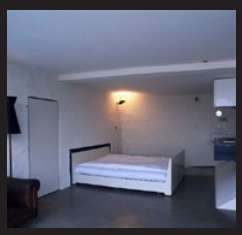
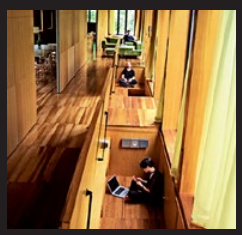
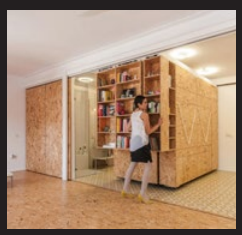
Space-saving techniques by the use of transformable architecture

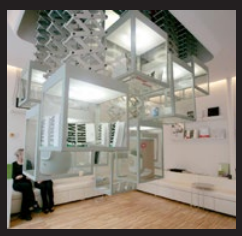


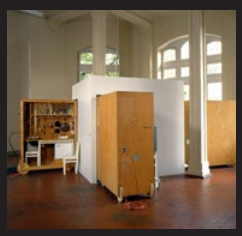
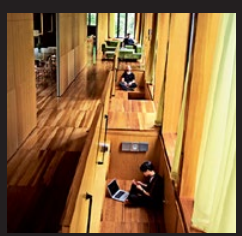







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Abstract

The focus of this paper is on transformable architectural designs, especially those that have the purpose to save space. This is usually achieved by enabling a space to be used in different ways and for different purposes by transforming it according to what is needed. The paper discusses the different forms of movable and transformable architecture and the various purposes for making transformable designs. Then spatial solutions and mechanisms of space-saving transformations are studied.
Reference projects were used for finding the essential categories and rubrics of transformable architecture which are important for the understanding. The case studies are then sorted according to the categories to give overviews of the great range and possibilities of transformable designs and which solutions are applied for which situations to save space.

Keywords:
transformable, flexible, space-saving, movable

Content

Introduction

The prices for houses and office spaces are getting more and more expensive in the city centres. The main reason for that are the very high prices for the building plots. As space is often the most expensive component when new buildings are built, many designers are searching for ways to get as much out of the space as possible. One way to do that is building higher buildings to get more usable space out of the plot, another way is to use one space for different functions and to compact the necessary space in that way.
This paper will discuss the different possibilities in transformable designs that are trying to gain space by compacting and changing the functions according to the needs of the user. The following research questions helped to define the topic and to structure the paper and the paper aims to answer them in the following chapters.

Research Question
How can transformable architecture help to use space more efficient?

Subquestions:

- what is transformable architecture?

- what are the reasons to make architecture transformable?

- which techniques are used to make transformations?

- which movements (sliding, rotating,...) are used in which case?

- when are the moving parts manually/ mechanically transformed?

Approach of research
First I want to define the different fields of transformable and movable architecture, because there are many terms existing for slightly different approaches, which make it often a bit confusing. By narrowing it down to four main categories it will be more understandable and clear.
In the next step I will discuss the different purposes that make architects choose a design which is transformable. This purposes could be for instance climate-related, what means that the architecture would be able to adapt to different weather conditions. Another purpose would be flexibility, for easy changes of the functions, to be as free as possible. Functional transformability reacts to different needs of the user and is mostly made to save space. This is also the main topic of the paper.
The following step is to determine the spatial solutions for this kind of designs, that means the location of the functions in a space and how the space – function relation is working.
Then I will look closer into the movements, which are necessary to make transforming designs. Movements can be either translating, meaning a movement from one place to another or rotating. To make something move numerous options are existing like sliding, folding, flapping, etc..
In the end several case studies will be presented and categorized according to the findings of the paper.

Objective
By collecting and studying reference projects that use transformable architecture I want to discover the different possibilities and ways to use transformable elements. I want to figure out what transformable architecture is exactly and what the important factors are to design something that can move or transform. The aim is to create a

kind of toolbox with all the options, purposes and solutions in transformable architecture for the later design.

Relevance

The paper discusses several transformable projects and explains the essential factors of transformable designs by using the reference projects. The reseach is gonna be used for the later design, which is the transformation of an old office building in the centre of Amsterdam. By using transformable elements for the design I want to make it flexible for different uses to save space in that way.

