Guiding Light

Ambient Light Guiding System for the Mobility Support of Elderly People

Applicable software components

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Preface

This document forms part of the Research Project "Ambient Light Guiding System for the Mobility Support of Elderly People (Guiding Light)" funded by the Ambient Assisted Living Joint Programme (AAL-JP) as project number AAL 2011-4-033. The Guiding Light project will produce the following Deliverables:

D1.1 Medical, psychological, and technological framework

D2.1 Applicable hardware components

D2.2 Applicable software components

D3.1 Solution package description

D3.2 Implementation report

D4.1 Communication strategy

D4.2 Stakeholder management report

D5.1 Field test report

D6.1 Report on market analysis

D6.2 Dissemination plan

D6.3 Final business plan

D7.1 Consortium Agreement

D7.2 Periodic activity and project management report

D7.3 Final report

The Guiding Light project and its objectives are documented at the project website www.guiding-light.labs.fhv.at. More information on Guiding Light and its results can also be obtained from the project consortium:

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1. Introduction

The aim of our project is to develop, tentatively implement and empirically evaluate an intelligent lighting assistance for maintaining and improving indoor and outdoor mobility of older people at different stages of ageing process and to prepare it for market launch. As far as mobility of elderly is concerned, this goal is to be achieved by enhancing their spatial and temporal orientation by means of lighting wayguidance system.

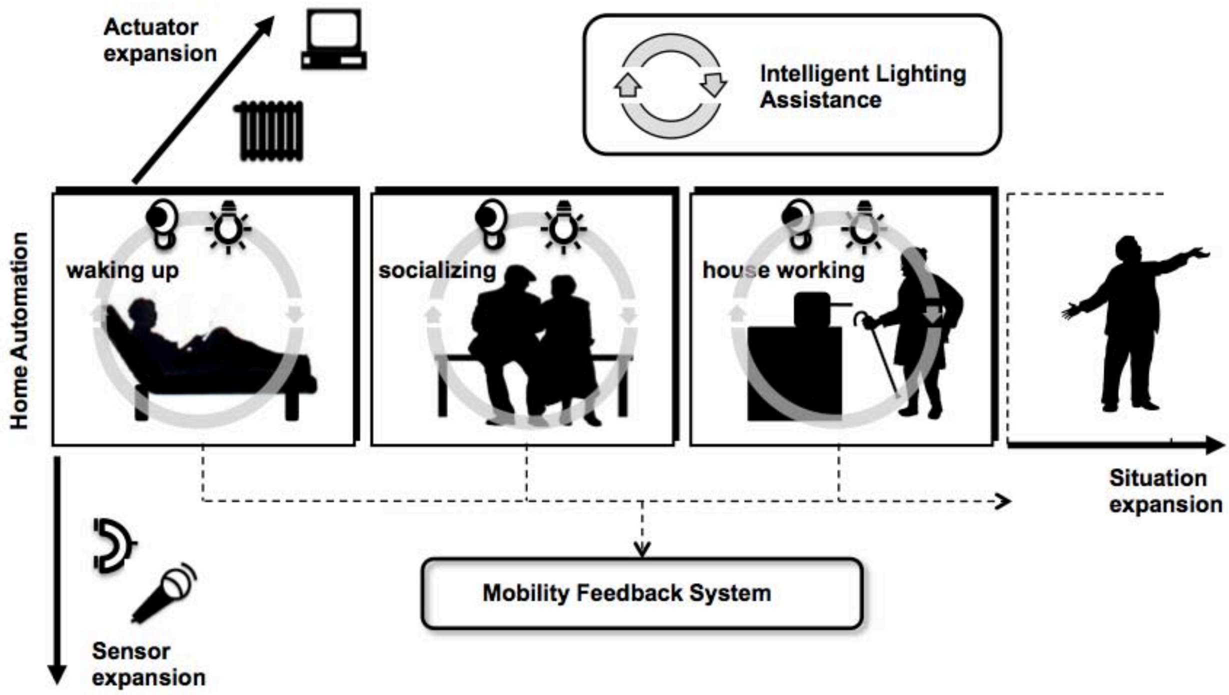


Fig. 1. Application scenarios and possible actuator and sensor expansions.

To this end we will develop an intelligent control loop for home automation, that supports navigation, consolidates personal circadian rhythm, and individually directs attention in a timely manner through automatic light quality and quantity variations and other ambient stimuli coding. We not only expect to achieve more directed mobility with the assistance of guiding light but also a better structuring of activities of daily living within ageing population. Combined with a distributed information system for feedback about nature and extent of individual mobility, the system will likely lead to better care services too.

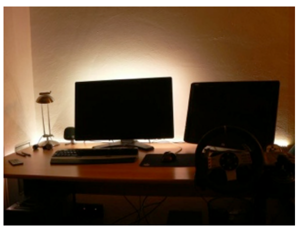
2. Effective stimuli

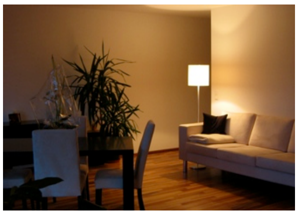
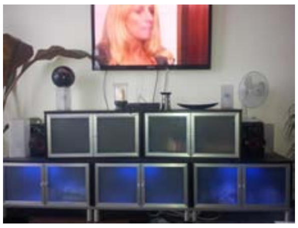
We would like to achieve mobility improvement by influencing temporal and spatial orientation of older persons through ambient stimuli. This is being done with supplying results from sensor data analysis to intelligent adaptation methods. These methods consist of data mining procedures, which automatically try to find the optimal state of electronical systems in older person's home in a timely manner. This means, that lighting wayguidance system will automatically redefine control parameters of actuators within a home automation system.

Generally, there exist many actuators within a home automation system, which can serve as ambient stimuli. Potential actuators are lighting solutions from a wide range (e.g. direct/indirect surface-mounted and pendant luminaires, light lines for emphasizing contours, miniaturized shelf lighting, recessed floor luminaires, table lamps and uplighters, emergency lighting as well as wall-mounted navigation sign luminaires), motor-controlled facilities (e.g. blinds, furnishings, doors, and locks), airconditioning equipment and all home facilities with communication interfaces. Finally, switchable power sockets could serve as actuators so as to automatically turn on and off other electrical devices (e.g. radio).

2.1. Spectrum of lighting stimuli

We decided to exclusively use lighting actuators as ambient stimuli for Guiding Light system, because there are a lot of lighting design options, which can be used for intelligent lighting assistance and improving mobility of older people at different stages of ageing process. Lighting design includes creating the optimal lighting for different daily activities while keeping in mind issues of visibility, biological effects, safety, and cost (Figuerio et al., 2011; Hidayetoglu et al., 2012, Marianne et al., 2011; Veitch & Galasiu, 2012; Wardono et al., 2012). In order to influence spatial and temporal orientation by means of lighting wayguidance system we have to select from the following options:

	Room lighting with different light intensity and light color temperature.		Illuminating objects to remember for a specific daily action.
	Room zones with different light intensity and light color temperature.		Accentuating staircase handrails to support directed locomotion.
	Different parameters of artificial light in relation to daylight.		Signaling by means of background lighting at specific points of interest.

	Eye-catching light zones depending on the time of day.		Highlight some furnishings.
	Facilitating delimited light zones within a room to extent stay within this zone		Luminaires following staircase in order to prevent falls or minimize fear about falls.
	Presenting light path within room to support directed locomotion.		Continuous row luminaire occasionally switched on for orienting support.
	Lighting up medicine cabinet for remembering medication use.		Continuous lightings for directing angle of view resp. gaze.
	Lighting up shoe closet for remembering to make a walk.		Digital light projector systems projecting information or symbols onto walls.
	Sel-illuminating table as an attracting light stimulus.		Illuminated information signs uses symbolic communication.
	Supporting selective attention by object illumination.		Light signals giving feedback oor light cues.

	Changing focus of interest by shining on table surface.		

Once more we decided to restrict the quantity of optional stimuli that will influence mobility of older people to temporal and spatial distribution of light intensity and light color temperature, since the management of these light control signal for all luminaires in all rooms of an apartment will become quite complex and proving evidence for causal effects by means of systematic empirical studies will become extremely difficult.

2.2. Light stimuli of Guiding Light

The two basic types of lighting stimuli are (a) zonal lighting, which concerns to illuminating restricted areas within rooms of an apartment where inhabitants typically perform specific daily activities at specific time of day and (b) ambient lighting, which concerns to the remaining living space where inhabitants perform various daily activities at variable times of day and pass through the apartment. Zonal lighting and ambient lighting differ from each other by means of light intensity and light color temperature of luminaires because both types of lighting stimuli can appear at the same time.

