User Needs for Mobility Improvement for people with Functional Limitations

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1. Introduction

According to the Eurostat statistics, 25.3% of the European Union (15 countries) population are "severely hampered" (9.3%) or "hampered to some extent" (16.0%). More specifically, these figures refer to "hampered in daily activities by any physical or mental health problem, illness or disability" (Simoes and Gomez, 2005; United Nations, 2003). Their quality of life would improve substantially if they could participate more actively in the society, while society itself could benefit from this contribution. The transdisciplinary project ASK-IT aims to support this and is developing an ambient intelligence system that provides information to people with functional limitations.[1] This addresses one of the main aims of the European Commission: increasing the participation of all members of the society (e-Inclusion). The idea is that people with functional limitations can benefit substantially from information on the accessibility of all types of services and infrastructure in our society (United Nations, 2003). For instance, a wheelchair user who has information on the accessibility of local meeting places can choose an accessible café to meet people. A visually impaired person who receives timely relevant information on actual arriving times of a tram can decide to take it. Important is that applications presented to the users are personalised, self-configurable, intuitive and context-related. ASK-It aims at supplying useful and timely information about mobility barriers and suitable offerings to overcome them on a mobile phone or a PDA-like device. Users will receive accessibility information tailored to their personal user profile. The information needs for every goal-directed action depend generally on the complex interaction between, on the one hand, the individual (physical abilities, psycho physiological capacities, cognitive resources etc.) and, on the other hand, relevant factors of the environment (objects in a scene, available tools, implicit and explicit

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[1] ASK-IT: Ambient intelligence system of agents for knowledge based and integrated services for users with functional limitations. Integrated project co-funded by the Information Society Technologies programme of the European Commission. Project number IST 511298; duration 2004 – 2008).

context rules etc.). Riva suggested accordingly to focus on relevant user activities when analysing requirements for ambient intelligence environments (Riva, 2005). The psychological frameworks Action theory and Activity theory are approaches to conceptualize goal-directed human behaviour. Action theory enables the division of complex actions into smaller behavioural units (Frese and Zapf, 1994). Activity theory stresses, moreover, the social context of human behaviour (Kuuti, 1993).

In order to develop these services, the user requirements need first to be established. This paper concerns this first stage: the route from an activity-centred specification of service content requirements to the translation of the identified requirements into a machine-readable format. The methodology for defining user requirements is presented briefly and applied to developing a communication platform to support social relations and communities of people with functional limitations. The methodology is built upon the definition of user groups together with the elaboration and implementation of relevant action and activity theory principles.

2. Methodology

2.1 The content areas and the user groups

The following areas are defined for which ASK-IT develops services for the users with functional limitations: "Transportation" to identify detailed transportation-related data content requirements, e.g. what barriers might exist across different transport modes, what effect uncertainties (such as delays), "Tourism and leisure" to identify everything related to what a tourist who visits the specific area or city would need to know (e.g. hotels, museums, interesting places, embassies etcetera), and leisure content addresses all sectors that are used in every day's life not only by tourists but by residents also. "Personal support services": finding and booking a (local) personal assistant for traveling or special care. "Work and education": Accessibility to schools and working environments and distance learning and -working. "Social contacts and community building": any content to enable making contacts with other people and with people with similar functional limitations, access to meeting places and access to virtual communities.

The user groups are classified on the basis of *functional* limitations. The ICF codes are applied that take into consideration the interaction between health conditions and contextual factors, and provide an adequate basis for the definition of user groups that has been proven to be appropriate in previous projects (Telscan, 1997; WHO, 1991). User groups were defined accordingly in two stages: first a main group classification, and second a nested sub group classification of different levels of severity. The one exception is the wheelchair user group which is classified as a separate main user group, because their functional requirements differ considerably from other users with lower limb limitations. The resulting user group classification has the following main groups: (1) lower limb impairment, (2) wheelchair users, (3) upper limb impairment, (4) upper body impairment, (5) physiological impairment, (6) psychological impairment, (7) cognitive impairment, (8) vision impairment, (9) hearing impairment, (10) communication production/receiving impairment.

2.2 Implementation of Action Theory and Activity Theory into the process of user requirements definition

Sommer et al. (2006) and Wiethoff et al (2007) described in detail the methodological approach for defining the user requirements, based on Action theory and Activity theory.