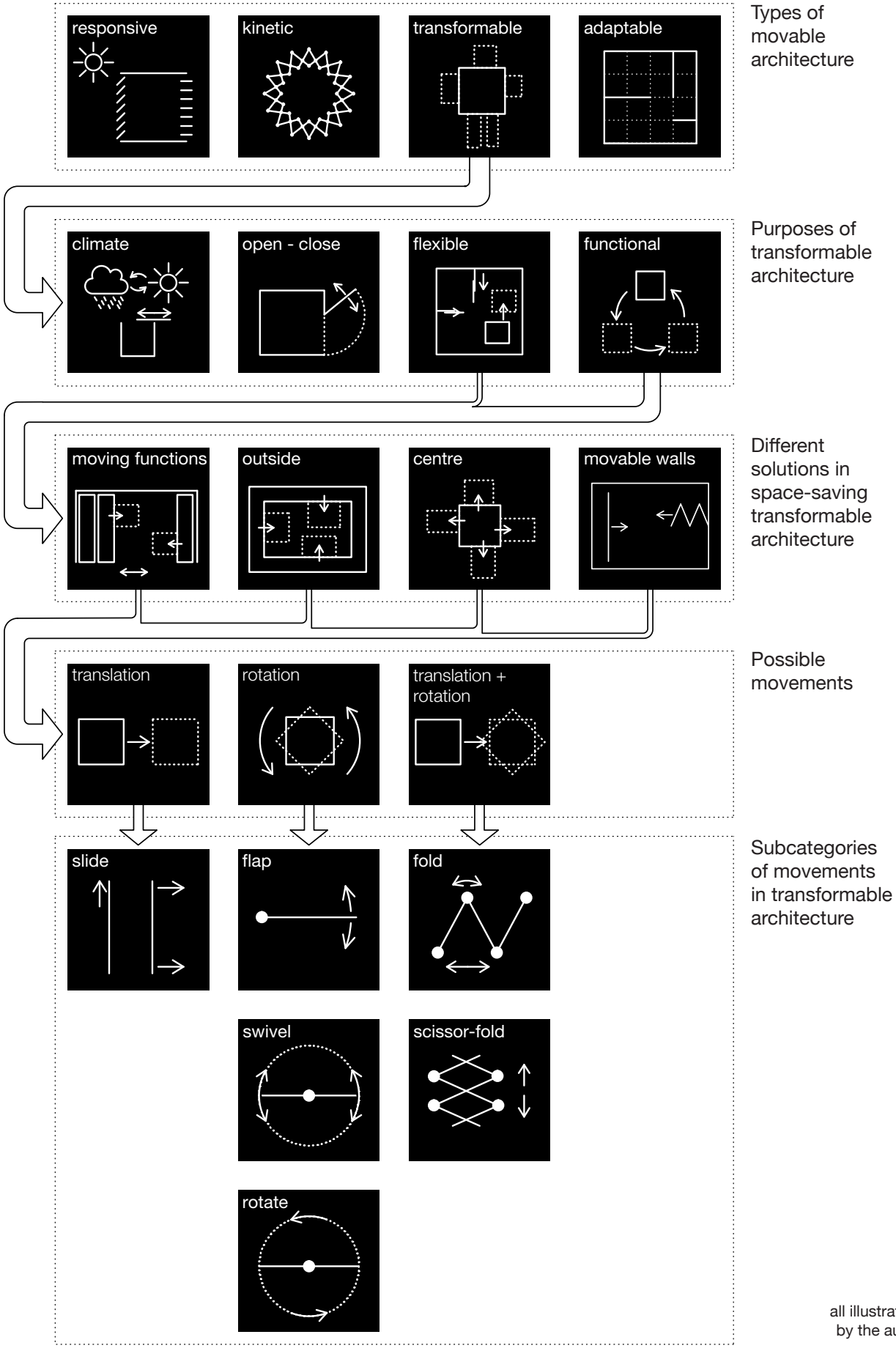
Method

In the beginning I started the research by searching for architectural designs with transformable elements in the Internet and in literature and I collected all the projects that seemed interesting to me.
By making a database of these projects and assigning them to different categories I was able to narrow this very long list down to the projects that are really essential for my research and I was also able to understand what the main categories and factors of transformable architecture are.
Together with literature, especially the book *Move: Architecture in motion, dynamic components and elements* (Schumacher, Schaeffer, 2010) and *Flexible: architecture that responds to change* (Kronenburg, 2007) were very helpful, I studied the different solutions, purposes, mechanisms and so on in the designs more in detail.
The objective was to create a tool for designing with transformable elements, especially for the purpose to save space. The paper gives an overview of the wide range of transformable projects and helps to understand the different possibilities and ways transformable projects can be designed.
The database that I made while I was collecting reference projects, I arranged according to the following categories: project name, architect, year and location. In that way I had a first overview of the projects but I also realized that the list is to long and the project range is to wide, because I collected not only transformable, space saving projects from the beginning but basically anything that seemed interesting, so the list was about 60 projects. In the next step I defined the different terms of architecture with movable elements and gave to the database according to that a new category with the options adaptable, responsive, kinetic and transformable. After that I defined the purposes for making transformable architecture and sorted the list according to this category. Then I organized the projects according to space-saving or not, in that way I made the list smaller, there were now a bit less than 30 projects left. From there on I was working only with the projects which are space saving.

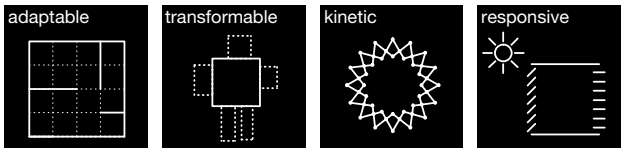
In this paper I will discuss in every chapter one category of terms/ solutions/ systems/ etc., which is important for transformable projects and in the end of each chapter I will give an overview of the projects according to the category. In that way the paper aims to illustrate the wide range of possibilities and tries to figure out the coherences of the different options.

The next page shows an diagramatic overview of the approach of research and how the specific route through the different topics was chosen. The icons that stand for specific categories within the field of transformable/ flexible architecture help to orientate in the paper.

Approach of research



all illustrations by the author



Definition of different terms of architecture with movable elements

When I started researching about transformable architecture I noticed that there are many words flying around, that are used for describing different forms of movable designs. This terms are not very clearly defined and vary in different publications about this topics. Often the authors define the terms according to their needs, depending on the specific field that they are writing about.
These terms are for instance: flexible, portable, adaptable, kinetic, manipulable, transformable, mutable, reconfigurable, responsive, collapsible, revolving, etc.. I want to narrow down these categories (according to the research of Joshua David Lee, 2012) to four generic terms, which are kinetic, responsive, transformable and adaptable. This terms are able to categorize most of the designs with movable elements.

Adaptable Architecture

According to the Oxford English Dictionary (OED) adaptable means: *Capable of being applied or used in different conditions or contexts; capable of being modified, altered, or amended, esp. so as to be put to a new use or serve a new purpose. Able to adjust to new conditions or situations, or to changes in one's environment*. Adaptable Architecture is mostly socially motivated and is therefor is able to be changed according to changing users or changing needs of users.
Examples are the open floor plans of Le Corbusier like the Dom-ino House system (fig. 1), where load bearing walls are not necessary, this enables to arrange the layouts very freely and they are also changeable after construction. Other examples are movable wall systems, that are able to divide spaces into different configurations very rapidly.

Kinetic Architecture

In the book Ephemeralization (Michael Fox, 2001) "*kinetic architecture is defined generally as buildings and/or building components with variable mobility, location, and/or geometry*", this is reached by "*folding, sliding, expanding and transforming in both size and shape*". The motion is very important in kinetic designs, often more than the actual function and many times it is designed to get attention. The moving parts and mechanisms are mostly clearly visible.
Good examples are the architecture of Santiago Calatrava or the Rolling Bridge by Thomas Heatherwick (fig.2). Many kinetic designs are rather sculptures than architecture, as many designs have not a actual

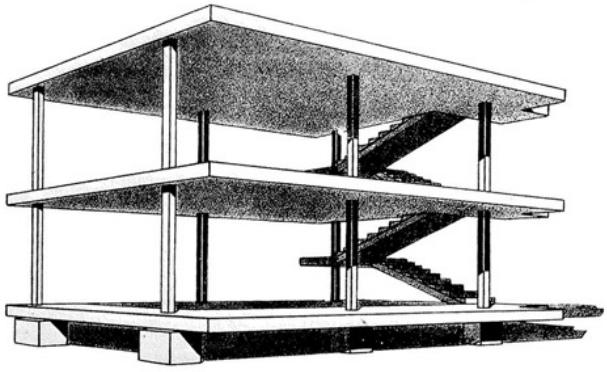


fig.1, Dom-ino House, Le Corbusier

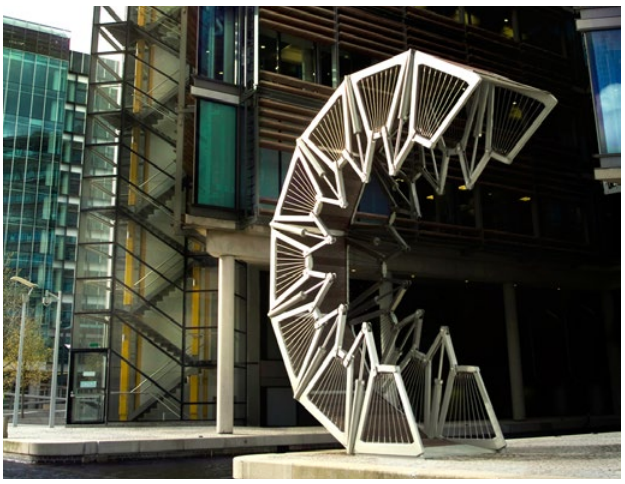


fig. 2, Rolling Bridge, Heatherwick Studio

function but make for instance the wind visible through movable parts.

Responsive Architecture

The word responsive comes from the Latin word *respondere*, which means to answer or to react to something. In the article "*Responsive systems/appliance architectures*" from the Architectural Design magazine it is described as follows: *‚responsive' suggests mutual reaction and exchange, with adjustments occurring continually on both sides of the equation* (Hookway, Branden and Perry, 2006). So Responsive Architecture describes elements which are able to answer quickly to a environmental or social changes in the built environment.
Often responsive elements are facades that can respond to different weather conditions like the Insitut du Monde-Arabe in Paris (fig.3) by Jean Nouvel or the American Pavilion for the Expo of 1967 in Montreal by Richard Buckminster Fuller.