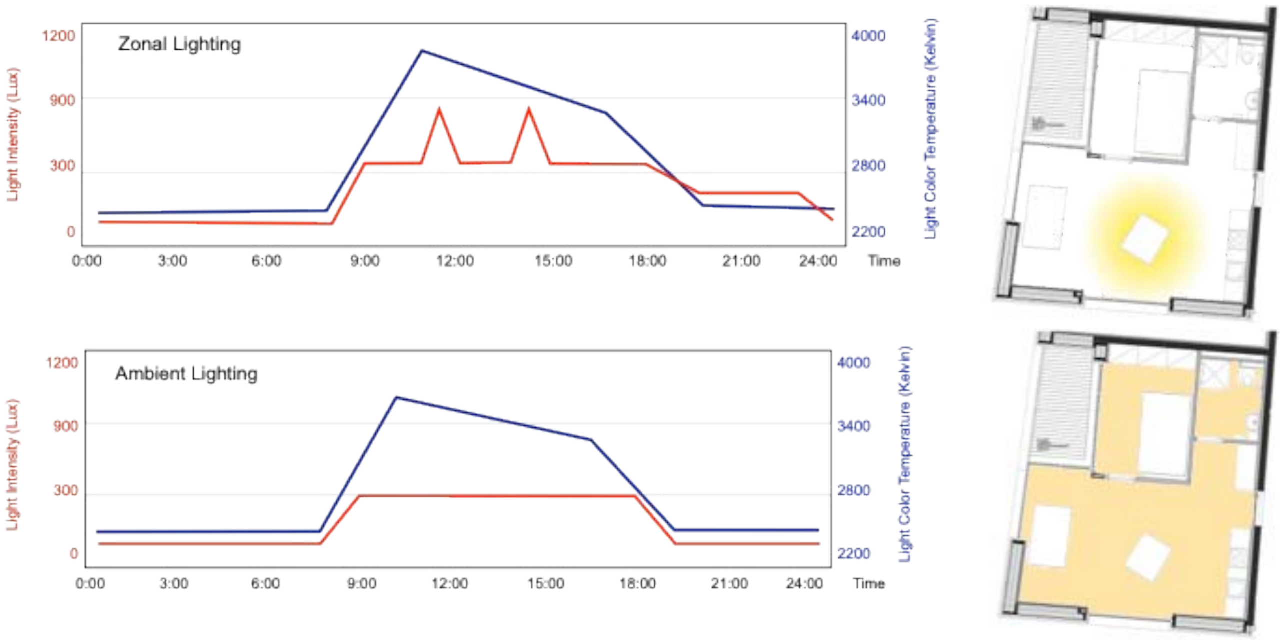


Fig. 2. Example for two basic types of lighting stimuli within Guiding Light.

3. Different software architectures

3.1. General architecture

Guiding Light system will consist of modular and open architecture makes it easy to integrate it in building management systems and general assistive environments as a stand-alone product as well as an add-on or option for already existing systems. A building management system is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as lighting, ventilation and power systems. It consists of software and hardware.

The topology of most building automation networks consists of a primary and secondary bus which connect high-level controllers (e.g. from Beckhoff) with lower-level controllers, input/output devices and a user interface. The primary and secondary cable based bus can be KBX/EIB or DALI. Some newer building automation and lighting control solutions use wireless mesh open standards such as EnOcean. Most controllers are proprietary. Each company has its own controllers for specific applications.

Most building management systems can provide interoperability, allowing users to mix-and-match devices from different manufacturers, and to provide integration with other compatible building control systems. Inputs and outputs are either analog or digital. Analog inputs are used to read a variable measurement. A digital input indicates if a device is turned on or not.

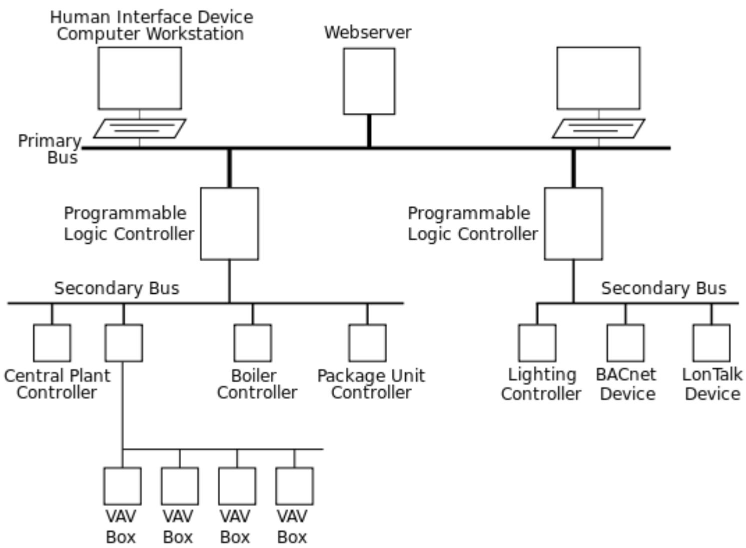


Fig. 3. General architecture of building management system (Source: Wikipedia).

Within our project we have to build on a very flexible solution, because Guiding Light should be open to different building management systems. We distinguish between cable based solution and wireless solutions and will use EnOcean in latter case. The EnOcean technology is an energy harvesting wireless technology that combines micro energy converters with ultra low power electronics and enable wireless communications between batteryless wireless sensors, switches, controllers and gateways.

Sensors and actors can be connected via an EnOcean gateway (e.g. Thermokon STC-Ethermet) with central processing unit. Lightings might be DALI-lighings. Light intensity and light color temperature of these lightings are variable within a predefined range. The range for ambient lighting will be 0-300 Lux and 2200-4000 Kelvin. The range for ambient lighting resp. task lighting will be 0-2000 Lux and 2200-4000 Kelvin. Sensors are motion sensors (e.g. Thermokon SR-MDS BAT) and light intensity sensors (integrated within motion sensor). Light switches are communication via EnOcean too. We have to check, whether we will be able to log manual use of light switches. At the entrance we implement light sensitive barriers. Since we did not find EnOcean sensitive barriers, we might use door EnOcean switch contacts.

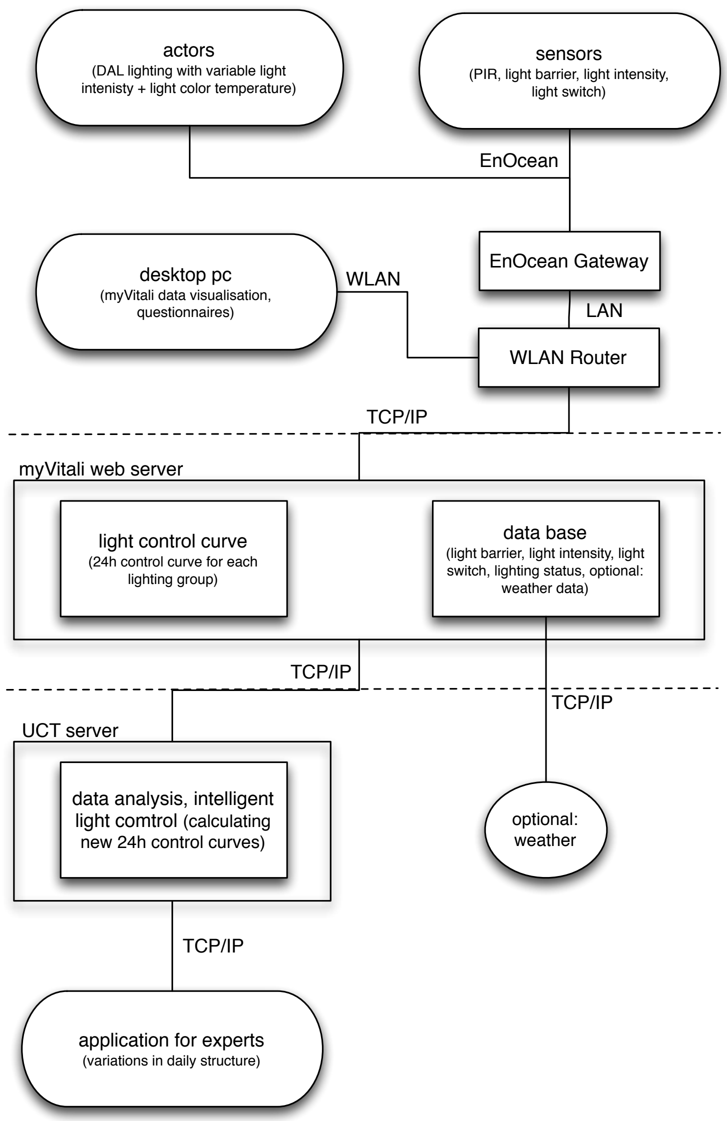


Fig. 4. Wireless solution to integrate Guiding Light in a building management system.

For data communication between EnOcean and DALI-EVGs within lightings we have to search for a new data interface. Maybe, Ökoled (www.oekoled.at) can provide such an interface. We will use a WLAN-router for connecting end user interface (e.g. handheld computer) with Guiding Light system. End user interface will be used for mobility data visualisation and for presenting questionaires during the filed test phase.

3.2. Alternative software architectures

In some cases we would prefer cable based bus systems, e.g. when radio technology does not work properly due to high data transmission or radio waves are not be transmitted. There are two relevant bus protocols: KNX EIB and DALI. KNX EIB uses shielded twisted pair cables, through which the signal as well as 30V DC link power is transferred. For data transmission, a balanced baseband signal coding is used with a baud rate of 9600 bits per second. The Digital Addressable Lighting Interface (DALI) is an interface definition in building automation for the transmission of control signals for lighting devices. DALI ballasts are wired in parallel and linked with one another via the controller.