The central issue in the methodology is the analysis of various types of goal-directed human behaviour (Riva, 2005) in hierachical-sequential action patterns and being organized by higher levels of action regulation.

Activity Theory (Engeström , 1987 and Kuuti, 1995) considers, in particular, organisational issues and the social cultural environment to be very important. In the theory 'activity' is defined as the 'minimal meaningful context for understanding individual actions' (Kuuti, 1993). The activity entails: tool, subject, object, rules, community and division of labour. The object is the entity (or goal) that actors manipulate. The actors interact on the object with the help of artefacts (tools), within a context of roles, and under a set of community rules. This definition of an 'activity' is used in the current project to define the elements that need to be incorporated in our scenarios (see further). For the sake of the present focus on mobile work, the space- time setting is added to define the context of mobile work, i.e. synchronous vs. asynchronous, same vs. different location, mediated by what type of tool, under which rules, and who participates.
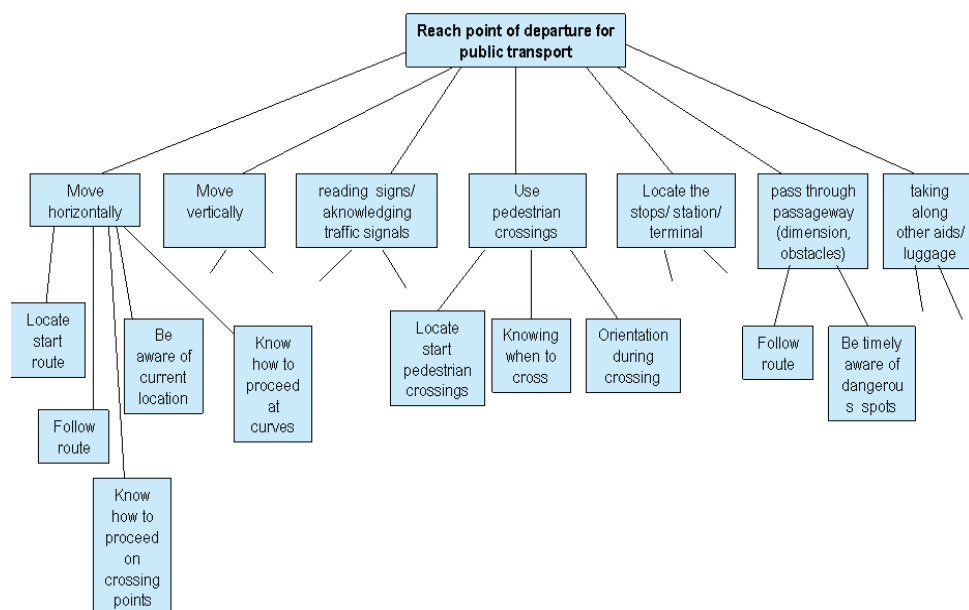

Figure 1. Example of a hierarchical-sequential action process: A severely visually impaired pedestrian finding the station or leaving the station

Figure 1 shows, as an example for a hierarchical-sequential action process, the flow of actions and operations of a visually impaired pedestrian to reach a station for public transport or leaving a station. Decomposing complex goal-directed actions in this manner enables, with sufficient detail, to identify specific support needs of users with different types of functional limitations. For the transport context, it would involve the specific types of information a visual impaired pedestrian needs to be able to navigate and walk safely, what aids people usually have (stick), or may have (dog), and what requirements this involves for

the environment. For the social contacts context, it would involve knowledge about the specific patient communities or peer groups available for your user group, or specific communication opportunities if your communication options are limited (speech impairments, hearing or visual impairments).

Information need	Information element	Conditions / Attribute	Value/ type	Value limit	Priority
Find accessibility information	Accessible dedicated mailing list	Name	Text		2
		Description	Text	W3C guidelines	2
	Accessible supporting document repository	Name	Text		2
		Description	Text	W3C guidelines	2
	………				
Add location specific information through a storage unit	Voice driven Recording equipment	Available	Yes/No		1

Table 1. An extract of the Enabling social contacts and community building Matrix 3 for the visually impaired users. Priorization level 1: nice to have; 2: important; 3: essential

Then, the hierarchical sequential action process is transformed into a set of matrices. The first matrix (Matrix 1) involves the *preparation* of activities (e.g. planning a trip at home). The second matrix (Matrix 2) involves the *execution* of activities (e.g. reaching a destination by public transport). The ASK-IT service is aimed to provide assistance at both these two stages. Each row in the matrices corresponds to a specific activity, action or operation. The columns of these matrices specify for each user group separately the information requirements, specifically for that activity, action or operation. For instance, for "use pedestrian crossings", information elements contain for the severely visually impaired people: "locate exactly the start of the crossing", "knowing when to cross", "orientation during the crossing". The attributes describe in a structured way the environmental factors, which make / do not make accessible operations possible. To each action a set of user group specific attributes can be mapped, e.g. accessible steps to a meeting place.