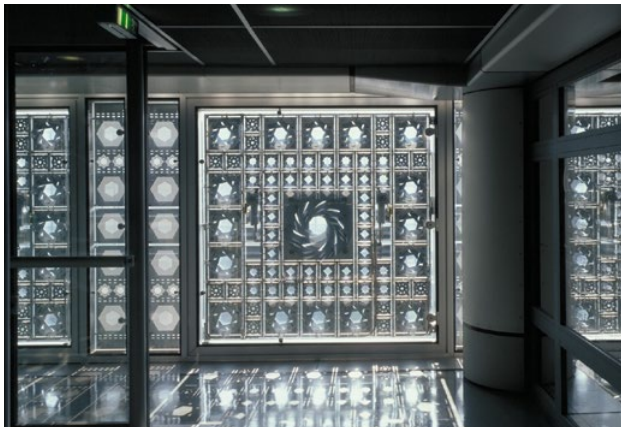
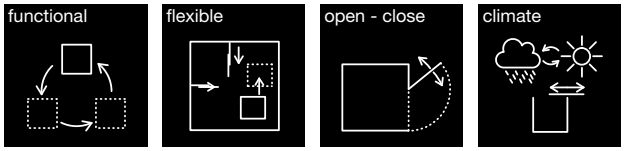


fig.3, Institut du Monde Arabe, Jean Nouvel

Transformable Architecture

According to the OED the word transform expresses a *change in the form, nature, or appearance of something*. In the book *Flexible: architecture that responds to change* transformable architecture is described as "*buildings that change shape, space, form or appearance by the physical alteration of their structure, skin or internal surface, enabling a significant alteration in the way it is used or perceived*" (Kronenburg, 2007). In *Transformable and Kinetic Architectural Structures* it is characterized as "*a distinct class of structures consisting of rigid, or transformable elements, connected by moveable joints that can change their geometry reversibly and repeatedly and have the innate characteristic of controlled reconfiguration*" (Asefi, 2010). So transformable architecture are designs that can be changed according to different functions. The focus lies less on the aesthetic appearance but more on the functional performance.
Examples are moving stadium roofs to react to different weather conditions or transformable furniture systems that can be used for different purposes and to safe space in that way.

The following page gives an overview to projects sorted to the four categories of architecture with movable elements.
The focus of this paper will be on transformable designs that are able to react to socially or environmentally related changes. In the next chapters this kind of designs will be discussed more in detail.



Purposes for making transformable designs

By assigning the projects of the database to their purposes I found out that there are four main reasons, at least in the projects that I was studying, for making transformable designs. These purposes are: adaptability to the climate, opening and closing of buildings or functions, flexibility and transformation for functional reasons. Now the purposes will be explained more explicitly.

Reaction to different climatic conditions

Climate-driven transformable designs aim to control the climate for more comfort in the building or for adapting a building to different weather conditions and making it more useful. Mostly the designs protect the user from the weather, like strong sunlight, rain or wind, examples for that are movable roofs of stadiums and theaters like the Wimbledon Stadium or the Starlight Theater. This means most of times any kind of devices that are able to close a building to protect from external influences. The transformable elements are located within the envelope to shelter the internal spaces.
Some projects are also designed to achieve the opposite, instead of protection they are reaching to expose themselves to the exterior in case of good weather conditions, like the Living Room by Seifert Stoeckmann (fig. 4). This house can draw one room out of the envelope, which is then without roof. The transformation can be either controlled by the users, it has to be done mostly manually in this case, or a system with sensors is controlling the transformable elements and the devices close or open according to sun, wind, rain and so on.

Often climate driven transformations aim to make the building more sustainable, so can the sun help to heat a building or the sun can be kept outside to need less air conditioning to safe energy.
In an article in the Detail magazine the necessities of a sustainable building for temperate climate zones are described, it says "*A flexible, ‚intelligent' external skin is needed, therefore, capable of admitting daylight at certain times and keeping it out at other times*" (Detail, no. 42)


fig.4 Living Room, Seifert Stoeckmann

Opening – Closing

Projects with transformable elements which purpose is to open or close a building are often done to make it clearly visible from outside whether the building or functions are currently in use or out of use. So it is possible to see immediately whether you can enter or not. Sometimes the designs even aim to merge with the surrounding environment to make the building disappear. In that case the building or the function is only visible when it can be used.
An example is the Palatinate Cellar entrance by Santiago Calatrava (fig. 5). The entrance folds up from the ground and allows the visitor to enter into the cellar, in the closed state it is becoming one with the ground.
In that way the structure is protected from environmental influences like weather

fig.5 Palatinate Cellar, Santiago Calatrava

or vandalism. But in the times when the building is opened it is often a big inviting gesture and the inside is getting exposed. Buildings of this type often have a public or retail function.

Flexibility

Flexible spaces are designed when the user wants to use a space for different purposes or when the space should be not fixed to one specific function but rather easily changeable to anything. Flexible designs often consist of a free space and a movable partition system to divide it according to different functions, an example for that is the Nine-Square Grid house by the Japanese architect Shigeru Ban. The layout is a open square space, in the walls are sliding partitions to divide the space into different rooms.

Another possibility for flexible designs is to make the functions movable and let them divide the space directly without any partitions, like the Naked house (fig. 6) by the same architect as the previous project. The


fig.6 Naked House, Shigeru Ban

different functions of the house, like bedrooms, working spaces, closets, etc. are located in small rolling boxes. In that way the layout constantly changes.

Many flexible designs are residential projects or office spaces.

Functional transformability

This type of transformations enables the user to use a space for more than only one function. The functions that are not needed are moved away, often to save space, in that way a room can take on several uses which are quickly to exchange. So could a room be used for instance as a bed room and as a dining room, when the bed and the dining table are movable and exchangeable by themselves. An example is the Total Furnishing Unit (fig. 7) by Joe Colombo, the idea was to put all necessary functions into a compact box that can be put in any space to make it inhabitable.

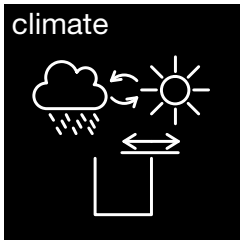
The general principle is always to transform the functions and to change between them in one room. How it can work exactly will be discussed in the next chapters.

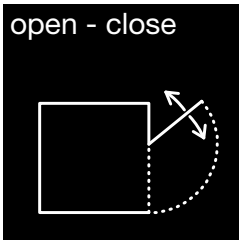
The difference between flexible and functional transformations is that functional transformations are predefined exchange-

fig.7 Total Furnishing Unit, Joe Colombo

able functions that are able to change their appearance reversibly and repeatedly. Flexible transformations instead aim to provide total freedom to the user to make anything possible.

The next two pages give an overview of projects sorted according to the previously discussed categories.