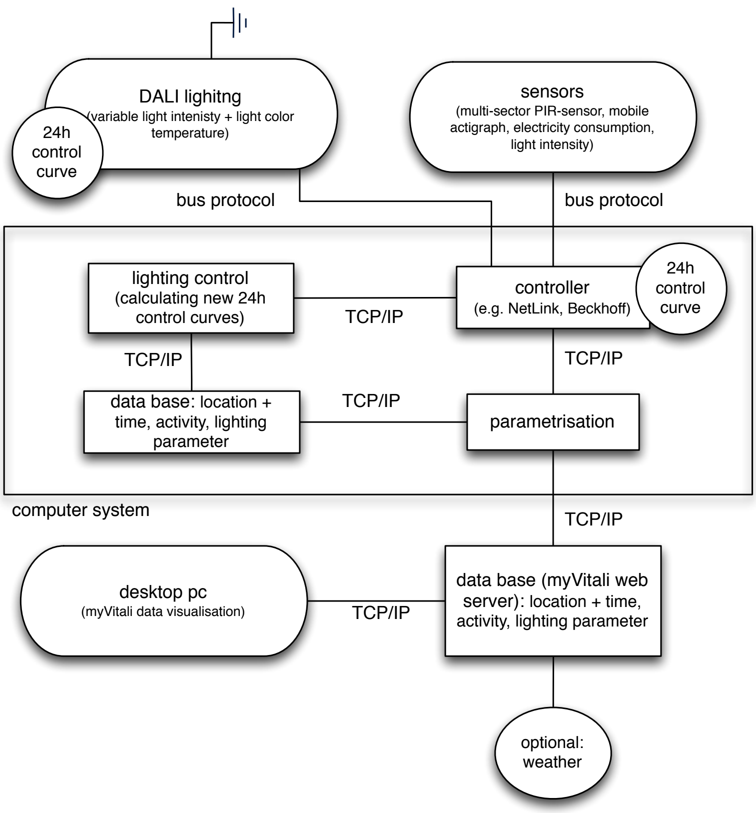


Fig. 5. Cable based solution to integrate Guiding Light in a building management system.

In some cases apartments of older people are already integrated in an existing building management system. In this case we have to implement an interface between existing building management system and our light wayguidance system. Such an interfaces is ADS (Automation Device Specification), a platform and device independend protocol for reading and writing of data and for commando transmission from Beckhoff. For Guiding Light we would prefer buildings without an existing building management system.

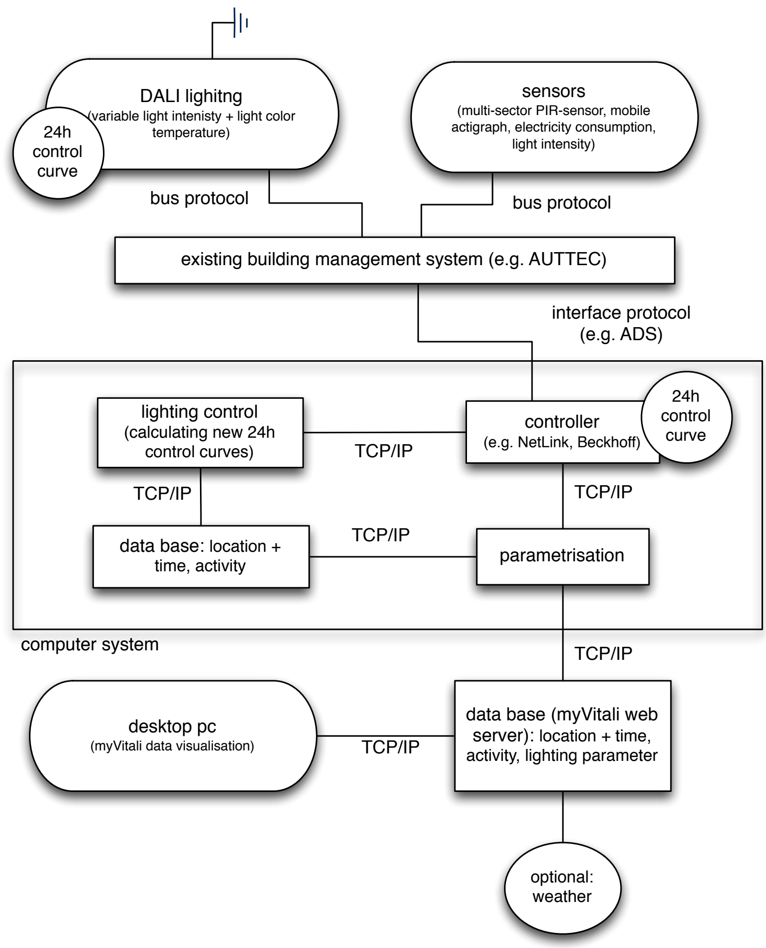


Fig. 6. Solution for connecting with existing building management system

We have to check the localisation of our 24 hours light control signals within a building management system. Possibly this could be within controller for light management (e.g. Netlink), within electronic ballast for lighting devices or as part of the intelligent control algorithm. It has to be checked what kind of signals can be transferred via EnOcean protocol, since this is a new kind of data transmission. If 24 hours light control signals are localized on myVitali server, home automation system of Leit3 GmbH (www.leit3.com) will be used.

4. Data base model

4.1. Data flow

Most of our data will be recorded within the apartment of older persons. Many of them concern to the mobility of older persons and to the indoor lighting conditions within the apartment. Recorded data are used for control algorithm of lightings within the system and for giving feedback on mobility to inhabitants (older persons) and care givers (e.g. family members, care services). Within apartment data will be transferred via building management system or light management system (see chapter 5).

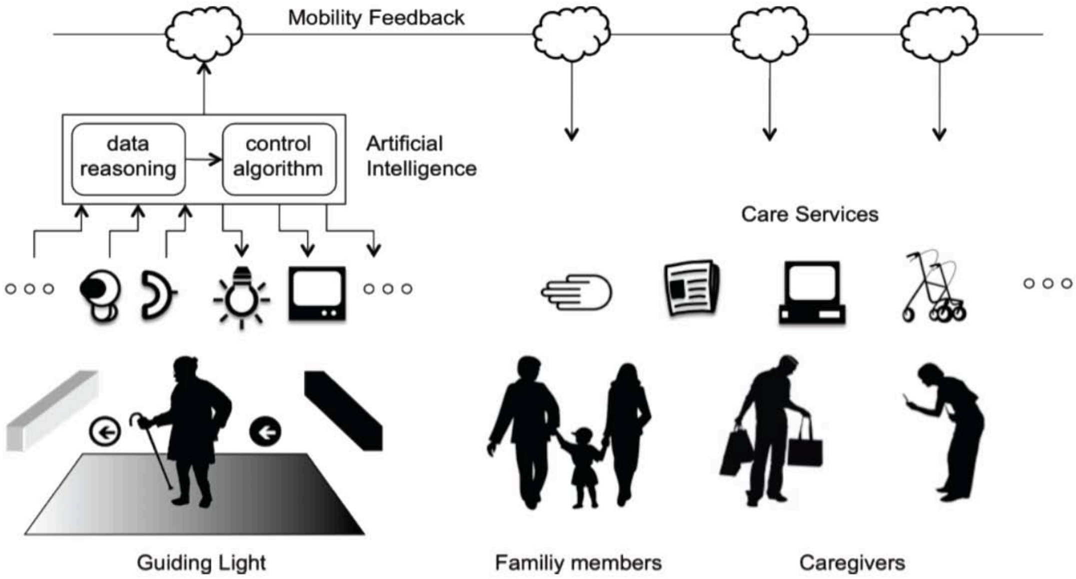


Fig. 7. General data flow within Guiding Light.

Some apartments will have a building management system with internal data server and some apartments will have no internal data server. The latter apartments will transfer their data to cloud server. On Guiding Light server we will aggregate data derived from different apartments with and without data server. Guiding Light server will provide all relevant data for Guiding Light applications designed for requirements of primary and secondary end users.

Data management is designed to run on MySQL server on the same machine as the web server for performance reasons. Communication to the system is done over secure https requests using the JSON data format. The advantages of JSON in contrast to XML based data exchange structures are the better efficiency (less overhead as no tags are used) and easier processing on the client side. Both of these advantages are especially beneficial in the mobile space.