Then, Matrix 3 is produced. This matrix defines for each information element the characteristics of the attribute (type of variable, e.g. a value, a description), and the

prioritisation (essential, important, nice, neutral) of the attribute. Table 1 shows the translation of the action process "Find accessibility information" and "add location specific information at the location through a storage unit" into required information elements for the visually impaired people: Matrix 3.

3. Content modelling procedure

The goal of the content modelling procedure is to provide a formal description of user information needs in a computer understandable and interoperable format, based on the content requirements as presented in table format (see Table 1). The outcome of the modeling procedure is a set of computer-interpretable models that represent the user information needs. These models describe the pieces of information that should be exchanged between the user and different data sources or heterogeneous applications. By imposing a set of constraints on data, a common delivery format is dictated. Thus, when a user with a functional limitation requests a new service, the common data format, which acts as an information filtering facility, guarantees that the user gets access only to valid data values. XML was chosen for representing models, because it is by far the most supported content representation language today. An XML-schema is a definition of the structure of an XML document. Given an XML document and a schema, a schema processor can check for validity, i.e. that the document conforms to the schema requirements.

The procedure for moving from the content requirement matrices to the XML schemes involves the transformation of the matrices into a *tree* structure, consistent with the notation of an XML schema. Each concept related to a specific user information need is encoded as an information element composed of several attributes, related to values of information that the user desires to know in order to be able to read. In Table 2, an example of one *information element* and its *attributes* are shown: this example is for supporting reading for the visually impaired. The full description of the content modelling procedure is presented in (Sommer et al, 2006).

Information Element	Attributes
Reading	Screenreaders
	Visual aids
	Audio signals
	Sound volume control for the use of a product with voice output (in a public area)
	Etc.

Table 2. Division of information elements into attributes and their description

The next step is to create the corresponding XML-Schema document. The latter is actually a representation of a collection of elements as the one described in Table 2. A graphical representation of an arbitrary information element comprised of three attributes, is illustrated in Figure 2. This tree-like graphical representation is provided by the XMLSpy

authoring tool, which supports automatic generation of XML code by knowledge engineers, without requiring a deep knowledge of XML. The corresponding XML-Schema document that describes the element of Fig. 2 is given in the code segment of Figure 3. The author creates the tree, which is illustrated in Figure 2 using a set of an appropriate graphical user interface, while the authoring tool automatically generates the code shown in Figure 3.