Kubus
Sturm und Wartzech


Living Room,
Seifert Stoeckmann


Lakeside Stage,
Werkraum Wien with hans Kupelwieser


House No 19,
Korteknie Stuhlmacher Architecten


Ernsting Distribution Depot,
Schilling Architekten


Fahrt ins Grüne,
Kalhöfer – Korschildgen


Milwaukee Art Museum,
Santiago Calatrava


Sliding House,
dRMM Architects


Rolling Bridge,
Heatherwick Studio


Shop entrance,
Nickel und Wachter Architekten


Bloomframe Window,
Hofman Dujardin Architects

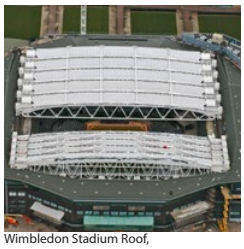

Institut du Monde Arabe,
Jean Nouvel


Montreal Olympic Stadium Roof,
Frei Otto


m.poli Kiosk,
Brut deluxe


Theresienwiese Service Centre,
Staab Architekten


Shakespeare Theater ,
Renato Rizzi


Wimbledon Stadium Roof,
Capita Symonds

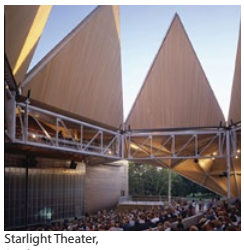

GucklHupf project,
Hans Peter Wörndl

Palatinate Cellar,
Santiago Calatrava


Sharifi-ha House,
Next Office

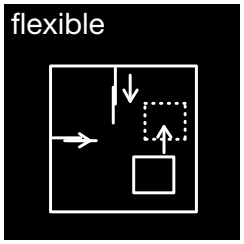

Baer House,
Steve Baer

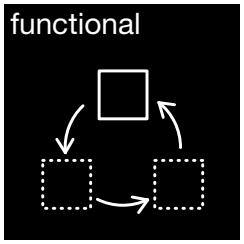

Store Front,
Steven Holl


Starlight Theater,
Studio Gang


Oita Stadium,
Kisho Kurokawa


Garden Hut
Eightyseven Architects






Studio 8,
Gruppe OMP


Archilab Living Room,
Juan Pablo Molestina


Total Furnishing Unit,
Joe Colombo


Drawer House,
Nendo


Crate House,
Alan Wexler


Naked House
Shigeru Ban


K-Space,
6a Architects


LaboShop,
Mathieu Lehanneur

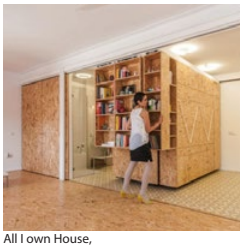

Bordeaux House,
Rem Koolhaas


Erika Mann Primary School,
Susanne Hofmann Architekten


BDA Wechselraum Gallery,
Bottega + Ehrhardt Architekten


Suitcase House,
Gary Chang


Multifunctional Dwelling,
Gary Chang


All I own House,
PKMN Architectures

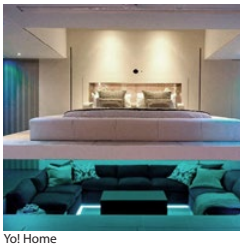

Chateaubriand Private Residence,
Jacques Bilodeau, Marc-Andre Plasse


Nine-Square Grid House,
Shigeru Ban


Black Treefrog,
Splitterwerk


Creative Hub Euro RSCG offices,
Atelier Phileas


Kubus
Sturm und Wartzech


Yo! Home
Simon Woodroffe


Fukuoka Housing,
Steven Holl

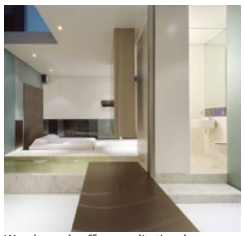

Penthouse T.O.,
pool Architektur ZT GmbH


Home/ Office for a graphic designer
Roger Hirsch, Myriam Corti


Copper Suitcase,
Penda

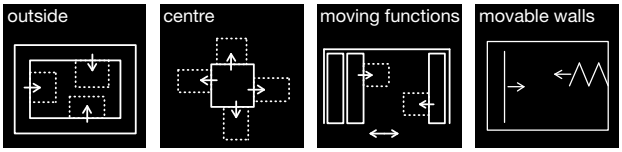

Optibo,
White Design


St@ndby Office,
Bothe Richter Teherani


Womb: work, office, meditation, base
Johnson Chou


CircuitBox,
Studio X Design Group


A House in a Suitcase,
Eva Prats y Ricardo Flores



Different solutions in space- saving transformable architecture

The reason to make functional transformations is most of the times to save space. Space saving transformations use mostly two elements, one component is the free or neutral space, the other one is the function which activates the space for a specific use. The functions are movable inside the space or out of the space to make it possible that the space can be used for different purposes (fig. 8). In this chapter the possibilities are getting discussed that can be used to gain space by using transformable designs. Therefor the relation between space and functions play an essential role.
It is important to store the functional elements that are not in use as smart as possible somewhere outside the neutral space. There are different solutions existing where the functional components can be stored when they are not needed. In the reference projects that were studied for the research I found four different possibilities, so the location of the functions are either on the outside of a space, in the centre or the functions can be moved through the space or the space is changed by flexible partitions.

General principle:

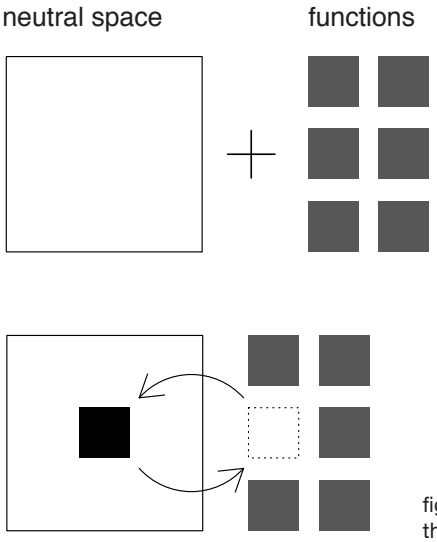


fig. 8, illustration by the author

Functions on the outside
The majority of the reference projects are working in that way, as it is probably the easiest way to use a room for several functions. The components are moved mostly manually into the space when the respective function is needed and afterwards out again. The location of the components can be in or on the outer walls that are limiting a space, but they also can be hidden in the floor or coming from above. By bringing in a certain function the neutral space gets activated for a use. The functional installations in that case are mostly designed for one specific space and are fixed to this.
According to the locations different mechanisms are used like sliding or folding. The mechanisms will be discussed more specifically at a later point.
An example for that type is the Drawer House by Japanese firm Nendo, like the name suggests the elements are drawn into the space from a wall where all the functions are sitting in, or the function is opened to enlarge the space for using it by including the neutral space.
The apartments in the Black Treefrog by Splitterwerk are consisting of a free space surrounded by the functions that are hidden behind folding walls. By folding away the partitions the several functions are set free and the whole space becomes a bathroom, living room or kitchen.

Functions in the centre
The concept of centralized functions is basically the same as if they were coming from outside. So it is a neutral space and it gets activated by adding a function. The previous type is working from the outside to the inside, while this concept is inverted,

as a result it is working from the inside to the outside. The functional components are most of the times compacted to a nice little box that is located in the middle of a room and often also can be moved to inhabit a different space or to make room for other activities. By using this principle often several functions can be used at the same time because the elements are moving from a central point into different directions, while the functions that are located on the outside are coming into the same space and would interfere with each others in this case.
The Archilab by Juan Pablo Molestina has the size of a small wardrobe. It contains several elements like a bed, storage spaces and a table which are folding out from the box. The Standby office by Bothe Richter Teherani instead has only one function. The rollable box contains all necessary elements for a one-man office. When the work is done it simply can be moved away to make room for something else.

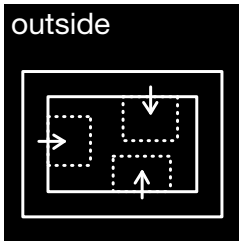
Movable functional walls

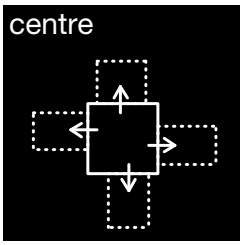
The idea of that concept is to move the functional components through the room to make space at the location where it is needed, like the mobile shelving systems that are used in archives. The functions are not stored somewhere to safe space as it is done in the previous systems, but instead the space which is needed for a function is shifted. It is probably the most complex type because the room has to be provided with a system, for instance rails, that allows the functions to move. Usually the movement that is used is sliding.
A nice example is the Multifunctional Dwelling by Gary Chang. It is an apartment in Hong Kong which has only a size of 32 sqm, through movable functional walls it can be transformed to 24 different configurations which allow to have all the functions that are needed for living in reasonable sizes.
The projects are mostly with residential uses in large cities, where living space is very expensive.

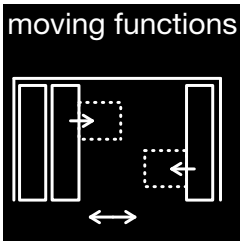
Moveable walls

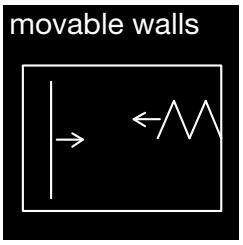
Moveable interior walls are another way to change a space to use it in different ways. It is possible for instance to divide a big space easily and fast into smaller rooms with this system. It does not make the functions move to gain space but enables the user instead to use a space in different ways. So it also saves space in a way because if it would be designed in the conventional way without movable partitions all the different rooms would be needed and therefor more space would be required. Moving wall systems have often sliding mechanisms, therefor a rail system is needed, another way is to make the walls foldable. The Fukuoka Housing project by Steven Holl, for instance, features in every apartment folding walls that can either divide the apartment into small private spaces or make it possible to have a big common space.