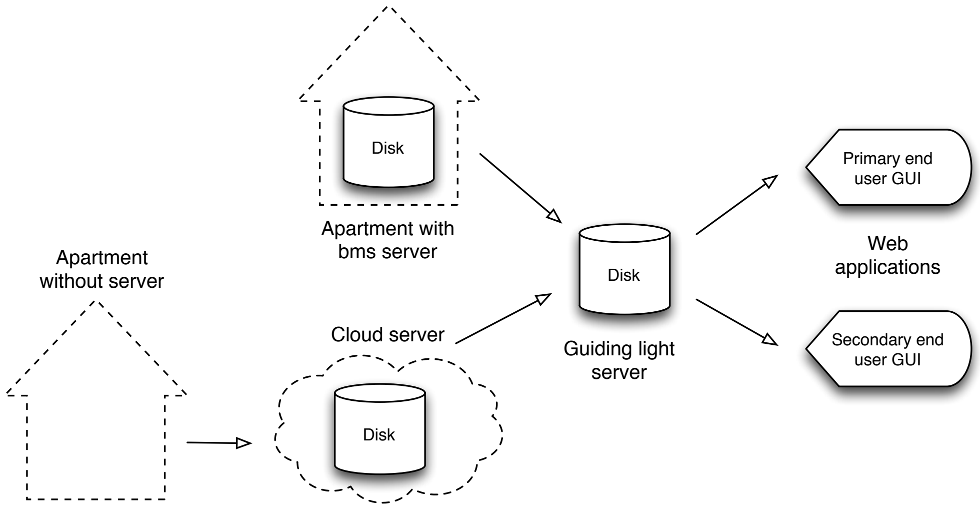


Fig. 8. Data management within Guiding Light.

Since we decided be follow a platform independent approach to run applications on Mac, Windows, iOS, Android or any other platform, we will develop web-apps on MVC (Model-View-Controller) architecture executable in an HTML5 compliant Web-browser (e.g. the latest versions of Firefox, IE, Chrome and Safari). Applications will be programmed in PHP, HTML5, CSS3 and JavaScript using Apache web-server and frameworks like Symfony PHP, jQuery and jqPlot in order to be easily maintainable and extendable.

4.2. Data structure

Basically, within an apartment we can select from a big set of sensors and it will depend on light wayguidance principles and cost factors, what kind of sensor information will be used for Guiding Light.

- presence sensor data (motion within room, pressure on furniture)
- entrance sensor data (door contact switches, uni- or bidirectional light barrier)
- position of doors and windows (door and window switches)
- indoor and outdoor brightness sensor data (light intensity)
- status of lightings (on/off, control parameters)
- manual use of light switches (on and off command)
- use of electrical devices (on/off)
- indoor and outdoor temperature
- indoor air quality (carbon dioxid, humidity)
- information about weather (sunlight duration, rain quantity, wind strength)
- electronic recording of the inhabitants vital data (e.g. blood pressure).

We decided to focus on presence sensor data using motion information, entrance sensor data, indoor brightness data, status of lightings, and manual use of switches. These data are required for main principles of Guiding Light system. However, Guiding Light should be able to include other sensor data mentioned above.

Furthermore, we have to prove whether information about weather (e.g. hours of sunshine per day) can be acquired from an external provider. It is important to document with which control parameters lightings are active because we will reprogramme light control curve signal on a regular basis.

Data are transferred by means of cable connections to a building management controller or by means of wireless connections to a building management gateway. Data are stored on different servers, depending on existing building management systems or existing technological conditions at test installations (see following figure).

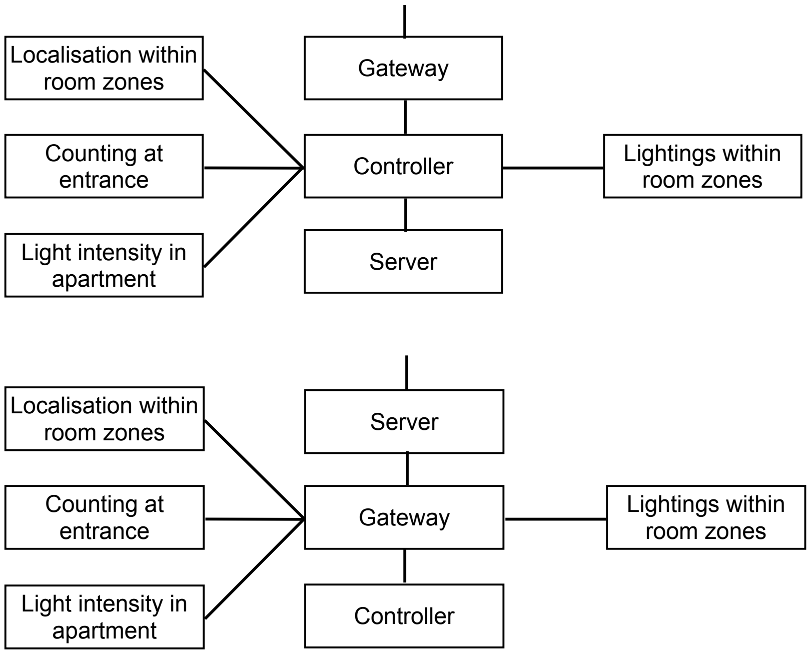


Fig. 9. Different data management approaches within Guiding Light

Lighting control systems typically provide the ability to automatically adjust a lighting device's output based on chronological time (time of day), occupancy (presence of persons), daylight availability (indoor light level), events or alarm conditions, and program logic. Typically, light control is scene-based and/or daylight-dependent and presence-dependent according to requirements of inhabitants.

There exist several control strategies. Scheduling is the strategy of tuning lights on or off according to need or program. Manual scheduling involves switching by building occupants, while automatic scheduling may include time switches, occupant sensors, photocell switches and other means of switching lights by automatic control devices. Scheduling can be implemented effectively with switching controls. Switching technology is inexpensive and do not require special expertise to install.

Dimming is reducing power to electric lights in accordance with the exact lighting needs of the inhabitants and their daily activities. Dimming is in general a more expensive daylighting control technology (when including the cost of dimming ballasts) in comparison to switching and is ideal in applications where occupants are engaged in small motion activities(sitting, reading, typing). In an old installation (where there are no dimming ballasts) switch is more appropriate even though the light changes caused are more abrupt.

We decided to use both strategies: switching and dimming. This includes timer programmed switching on and off lightings as well as switching on and off in relation to presence and indoor light level (see following figures). We will use dimming parameters from predefined 24 hours light control signal curve to provide different light intensity and light color temperature at different time of day.

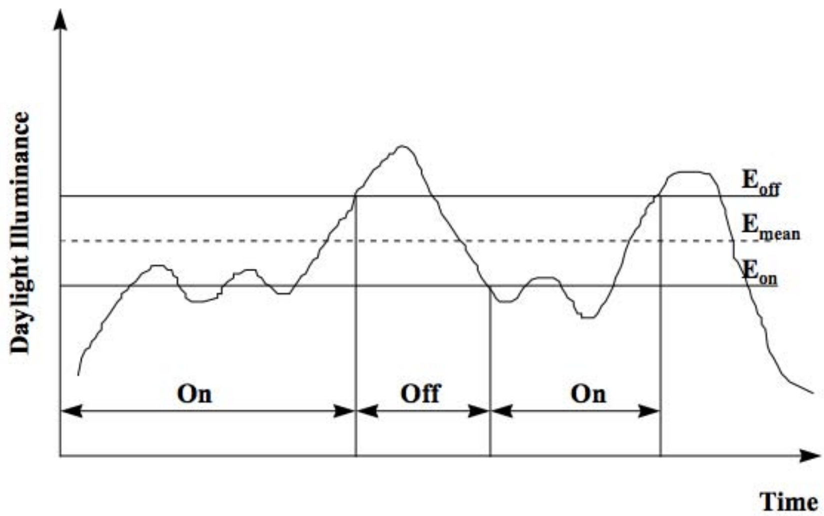


Fig. 10. Switching on and off light in relation to indoor light level.

For control strategy of Guiding Light we need information about dim levels of lightings (probably warm and cool light luminaires) for 24 hours a day, information about motion control and minimum light level (for switching light on and off in relation to presence and light level), and information about time control for automatically switching lights on and off according to a predefined time schedule.

Within the Guiding Light individual lighting assistance will be implemented by intelligent control loops in room automation, where results from continuous mobility monitoring are used for reprogramming 24 hours light control signal curves. For developing intelligent control algorithm we have to define input and output signal as well as methods for data reasoning and switching as well as dimming logic. Input signals will be mobility parameters such as amount of activity at specific time within indiviual and daily structures. Output parameters will be light intensity and light color temperatur of all lighting groups within an apartment. Switching and dimming logic will depend on selected methods for data reasoning. For this reason we will search for adequate methods from artificial intelligence area.

5. Different light control systems

5.1. Light management systems

With indoor light management systems one can schedule the light operations in any area within the building, or monitor occupancy patterns and adjust lighting schedule as required. The following figure shows the structure of a light management system with one controller, often a microcontroller that has some embedded control algorithm.

External devices, such as sensor to detect light level or occupancy and timing device for scheduling are connected to the controller. With user interfaces - a button, display or even a computer software - the user can interact with the system. The controller then sends signals to ballasts and actuators that control the lights. Often light management system is integrated in building automation.