Figure 2. A XMLSpy-generated graphical representation of an element with three nested elements as attributes
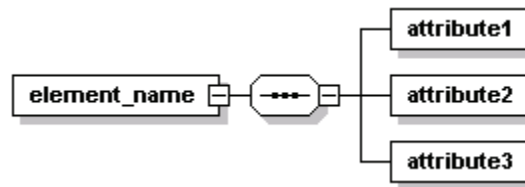
```
<xs:element name="element_name">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="attribute1"/>
      <xs:element name="attribute2"/>
      <xs:element name="attribute3"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

Figure 3. An element with attributes in XML-Schema

In the example shown in Table 2 each element is specified by the xs:element identifier. Since the element 'element_name' consists of three elements (i.e. more than one other element), it is a complex data type. This is specified by the identifier xs:complexType. The xs:sequence literal represents an ordered collection of elements that describe the list of three attributes that constitute the 'element_name' in Fig. 3. Primitive XML data types can also be encoded in any schema in order to describe simple data values of the various structural elements. For example, in order to represent temperature in Celsius degrees, the xs:decimal type, which is suitable for representing decimal numbers, would be used. The application of the transformation of the content requirements into the XML tree-like structures will eventually result in tree representations.

4. Application of the methodology to route navigation for visually impaired

Within the ASK-IT project, in collaboration with The Hague City council, a research and development subproject in the field of supporting route navigation is performed. The aim of the subproject is to increase the mobility of severely visually impaired visitors and inhabitants of the Hague. The subproject focuses on the subgroups 8b and 8d (Table 3).

8a. Light or moderate limitations (visual acuity, slow accommodation, etc)	Difficulties in reading, identifying symbols, alternating between displays and road environment
8b. Reduced field of vision	Difficulties in seeing approaching traffic, crossing streets, etc
8c. Limited night and colour vision	Difficulties in darkness or understanding codes or maps, etc
8d. Severe limitations, blindness	No reading or looking for specific locations, etc

Table 3. Subgroups visual limitations

For the groups 8b abd 8d, walking on the street without any aids or an accompanying person is virtually impossible. In general, all the people in this user group make use of a white stick, to warn the other traffic participants, and to feel where to walk and where there are obstructions on the path. In railway stations in the Netherlands, there are guide lines, and in some isolated parts of the cities, and some buildings too. Some people have a guide dog. Guide dogs warn the pedestrian for unsafe parts and obstructions, but they behave very differently concerning the use of guide lines. There are international guidelines for the shape of the lines on the tiles and paving of the tiles on the ground. Table 4 shows an extract of Matrix 3 concerning the guidelines.

Information element	**Conditions / Attribute**	**Value**	**Value limit**	**Priority**
Special guide surfaces should exist on all pedestrian routes, helping people with vision impairments move regularly and avoid possible obstacles (trees, etc.)	Minimum passage width stick user	mm	750mm	2
	Minimum obstacle free footway width	mm	1500mm	3
	Unobstructed height above footways	mm	2300mm	2
	Minimum width of guideline	mm	See W3C guidelines	3
	Minimum width of the separation of the lines on the guideline	mm	See W3C guidelines	3

Table 4. Extract of the Matrix 3 for visually impaired pedestrians. Priorization level 1: nice to have; 2: important; 3: essential

The following usage scenario illustrates how ASK-IT will support the navigation of a visually impaired person.

Josephine (45) lives in The Hague, the Netherlands and is completely blind. Her eyesight began to diminish only ten years ago, and she is now completely blind.

She is a highly educated specialist in information technology, and has happily been able to continue her work since her vision problems started. She lives on walking distance of her office and knows the route well.

Josephine is very keen on her independence and mobility, and likes to walk into the city, to visit friends, to meet in cafes and restaurants. However, she does not live in the city centre, but near a peripheral railway station. Therefore, it is very important for her to be able to make use of public transport, in particular trains and trams.

Happily, the City of the Hague has provided information on accessibility of public transport, tram stations and various public buildings. Furthermore, from the Central Railway station she can make use of the guideline for the blind, with additional information on her mobile telephone on various important destinations in the vicinity. All she has to do, as soon as she leaves the train, is to activate ASK-IT system on her mobile phone and attach the external loudspeaker on her shoulder, to keep her hands free. ASK-IT guides her from the train platform towards the streets where the cafes and shops are she wants to visit, the library, the Town Hall and the City Hall. Whenever she approaches the tram platforms, she hears which tram platforms host which trams. Whenever she approaches a crossing, she is warned beforehand by ASK-IT. Her stick helps her to feel the guideline on the ground and the obstructions nearby. When she goes through a passageway and along the exit of a parking garage, she is warned beforehand.