On the following page space-saving projects are categorized according to the four different spatial solutions.










Creative Hub Euro RSCG offices,
Atelier Phileas


Drawer House,
Nendo


Total Furnishing Unit,
Joe Colombo


K-Space,
6a Architects


Studio 8,
Gruppe OMP


LaboShop,
Mathieu Lehanneur


Yo! Home
Simon Woodroffe


Crate House,
Alan Wexler


Multifunctional Dwelling,
Gary Chang


BDA Wechselraum Gallery,
Bottega + Ehrhardt Architekten


Black Treefrog,
Splitterwerk


Optibo,
White Design

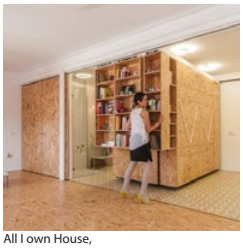

Home/ Office for a graphic designer
Roger Hirsch, Myriam Corti


CircuitBox,
Studio X Design Group

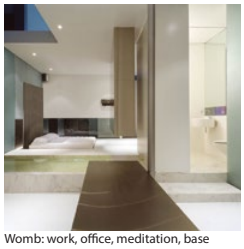

Nine-Square Grid House,
Shigeru Ban


Penthouse T.O.,
pool Architektur ZT GmbH


A House in a Suitcase,
Eva Prats y Ricardo Flores


All I own House,
PKMN Architectures

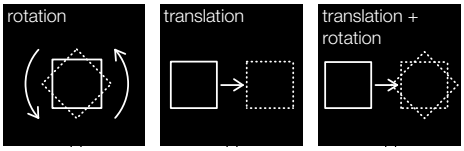

Fukuoka Housing,
Steven Holl


Womb: work, office, meditation, base
Johnson Chou


Archilab Living Room,
Juan Pablo Molestina


Suitcase House,
Gary Chang


Copper Suitcase,
Penda



Movements in transformable architecture

This chapter will be about the movements that are necessary to make a design transformable. For that reason I will first discuss the options of movements and afterwards the mechanisms that are used to make an object move in a certain way.
There are two different ways an object can move. Translation is the linear movement of an object from one point in space to another one while the orientation of the object stays the same. Rotation is the change of orientation of an object, so it rotates about an axis but its position stays the same. Each kind of movements has three degrees of freedom, depending on the change of the position of an object in a 3-dimensional space.
A door for instance rotates about the vertical axis for changing its position to either be opened or closed. So it has only one degree of freedom: rotating about one axis. A car instead has three degrees of freedom because it can move along the x- and the y- axis and it can change its orientation.
So every movement of rigid materials is either translation, rotation or a combination of them. These basic movements can be divided into subcategories.

Translation in transformable architecture
Translation in architectural designs have mostly a single degree of freedom, so it can be moved along one axis. In transformable architecture the mechanism that is used for this movement is most of the times sliding. Therefor a rail system defines the direction for the moving element.
When the moving object has a particular orientation the movement can be distinguished between parallel to the orientation of the object or perpendicular.
Parallel translation is used for moving partitions, to create different configurations of the space by sliding walls, an example is the Nine-Square Grid House.
Perpendicular translation is more difficult to achieve, because two rails are needed to move the object. Often it is used for movable functional walls like in the All I Own House by PKMN Architectures.

Rotation in transformable architecture
Rotating mechanisms can be differentiated to three different forms. Like translation movements, also rotating movements are mostly limited to one degree of freedom in architecture. There is the simple rotation or swiveling, used for instance for a pivoting window. The object can rotate back and forth but is limited to a certain degree.
Revolving mechanisms rotate often into one direction and are not limited, so they can rotate infinite, like a revolving door. The rotational axis of the previous two types are in the centre of the object to reach the balance of the forces.
When the rotational axis is outside the centre the object swings or flaps. An example is a door, there the rotational axis is located on the edge of the object, like in most of architectural examples.
So there are three forms of rotation: simple rotation, revolving and swinging.

The combination of translation and rotation
By combining rotation and translation more sophisticated and complex types can be created. So it is possible to achieve translation as a result by putting together two or more swinging elements to a folding element. This technique is often used when a large surface has to be transformed. A partition that consists of folding elements can be easily moved away and stored as a

compact element.
By combining two folding mechanisms by mirroring them, a scissor-folding systems evolves. This mutual combination restricts the folding mechanism to a one directional movement. So it can be used for translation of an object from on point to another like in the LaboShop by Mathieu Lehanneur. In this project glass boxes that contain samples can be moved down from the ceiling by using scissor folding systems.

The largest number of the mechanisms that can be found in the reference projects have sliding and flapping systems and also some folding and scissor folding systems can be found.

Most of the projects that were studied are moved manually, but some are also moved automatically like the Yo! Home or the Multifunctional Dwelling. Automatic systems are mostly working with small electric motors or pneumatic systems like the Optibo project. Both of the types, automatically and manually moved, make often use of mechanisms that lower the necessary force that has to be used or change the direction of the force.

Simple Machines

The mechanical devices that are used for changing the direction, magnitude or point of application of the force to make an object move are called machines (fig. 9). One differentiates between four different simple machines that are known and were used already since ancient times. (Schumacher, Schaeffer, *Move: Architecture in motion*).
The most simple is a bar or rope which is used to either push or pull an object. The force and the direction that has to be applied stays the same but the point from where the force is deployed changes. To change the direction of the force a pulley can be used in combination with a rope. The third machine uses an inclined surface to change the magnitude of the force to lift an object up. The forth machine is the lever, which is a bar that rotates on the axis that is perpendicular to the bar. On the one side would be the object that has to be moved on the other the force gets applied. Depending on the difference of the distances from object and force to the rotating axis the necessary force changes.
When the magnitude of a force gets lowered by a mechanism to move an object it means that the distance gets longer to move an object from one point to another one. It is expressed in the formula W=F*s, W is the work that has to be spent, F is the force and s is the distance from point A to B.
By combining or expanding the simple machines more complex machines can be created, always with the goal to direct the effort that has to be applied as effective as possible. An example is a winch, which reduces the necessary force by extending the distance.

Simple machines:

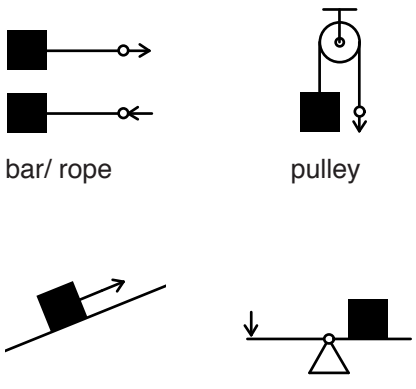


fig. 9, illustrations by the author

Conclusion

Starting by studying movable architectural designs in general, it is remarkable that every system has its own characteristics and important factors. The movable parts in responsive designs for instance are mostly on the envelope to influence the interior space, adaptable designs instead are influencing the whole building structure, by making it as easy as possible to change.