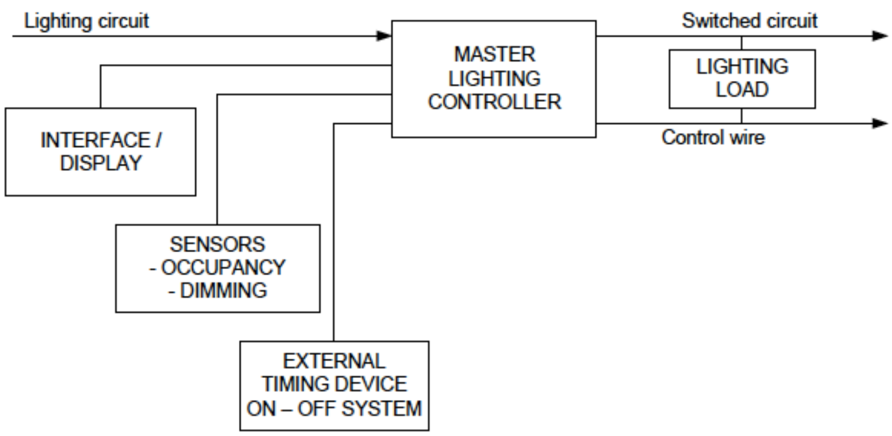


Fig. 11. Simplified illustration of a light management system.

For Guiding Light we need an open and highly flexible light management system, which enables the integration of different field bus systems like EIB/KNX, DALI, EnOcean, Beckhoff ADS, Ether-CAT, as well as data transmission via ZigBee, EnOcean, TCP/IP, and RS232 to a wide range of sensors and actuators.

It should be possible, that I/O-devices are combined with Central Processing Unit (CPU) in different modes. With a so called system-mode system should operate as client-server system with several peripheral computers. Development of Guiding Light monitoring and control algorithms is done in this mode. On the other side a so called easy-mode should not require a peripheral computer but monitoring and control algorithms should be pre-programmed and loaded with a default set of parameters on an embedded controller.

Finally, we should be able to develop customized extensions based on software development framework of light management system (e.g. DALI control interface) and to adapt features using an openly documented JSON-interface for handling and visualization applications.

We analyzed several commercial light management systems and found at least two systems which fulfill all our requirements: Litenet from Zumtobel and next.manager from AutomationNext. The following figures show the general topology of both systems.

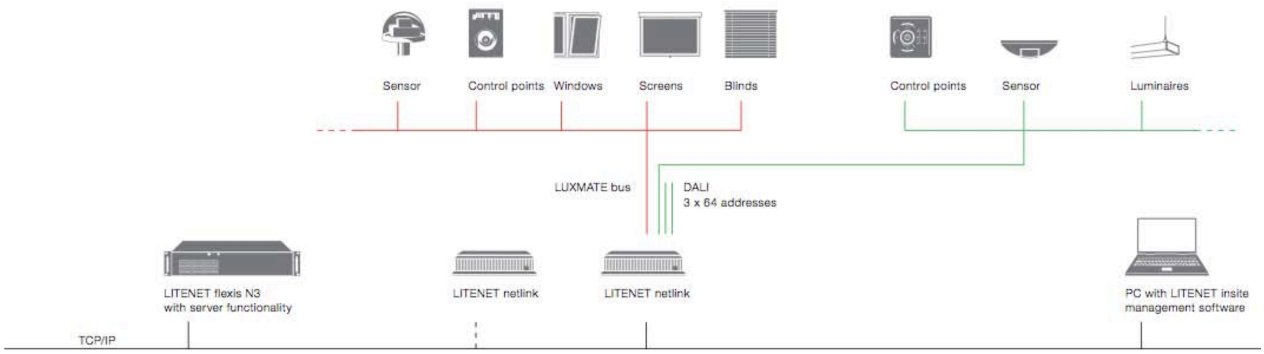


Fig. 12. Light management system from Zumtobel (www.zumtobel.com).

The Zumtobel control system is based on a field bus supporting free topology wiring, which ensures that future expansions or adjustments of the system can be made in an easy and cost-effective manner. All luminaires are individually controlled using a digital DALI signal or Luxmate bus, the scope ranging from a minimum level of 1-3% to 100%. All control modules feature the service of monitored outputs for localising malfunctions.

The AutomationNext control system integrates a wide variety of building automation devices and systems, consolidating these into one unified and easy-to-use platform. The next.bms provides a centralized configuration and visualization with easy operability and which undertakes the system-wide automation in conjunction with several next.controller/pro systems. The hardware independent next.manager controls the configuration and administration of all connected next.controller/pro systems.

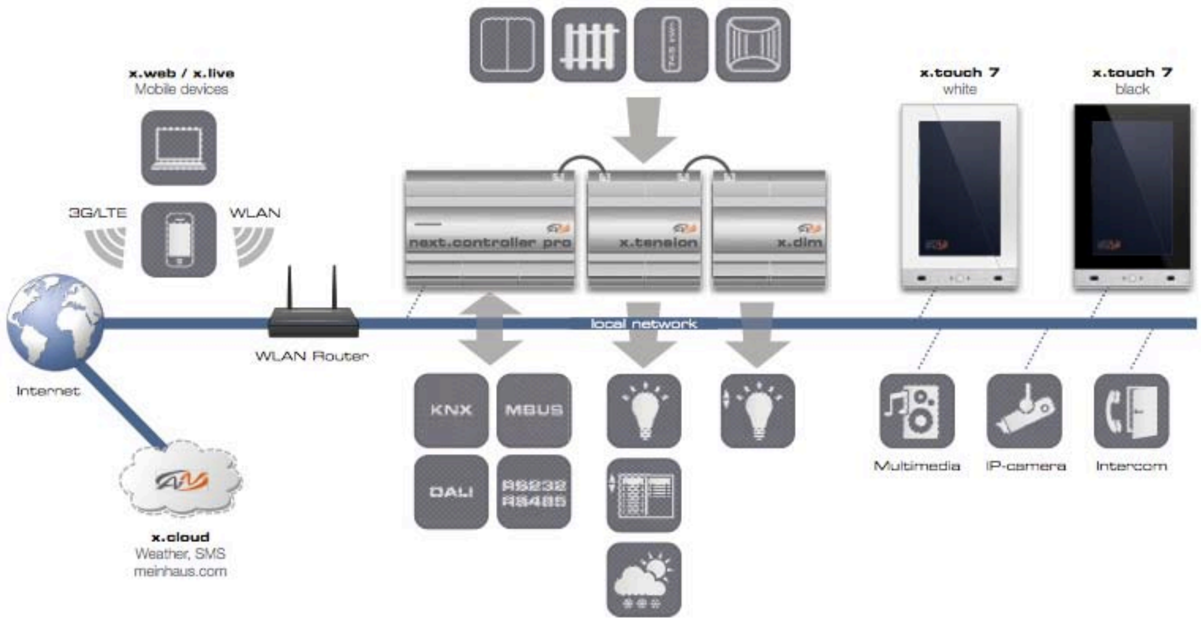


Fig. 13. Light management system integrated in building automation (www.automationnext.com).

We decided for primarily use of light management system from AutomationNext, because this system is open for further sensors and actuators which are not restricted to light management. This scaling might be necessary, if we will expand the function of our intelligent control algorithm to other stimuli such as HVAC, sound etc. FHV has installed a test equipment in his laboratories and has already developed some plugins for this system.

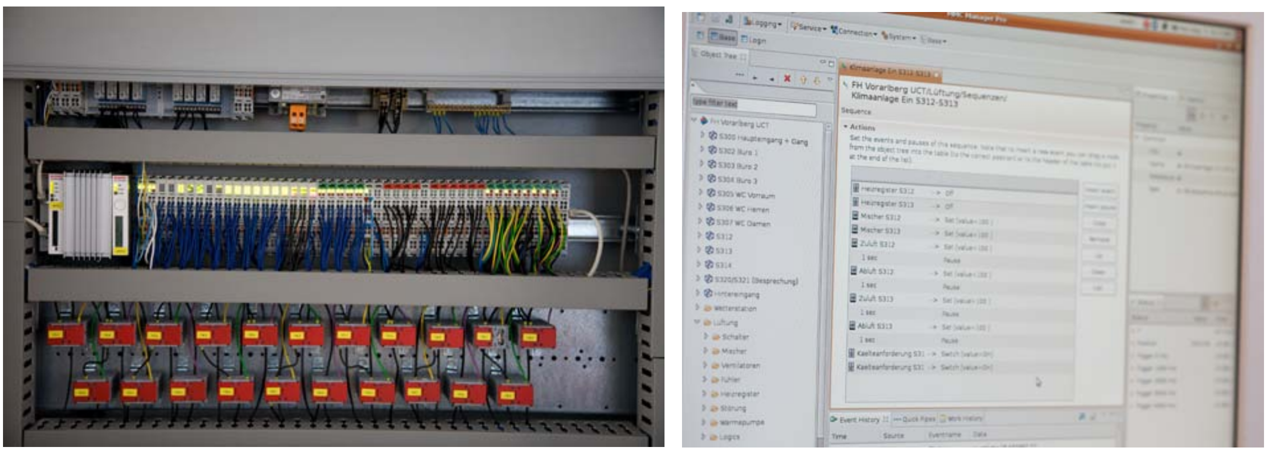


Fig. 14. Building management system as developing framework at laboratories of FHV.

5.2. Light bus protocols

Concerning light management protocol we are analysing DALI, 1..10V, DMX, and EnOcean. One main decision criteria are the cost factors.

