intensity of activities for this user to perform, etc. Hence, in future's research work, we should figure out i) how to define users' physical and health condition. ii) how to obtain the physical and health condition, iii) how to reason the personal limitation on the basis of physical and health conditions.

C3-Arranging activities based on factors like PP and PL

As mentioned in A1, when using CPSs, multiple faceted issues/factors have to be addressed which requires the network integration of the capabilities of multiple components. Hence in future's research work, author assumes that the leisure activities could be arranged on the basis of the factors like: i) personal preference (What does the user like?), ii) personal limitation (What the user can do?).

C4-Adptive reations to changing situations

As mentioned in A2, S-CPSs can be used to react to the change of situations which may suddenly happen. Obviously, in the domain of the supporting leisure activities, there could be large amount of situations, such as moods, health conditions, etc. In future's research, more changing situations should be found. In the meanwhile, the adaptive reactions to respond these situation should also be figured out. For example, the system can remind elderly to take a break when he/she are too excited about dancing to realize that his/her heart rate is faster than normal.

D. Summary

D1-CPSs can be used when i) multiple faceted issues/factors have to be addressed, ii) quick reactions are needed to respond to dynamic situations, iii) daily monitoring are needed. In future's research work, we need to figure out more issues, dynamic situations considering active leisure activities.

D2- In the context of supporting active leisure activities, the indicators (Data) of bebaviors (e.i: contact history) , health&physical conditions (e.i: heart rate, blood pressure,etc), moods as well as the context informations (e.i: high decibel environment) should be sensed and monitored. In future's research work, more relevant indicators are needed.

D3- Personal preference (e.i: Preferred activities, people, timeslot,etc) could be reasoned based on monitored behavior. Limitation could be reasoned based on health and physical conditions. Active leisure activities could be arranged based on preference and limitations. In the meanwhile, more adaptive reactions have to be found to respond to changing situations, such as moods, health conditions, etc.

The above mentioned contents reflect the factors, issues and aspects that should be further explored in order to utilize smart cyber-physical systems in the domain of supporting active leisure activities. Author believe that in future's research work, these factors, issues can be helpful for conceptualising other systems which are relevant to arrange active leisure activities and give quick reactions to suddenly happened situations.

5.3.4 Relevance to SPD and DFI

This graduation project is relevant to dual master programmes, hence it is necessary to explain that how this project can be related to the two master programmes.

A. Relevance to Strategic Product Design (SPD)

The focus of Strategic Product Design(SPD) Master's Programme is on the business context of product and service design. The programme's emphasis is on translating a company's strategy and market opportunities into strong product or service portfolio.

The main objective of this thesis is to explore the application opportunities for Cyber-Physical Systems in assisting elderly's active leisure activities(ALAs). In the exploration part(Part 1), the knowledge about the following three aspects are found out which pave the way for opportunities exploration:

• The type of ALAs which should be focused in this thesis (Resistance training were finally selected as the focused ALAs).

• The needed services for assisting elderly's resistance training participation and performance.

• The possibility for implementing the services mentioned above using sensing and reasoning technologies.

In this process, the techniques like: Focus group interview, literature review as well as website browsing is used to find out the above mentioned knowledge. Once the opportunities are defined, a CPS-based concept was generated and selected which is followed by technologies exploration for implementing the concept. This thesis is ended up with a detailed use case scenario and a demonstrative prototype which can be considered as service portfolio

Obviously, this process clearly shows i) how the application opportunities are explored and ii) how can the explored application opportunities be translated into a concrete CPS-based system which can provide technological servicing to assist elderly's resistance training performance. Hence this thesis is highly relevant to Strategic Product Design (SPD) Master's Programme.

B. Relevance to Design for interaction(DFI)

The Design for interaction (DFI) Master's Programme focuses on the ways in which people and products interact. The programme deals with the question: how does a user understand, use and experience a product?

In conceptualisation (Part 3) of this thesis, a design goal, an interaction vision as well as a list of Requirements are defined on the basis of the finding from exploration (Part2).Based on the three aspects, three CPS-based concepts were generated. All of the three concepts show the interactions between users and the CPS-based system.

After the concept selection session, a optimal concept was selected from the three and detailed in detaling part (Part 4). The detailing ended up with a use case scenario and a demonstrative prototype. Both of the two show how potential users come across the whole system.

Obviously, this thesis includes not only the interaction vision definition, but also a conceptualized CPS-based system translated from interaction vision. A concrete prototype and a use case scenrio can clearly show the interactions between potential users and CPS-based system. Hence this project is also highly relevant to Design for Interaction(DFI) Master's Programme.

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