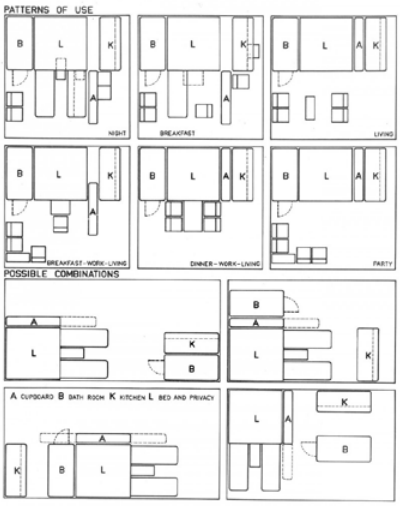
The purposes of transformable designs are very different but they all have in common that they are reacting to a environmental influences. Climate driven transformations are adapting to weather conditions and are enabling the users to use a space in a more appropriate way. Systems with the purpose to open or close a structure are reacting to the use and protect the structure when it is out of use. Also the size of a transformation depends on the purpose. Functional transformations can be very small, it can be for instance a table that is folding out of a wall. Transformations that are flexible are instead effecting the whole space and systems like rails have to be provided to make the space transformable.
By looking closer to the spatial solutions of space-saving transformations, one sees that if for example the functions are located on the outside the system is much more fixed and has to be designed specifically for one space. When the functions are located in the centre instead, the system can be used for any space. The most sophisticated system, movable functional walls, transform a space often in a very impressive way and many configurations are possible, but it is also probably the most elaborated and expensive solution.
There is a wide range of mechanical systems that can be chosen for the moving components. It is depending on the kind of transformation and the movement that has to be reached and also if it has to be moved manually or automatically, which then again depends often on the weight of the element.

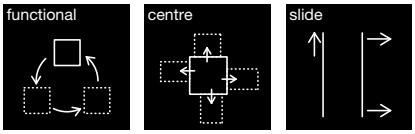
After all one can say that there are lots of different possible combinations of systems for transformable designs. Which system gets applied in which case always depends on the specific space and the purposes that want to be achieved.

Appendix

In the appendix case studies get presented that were used for the research. They are categorized according to purpose, spatial solution and movement, so it is possible to see the wide range of different approaches and combinations.

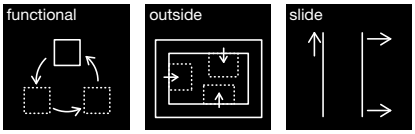
Total Furnishing Unit, Joe Colombo

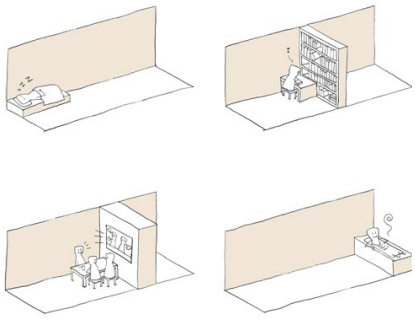




Description:
Colombo combined all of these ideas of machines for living into his Total Furnishing Unit, a large — but theoretically portable — block that comprised kitchen appliances and storage, bookshelves and television, bathroom, wardrobe and stowaway bed. The user only had to plug it in.

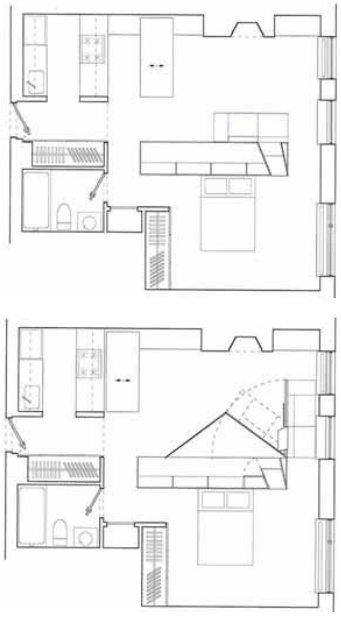
Drawer House, Nendo

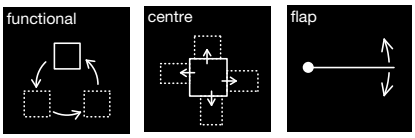




Description:
The residential functions are condensed into one side of the wall, and can be pulled out when necessary, like drawers. A simple mechanism, but this adaptive and flexible space is very effective in the limited housing situation in Tokyo.

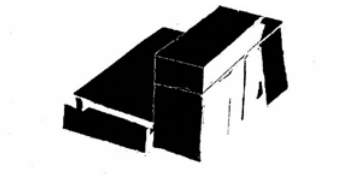
Home/ Office for a graphic designer
Roger Hirsch, Myriam Corti

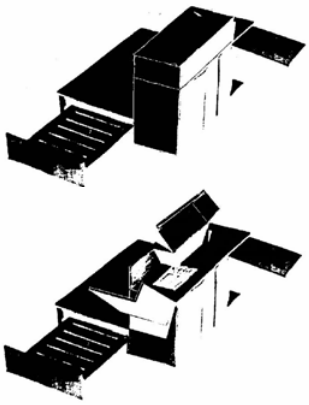


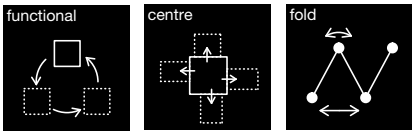


Description:
This graphic designer‘s home doubles in function as an office that must accomodate two to three persons at work. This is achieved in a 56 sqm area through a freestanding 4 x 2.4 meter cabinet that contains the office equipment and divides the space into living and sleeping quarters.

A House in a Suitcase, Eva Prats y Ricardo Flores

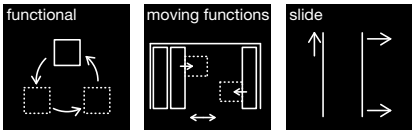






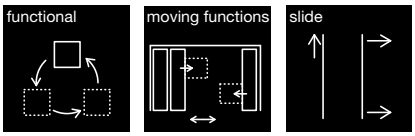
Description by the architect:
The project investigates minimum space in our daily activities; the pieces of furniture open according to each moment of the day. Thus, the unique space of the room 9x3x3 metres varies in size and use during the everyday activities. These two big packages are the ones that put the inhabitants in relationship with the space of the room. When they open them, they guess why they have such size: in their different parts, hidden uses appear and fragment the big unique space into smaller spaces of human scale.

K-Space, 6a Architects



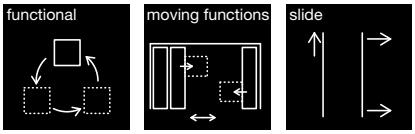
Description:
The installation for both permanent and temporary spaces adapts a library archive storage system. Five of these units are specifically designed to combine display and storage, and slide on tracks to reveal or conceal products, transparency and opacity. The units reveal its contents through the perforations and mirrors the surroundings in its surface creating a constantly changing installation.

Multifunctional Dwelling, Gary Chang



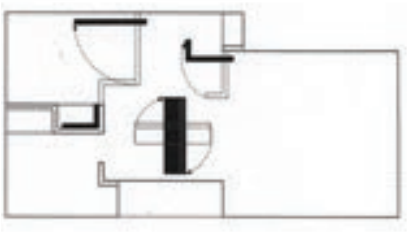
Description:
The Japanese had been doing it quietly for years, of course. But “Domestic Transformer”, the catchy name that Chang, founder of the Edge Design Institute, gave to a 32 sqm Sai Wan Ho flat which can be configured into at least 24 different layouts, due to sliding wall units, fold-down tables and pull-out cabinetry, has been widely documented, and is still referred to in design articles today.

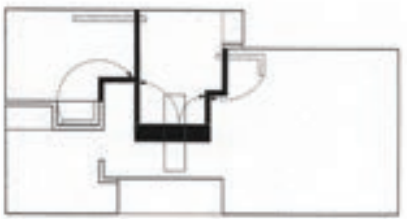
All I own House, PKMN Architectures

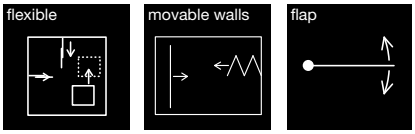


Description:
Movable library-style shelving units slide from side to side to reveal and hide compartments that serve various functions in this Spanish apartmentby Madrid-based PKMN Architectures.
To maximise the functionality of the restricted space, the kitchen, bedroom and storage are housed within a series of moveable units made from heavily textured oriented strand board.