Figure 4. A visually impaired pedestrian explores the different routes on the crossing point of the guideline during the test

Currently The City of The Hague is installing and testing a guideline with additional information (Molenschot et al., 2006, 2008, Wiethoff et al, 2006, 2008). The guideline is produced by TG Lining and the information module by Connex-IP – RouteOnline in cooperation with ASK-IT. The guideline runs from Central Station to a few main public buildings in the vicinity, and will be extended up to the Dutch Parliament.

Figure 5. An example of a Smartphone to use ASK-IT to guide visually impaired pedestrians in The Hague

5. Pilot test

Wiethoff et al (2008) presents the first part of the pilot study currently carried out to test the guideline with ASK-IT information module to navigate and to be aware of the environment. The second part of the test will be carried out in the fall of 2008. IN this chapter, only the opinion of users is presented on what the ASK-IT module could mean for them.

In how far was the collection of user needs and the translation of the user needs into a concept for increasing the mobility of the visual impaired user successful? Sixteen subjects, all heavily visually impaired have thus far participated in an empirical study and replied.

In the study, they all walked several tracks with use of the guideline, and in one condition with and in one other condition without the additional ASK-IT information. In Figure 4, one of the participants is using the guideline, exploring a possible detour to go to the entrance of a public building. In this part of the test, participants have to keep the smartphone with the ASK-IT module in their hand.

At the end of the test, they are interviewed. On the question:

 "Do you think ASK-IT could help improve:
- (a) accessibility at home,
- (b) planning a trip,
- (c)route guidance,
- (d) leisure and tourism,
- (e) work- and learning,
- (f) support abroad,
- (g) communities abroad? (more answers possible)"

Participants were particularly positive in their expectations of trip planning, route guidance and leisure and tourism and work and learning. (Fig. 6).

Possible contributions of ASK-IT
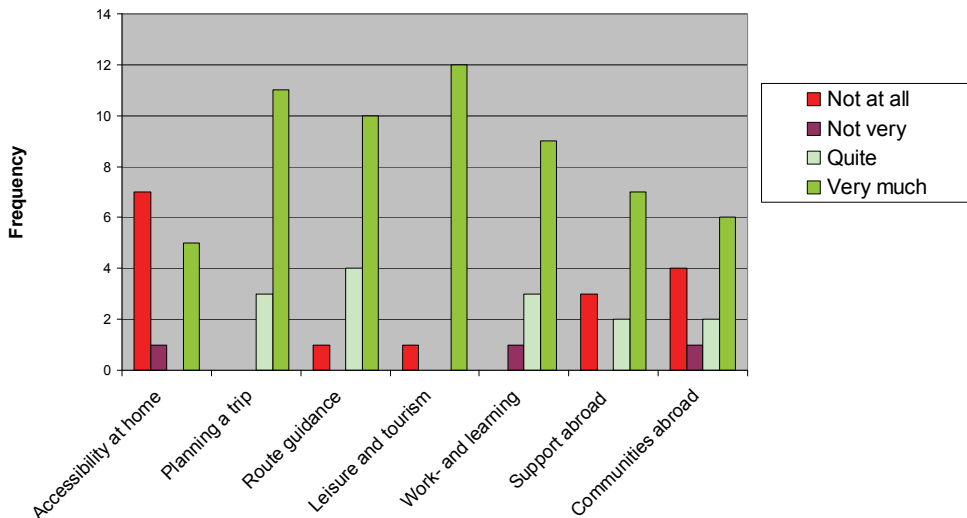
Apparently, the user requirements that were defined beforehand, concerning planning a trip, route guidance and receiving appropriate information on various types of buildings, and possibly also shops and horeca are useful. Furthermore, the accessibility information of buildings is considered of value for work and learning. Many of the severely visually impaired people, however, are currently out of work. Possibilities for re-integration into work is mentioned as very desirable. If ASK-IT can support inclusion of mobility impaired people back into work, then ASK-IT is certainly doing a fine job. A full report of the pilot study will be provided in Wiethoff et al (2009).

6. Discussion and conclusions

The above described content definition and modelling procedure has been successfully applied in the framework of the ASK-IT project. The matrix structure based on action and activity theory principles facilitated the systematic and extensive content requirements specification. Comprehensive content requirement matrices were produced. The tables include user group specific attributes for all identified actions and activities. For some domains, the domain of tourism and leisure, and the domain of transportation, there was the difficulty of the sheer extent of the activities and types of transport, and hence the huge quantity of information needs related to their performance by people with various types of functional limitations (Sommer et al, 2006). This was not so much the case for the social contacts and community building domain, or the personal services domain or the e-work and e-education domain. The lists of content requirements for all domains were evaluated and prioritised by representatives of different user groups.

Morganti and Riva emphasised recently that the focus of Ambient Intelligence for rehabilitation should be the support of the users' activities and interactions with the

environment (Morganti and Riva, 2005, p. 285). The integration of action and activity theory principles has indeed proven to be a suitable theoretical framework for the specification of content requirements for a mobile communication platform to support social relations and communities of people with functional limitations. The content requirements matrices provide, for each user group, a structured representation of information elements in the form of classes with attributes and limit values. This approach facilitates the subsequent creation of XML schemes, because the input for the content modelling procedure is immediately available in a format that can be converted into a machine-readable language without difficulties. The subsequent translation of the user needs in design of the ASK-IT components is, at least to some degree successful.

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