DALI (Digital Addressable Lighting Interface) is a non-proprietary interface standard for dimmable electronic control gears, offering greater functionality and greater ease of use. A maximum of 64 DALI ECGs can be controlled with a high degree of flexibility via a two-wire control line individually or in Broadcast mode and in up to 16 groups.
Switching and dimming are handled via the control line. There is no need for a relay. Important information such as the lamp status is stored in the control gear and is available to the controller.

1..10V interface controls lighting via an interference-proof dc voltage signal of 10V (maximum brightness; control line open) to 1 V (minimum brightness; control line short-circuited). The control power is generated by the ECG (maximum current 0.6 mA per ECG) The voltage on the control line is isolated from the power cable but is not at safety extra-low voltage (SELV). ECGs connected to different phases can be dimmed via the same controller. Modern dimmable ECGs with 1...10 V interfaces in combination with the appropriate controllers and sensors provide the basis for simple and cost-effective lighting systems. Control gear and controllers are connected to one another via a pooled two-wire control line.

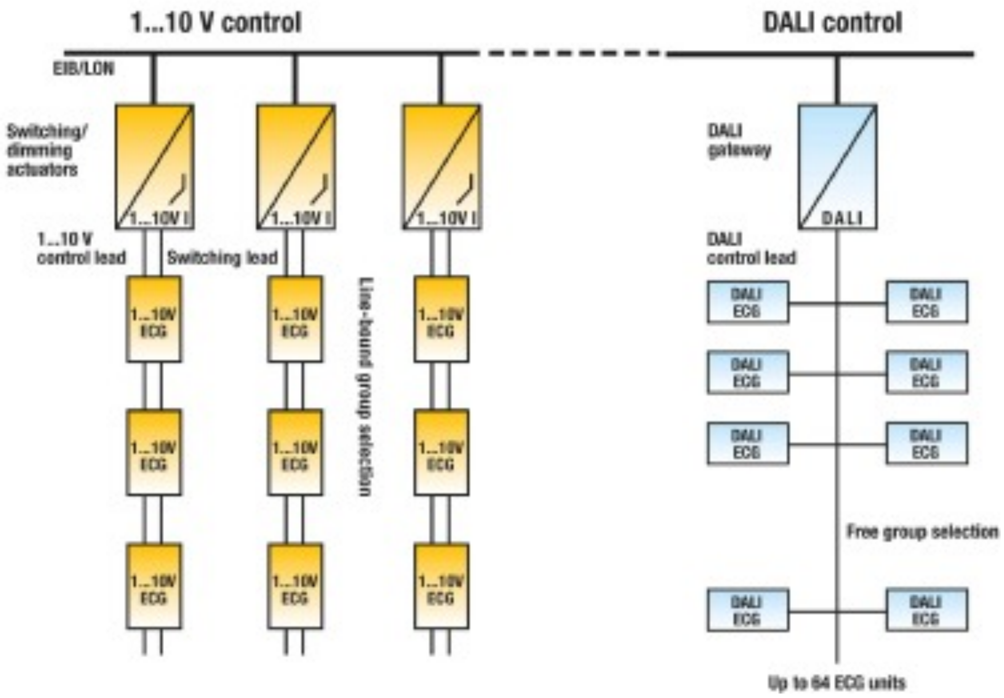


Fig. 15. Comparison of 1..10V and DALI topology (Source: Osram).

DMX stands for “Digital Multiplex” and is a digital communication protocol for lighting control. DMX is capable of controlling up to 512 lighting channels simultaneously. The data rate is an impressive 250 kilobytes per second. This means that it can handle scenarios in which a large number of RGB light points and dynamic high-speed color changes are needed with excellent results. Compared with conventional lighting control systems, DMX is therefore the first-choice technology for such challenging applications.

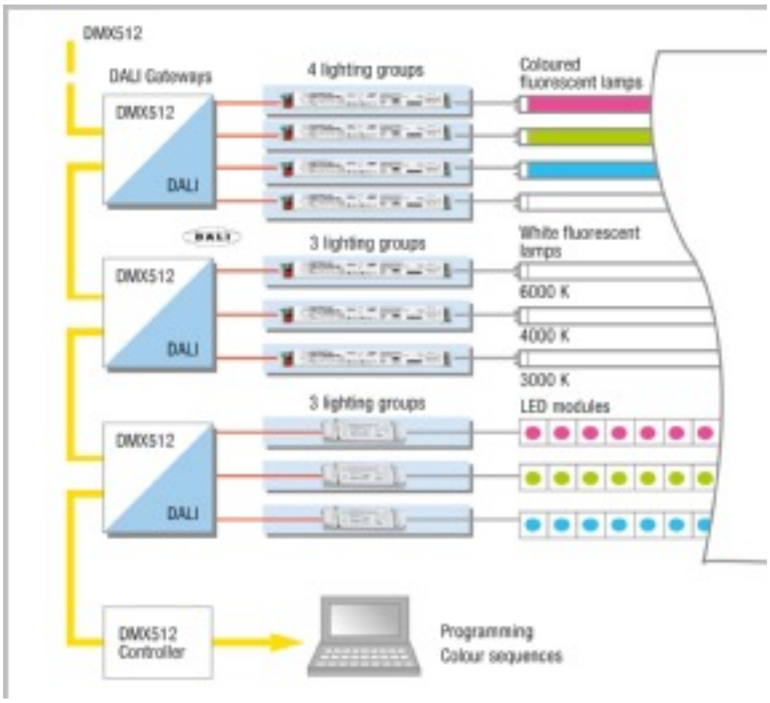


Fig. 16. Integration of DMX in a lighting installation (Source: Osram).

Finally, EnOcean is batteryless radio technology. The sensors take their energy from their immediate surroundings – tiny changes in movement, pressure, light, temperature or vibration are enough to transmit radio signals. The maximum range of the signals is 30 meters in buildings and 300 meters outdoors. EnOcean transmits the signals on the license-free 868 MHz frequency band.

We decided to use DALI protocol and EnOcean protocol for controlling lightings within the Guiding Light system.

6. Mobility monitoring

6.1. Comparing body worn sensors with room sensors

We conducted a pre-study in order to analyze advantages and disadvantages of manually mobility data recording, automatic data management, and ambient mobility monitoring. The latter approach combines unobtrusive data recording and automatic data management.

Initially test persons monitored their activity parameters with body worn sensors for which they had to document the recorded data manually by their own. In this case, data recording and data documentation was performed only sporadic by test persons. There were time intervals where they intensively used activity monitoring but there were also long time intervals where did no data recording or data documentation.

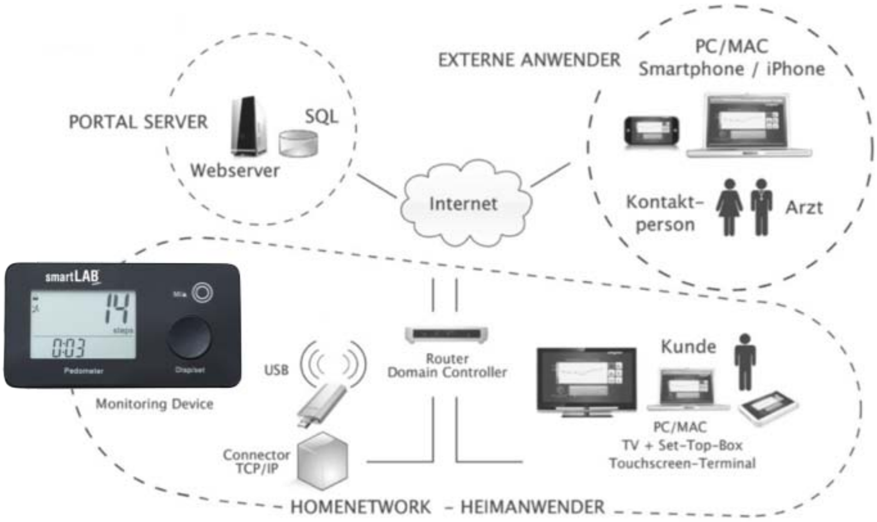


Fig. 17. Data flow for automatic data management.

Data quality became better with introducing an automatic data management. Test persons received new measuring devices (smartLAB-walk), which are automatically transferring measured data to a gateway inside the apartment via ZigBee. Test person used this body worn measuring device for activity monitoring differently (see ACCEL data lines and bar charts in the following figure). While one person used monitoring device almost each day during a week, another person used monitoring device very sporadic. During this test phase we had some problems with radio transmission for automatic data management.