Fukuoka Housing, Steven Holl

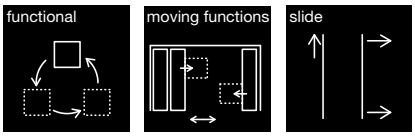






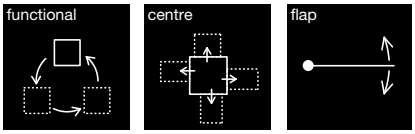
Description:
The 28 apartment interiors are conceptualized as „hinged space," a modern interpretation of the multi-use concept of traditional Fusuma. Diurnal hinging allows expansion of the living area during the day, reclaimed by bedrooms at night. Episodic hinging reflects change in family over time; rooms can be added or subtracted accommodating grown-up children leaving or elderly parents moving in. A sense of passage is heightened by three types of access, by allowing apartments to have exterior front doors, and by interlocking apartments like a complex Chinese box.

CircuitBox, Studio X Design Group



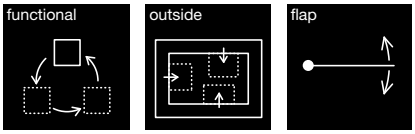
Description:
CircuitBox is a concept for a minimal dwelling conceived as a possible answer to the continuous reduction of inhabited space. It consists of a compact system that contains a multifunctional furnishing system equipped with all the necessary elements for contemporary living in a very small space.
CircuitBox is composed of a series of nested rings gradually decreasing in size and hanging from a rail system along which they slide, passing one through the other. The larger ring serves as a container for the other rings and has been anchored to a wall like an electric plug.

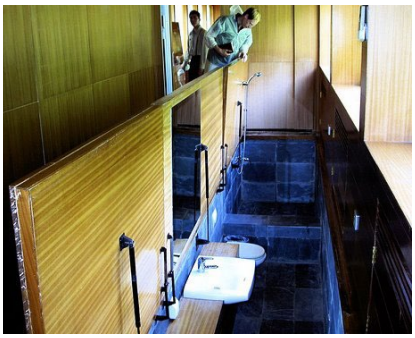
Archilab Living Room, Juan Pablo Molestina



Description:
The compact box transforms into several functions, like bed, couch, table and storage spaces by opening itself throug folding.

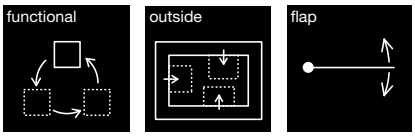
Suitcase House, Gary Chang

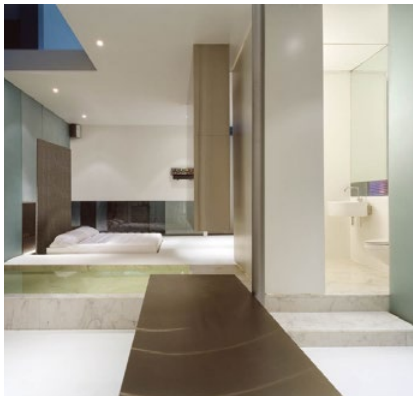


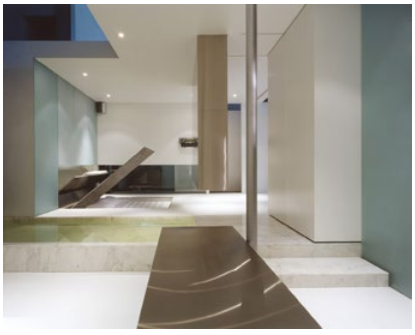


Description:
Organized around the idea of layered strata and perched above the dips of the chinese landscape, 'the suitcase house hotel' by Gary Chang marks the first architectural manifestation of a career-long idea of configurable spaces. For 'suitcase house,' a commission from the commune by the great wall, the proverbial image of a house is inverted in that specific programming transforms readily with a concealed landscape of pneumatically assisted floor panels.

Womb: work, office, meditation, base Johnson Chou

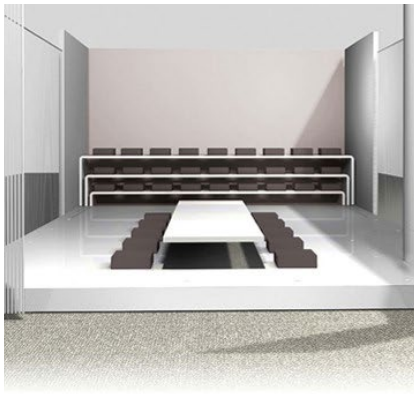


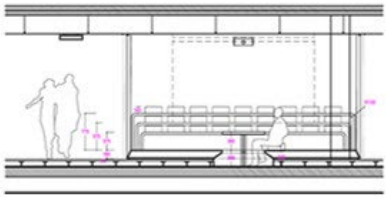


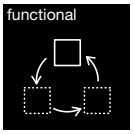


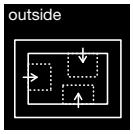
Description:
Toronto's Johnson Chou Design: Facilitated by furniture and cabinetry that pivot, appear and disappear into walls and floors with a touch of a button, Womb can be configured into four distinct programmatic rooms that occupy the entire 56m2 space; kitchen/dining, work/office, bedroom/living, spa/bath, all within a spare, zen-like meditative environment. Allowing one to modulate the space to be as elemental or complex as necessary achieved through automated elements, Womb proposes an alternative 21st century 'machine for living'.

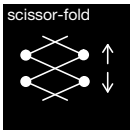
Creative Hub Euro RSCG offices,
Atelier Phileas





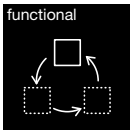


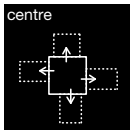


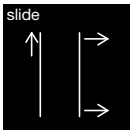


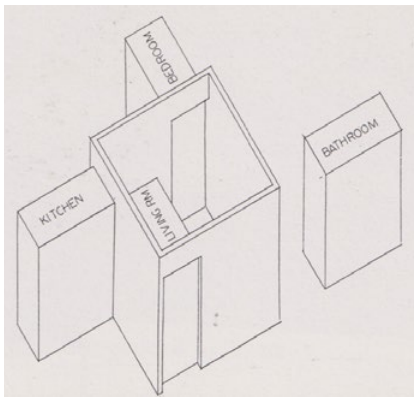
Description:
The purpose of reshaping the Creative HUB of Euro RSCG is to join and facilitate synergies between the 4 creative points of the agency: advertisement (20 creative staff, jointly or in competition between them), edition (17 creative staff, working alone or with another colleague in complex projects), visual identity (5 creative staff, working alone), internal communication (8 creative staff + free-lance: 5 people).

Crate House,
Alan Wexler



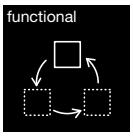


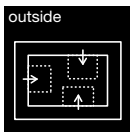


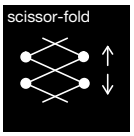


Description:
Crate House compresses an entire house in an eight-feet cube and four crates. This house examines our present lives as if historical. Each crate is like a diorama in an anthological museum. Each function is isolated and studied: kitchen, bathroom, living room and bedroom. When one function is needed that crate is rolled inside the core. At night the entire house becomes a bedroom and when the occupant is hungry the entire house becomes a kitchen.

LaboShop,
Mathieu Lehanneur

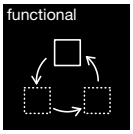


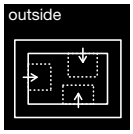


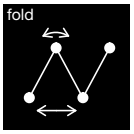


Description:
The LaboShop has a dual personality. By day it‘s a bookshop-sales outlet for the experiments, productions and publications of Le Laboratoire. By night its shop furnishings levitate to become light-filled caissons, freeing the floor-space for guests invited to taste the molecular cuisine of chef Thierry Marx, prepared in the FoodLab at basement level.
The arrangement recycles the system used in coal miners‘ dressing sheds, splicing it to the mobile lighting booms used in film studios.

Black Treefrog, Splitterwerk

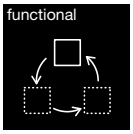


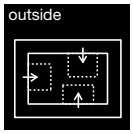


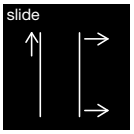


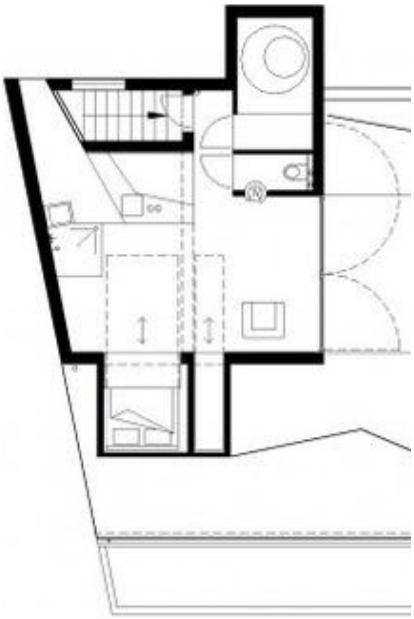
Description:
Splitterwerk designed an apartment in Black Treefrog, Austria, with a switchable structure that is enriched with events. The area of the Ivory Shell in the ground floor of this apartment is limited to 32 square meter, of this area 18 square meter are a funtionally neutral zone. The remaining 14 square meter are filled with specific, domestic functions, each of these functions can be individually activated and separately extended into the neutral zone. In this way, it is possible to arrange the hall, the kitchen, the dining space and the living room, each of which is 18 square meter.

Penthouse T.O., pool Architektur ZT GmbH



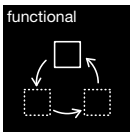


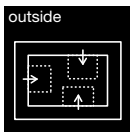


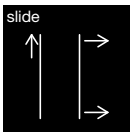


Description:
The room, offering all basic features of a complete flat, covers a surface of 18 square meters on the roof of an industrial building in Vienna. Because of structural reasons it woul have been impossible to add new building loads on the existing roofs, so the penthouse is restrained to the volume of a former water tank. Only covering structures for bed, table and cupboard, all of them can be pushed out of the room according to necessity, have been added. The kitchen unit is a steel console mounted above the sloping cover of the staircase beneath, the refrigerator is hanging from the ceiling.

Optibo, White Design

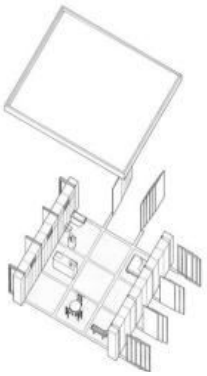


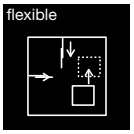


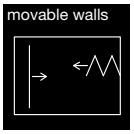


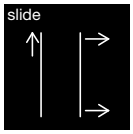
Description:
A sofa, chairs, dining table, and queen-size bed are all contained in a 24-inch deep space beneath the floor. Just a tap on the screen‘s table icon triggers a hydraulic hum. A cherry wood rectangle rises out of the floor to become a tabletop. Then comes the sofa.

Nine-Square Grid House, Shigeru Ban



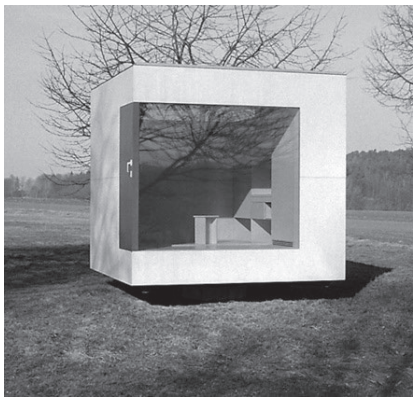


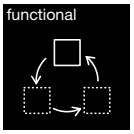


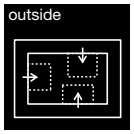


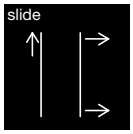
Description:
The spatial composition combines the systems of two walls and a Universal Floor. A large square floor space, 10.4 meters to a side, can be partitioned by full-height sliding doors into nine square areas. These sliding doors allow a variety of spatial arrangements, adjustable to accommodate seasonal or functional needs.

Kubus, Sturm und Wartzech



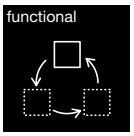


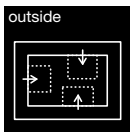


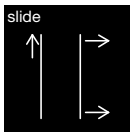


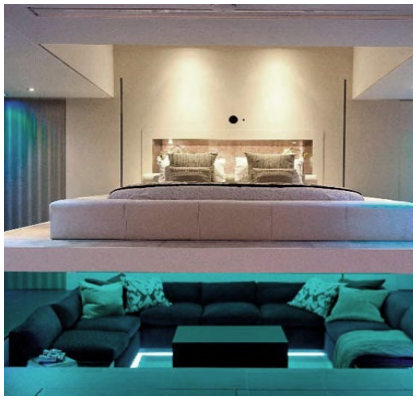
Description:
The concept foresees the various functions of a house accommodated in spatially discrete cubes. The first unit to be realized so far is the living cell. Enclosed on three sides by highly insulated timber-panel walls, it is supplied with electricity by photovoltaic panels, so that it is virtually self-sufficient in terms of energy. The fourth wall consists of triple low-E glazing with a xenon filling. This ensures considerable solar-energy gains, even in winter, and also creates a sense of spaciousness. Folding and pull-out furnishings transform the space into a realm for living, working and sleeping.

Yo! Home, Simon Woodroffe



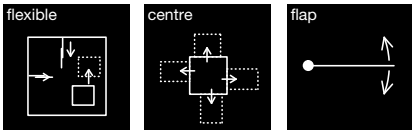


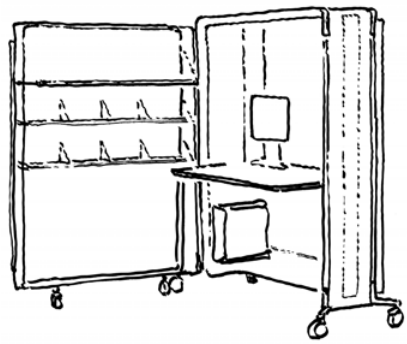




Description:
The prototype Yo! Home apartment squeezes all the rooms of an average two bedroom house into a space no bigger than a one-bedroom apartment. A master bedroom can be lowered down over the sunken seating area of the living room, while a breakfast counter slides out from the walls of the kitchen and a dining table folds up from the floor. Rooms can be reconfigured using sliding partitions, giving residents the option of an open-plan layout.

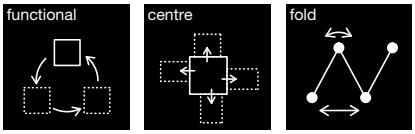
St@ndby Office,
Bothe Richter Teherani





Description:
This mobile office module caters to the needs of the modern office nomad, its “office in an office” concept enables you to work in your own secluded space. Even in an open plan office.

Copper Suitcase,
Penda



Description:
A copper-clad box for storing, exhibiting and selling paintings stands in the centre of this Hong Kong apartment, designed by Penda for one of China‘s biggest art collectors. Copper-covered hatches, doors and an oversized drawer will unfurl from a large cube to reveal valuable artworks, and an upholstered bar area where the collector can entertain potential buyers. A chunky desk, shelves and sofas will hinge out from the box to allow guests to appreciate views over city through the row of large windows, which runs along one side of the apartment.

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