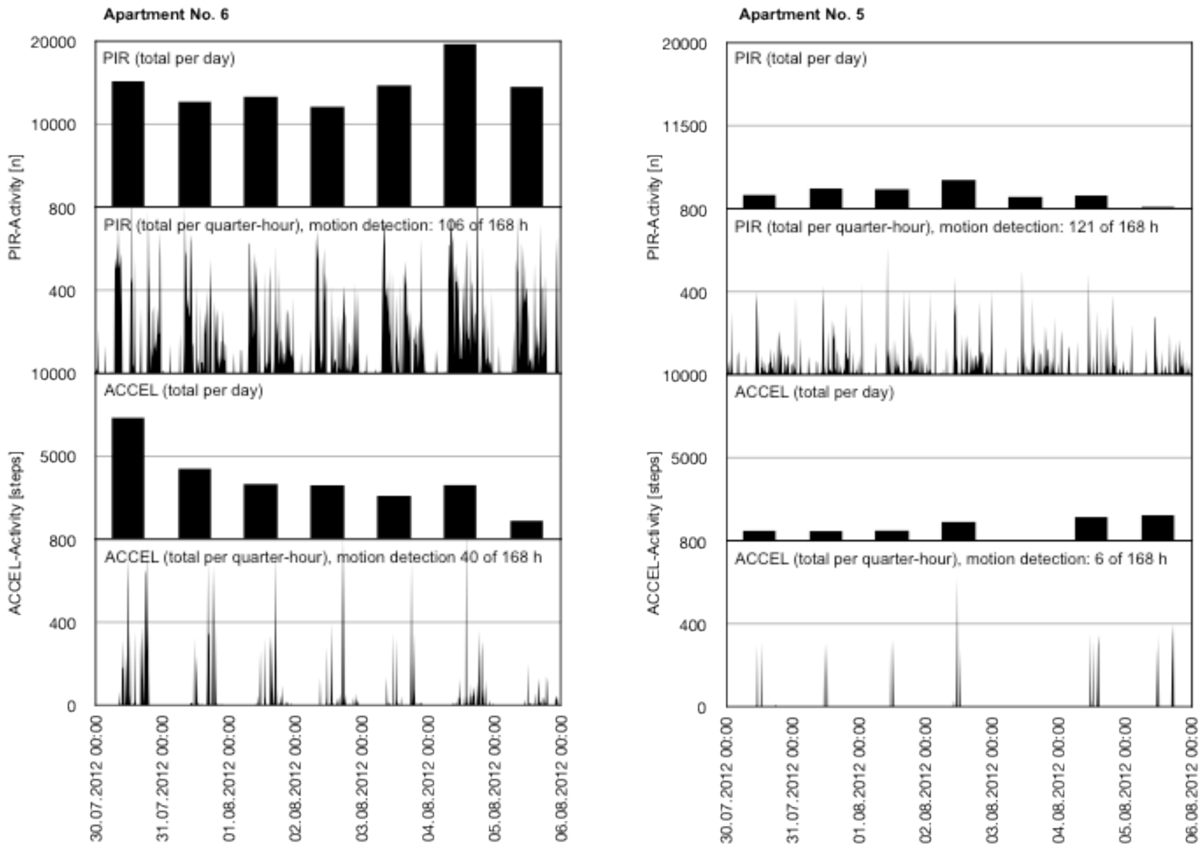


Fig. 18. Comparison of data form body worn sensors (ACCEL) and room sensors (PIR) for detecting motion/activity.

During the test phase where test person used body worn sensors, we also used embedded room sensors (Merten KNX Argus PIR-sensors) within the apartment of test persons for activity monitoring. In both cases recorded data were documented automatically. If we compare data form both systems in the figure above, we can see big differences in data quality. For 168 hours of observation time we received information about 106 hours respectively 121 hours with rooms sensors (that is 68 % of observation time). With body worn sensors we received only information about 40 hours respectively 6 hours (that is 14 % of observation time). This is why we decided to use embedded room sensors for mobility monitoring within our project.

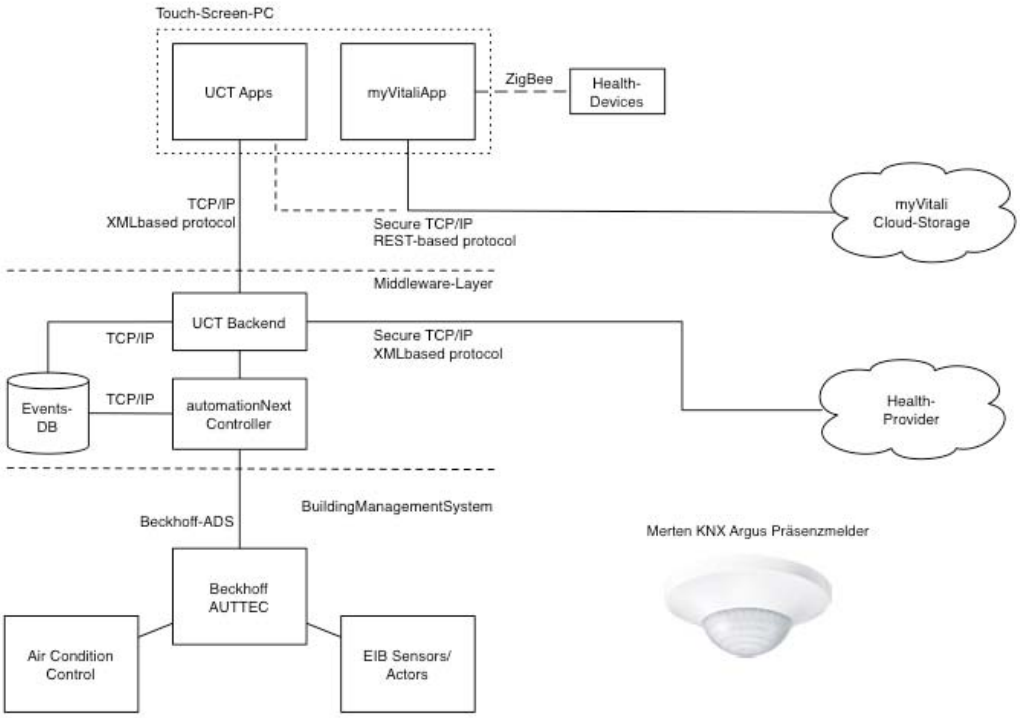


Fig. 19. Data flow for ambient mobility monitoring.

The use of sensors in buildings should be possible with normal techniques and at relatively low cost. In our example each room consists of a motion detector with a detection angle of 360°. The 360° detection angle is divided into four sectors with independent passive infrared sensors for each sector. The sectors are 90° each and can be parameterized individually. For each movement sensor the range, timing, and the sensitivity can be set for each block via parameters.

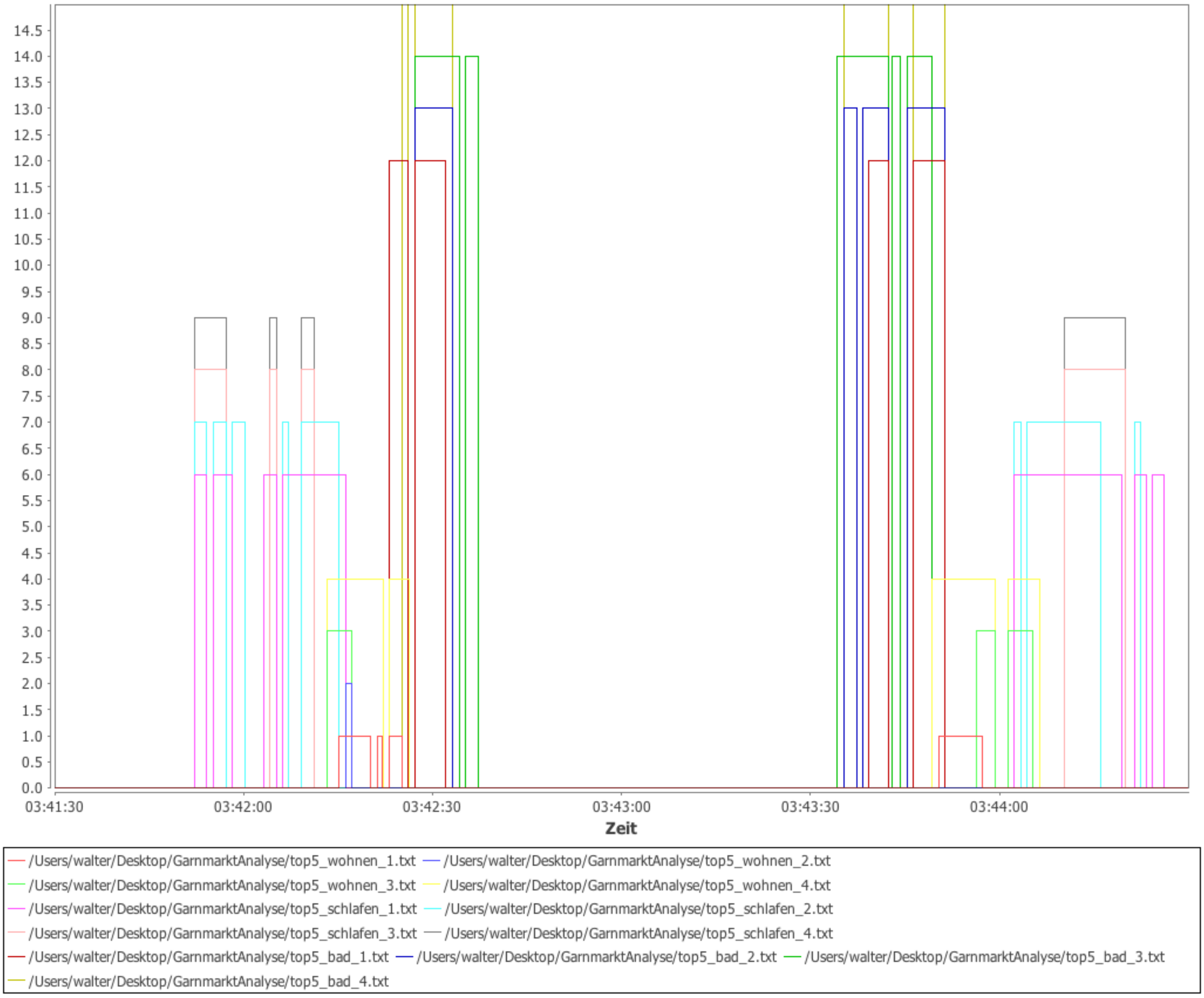


Fig. 20. Mobility data from four sectors of a single PIR-sensor.

The following figure shows motion patterns for one week in three different rooms of senior's flat (all four sectors per room) and corresponding overall activity measures per day/night on the top. Activity measures for day and night result from aggregation of all sectors of motion sensors in living room, sleeping room, and bathroom/toilet room of older persons within relevant time period. Night time period has be defined starting at 10 o`clock p.m. and ending at 5 o`clock a.m., following by day time period up to 10 o`clock p.m. The first person (apartment no. 5) has been diagnosed with temporal disorientation (following Mini-Mental-State Examination). The second person (apartment no. 6) shows normal spatio-temporal orientation. According to this diagnosis the overall mobility profile of the first person shows less overall intensity and more night activity in relation to day activity than the second person. Second person shows well structured history in activity in sleeping room with highest motion intensity in the morning.

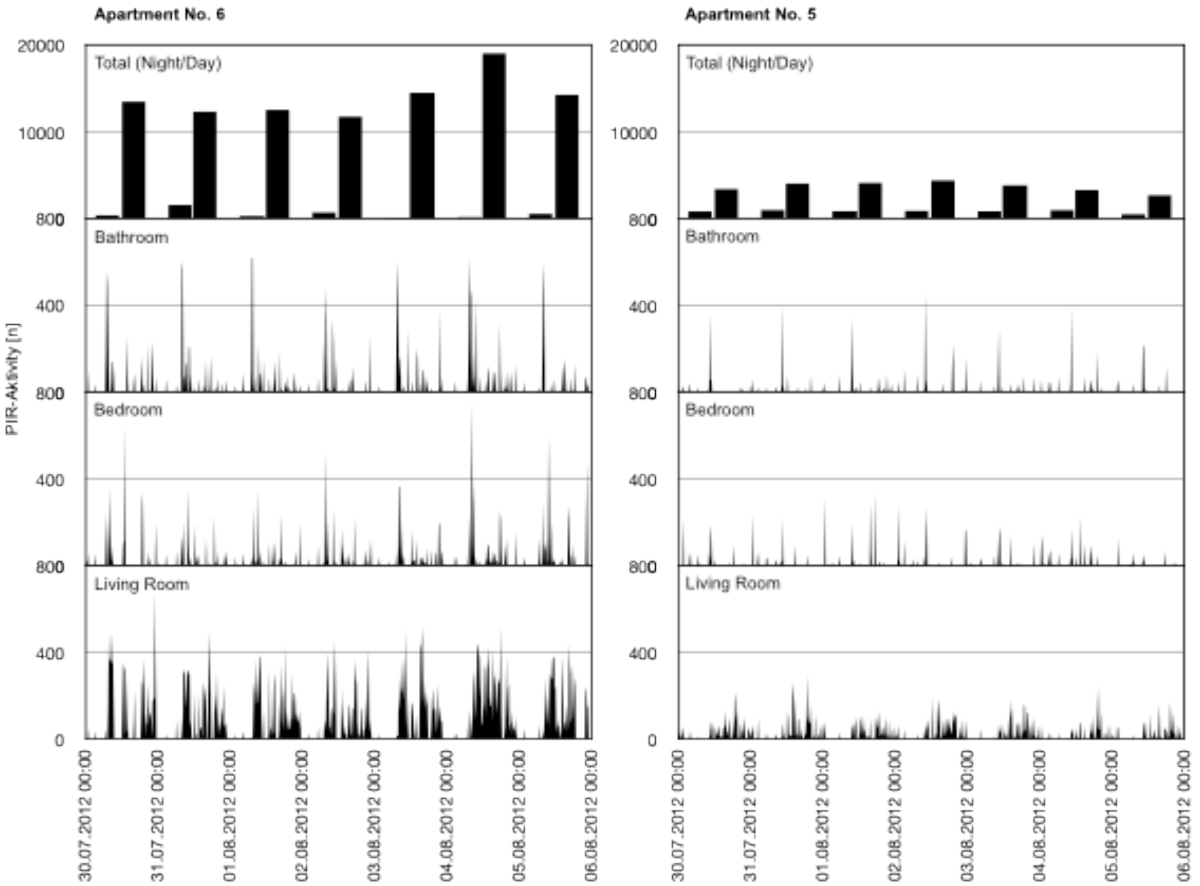


Fig. 21. Motion patterns of two seniors for one week in three different rooms of their flats and corresponding activity measures per day/night.

Both persons spend, however, nearly the same time of day inside their apartment. Additional mobility monitoring is performed in the form of trend analysis, pattern discovery, and association rules which is applied to data obtained from unobtrusive sensors to capture comprehensive information about what, where and when residents are performing different activities of daily living. Results from continuous monitoring are used for intelligent light control system and to derive certain measured values of individual mobility (e.g. general motility, dynamics of body movement, and distances in indoor as well as outdoor locomotion).

6.2. Calculating activity from PIR sensors

In our context activity concerns to body motion. Normally, PIR sensor signal is set to "true" immediately after detecting body motion, and is set to "false", if no body motion ist detected for one second. There are different algorithms for handling these PIR sensor data. Assuming a room zone with three sectors respectively three PIR sensors and four measurement time points the PIR sensors might be triggered differently at each measurement time point. Let us assume triggering sector 1 and sector 2 at t1, sector 1 to sector 3 at t2, sector 2 at t3 and not triggering at t1. Now we can describe these tiggerings with different activity patterns. In variant A it is the sum of triggerings for each measurement time point. In variant B the sum of triggerings for each measurement time point divided by the number of triggerings. In variant C we identify activity with value "1", if there is any triggering within the three sectors of a measurement time point

Variant A	t1	t2	t3	t4	Amount	Mean
Sector 1	x	x				
Sector 2	x	x	x			
Sector 3		x				
Result	**2**	**3**	**1**	**0**	**6**	**1,5**

Variant B	t1	t2	t3	t4	Amount	Mean
Sector 1	x	x				
Sector 2	x	x	x			
Sector 3		x				
Result	**2/3**	**3/3**	**1/3**	**0**	**2**	**0,5**

Variant C	t1	t2	t3	t4	Amount	Mean
Sector 1	x	x				
Sector 2	x	x	x			
Sector 3		x				
Result	**1**	**1**	**1**	**0**	**3**	**0,75**

Fig. 22. Different variants of single PIR sensor triggerings.

Summarizing single PIR sensor triggerings might be performed again in two different ways. First, all PIR sensor triggerings can be summed for a specified observation period, building an amount value of triggerings. This variant is like counting movements detected within a observation period. If no movement is detected within a time sampling interval of one second, this is ignored by this kind of parametrisation.

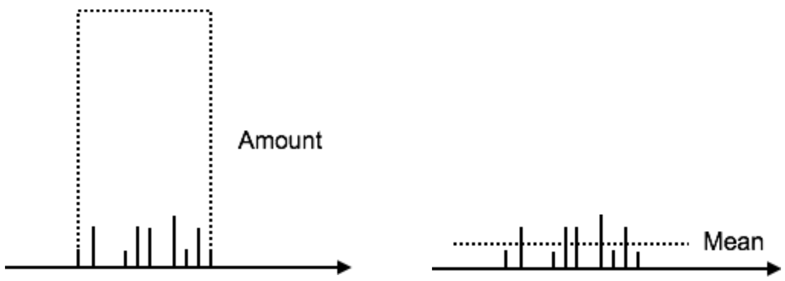


Fig. 23. Different variants of summarizing single PIR sensor triggerings.

Second, we can calculate a mean value of all triggerings per time sample interval within an observation period. If no movement is detected within a time sampling interval of one second, this is taken into consideration by this kind of parametrisation. By comparing the results of amount value and mean value for all three variants described in figure 22, we see relevant differences in the result.

We found, that amount value of variant 3 is the best kind of activity parametrisation. This is, why room zones may have different numbers of PIR sensors respectively sectors (preferably variant 2 and variant 3) and why higher number of triggerings does not mean more activity without fail, since a person may trigger more than one PIR sensor with one single movement (preferably variant3).

6.3. Primary enduser GUI for mobility monitoring

For Guiding Light we will give feedback about individual activity resp. mobility to end users. For this purpose we have to develop an easy to use and easy to understand software application that automatically receive information from respective sensors and visualizes the results from data analysis. In order to make a decision for possible software development we searched for commercial applications, which are available for activity monitoring. There are a lot of such applications available. Some ideas, how our application might look like are shown by means of some examples in the following figures.

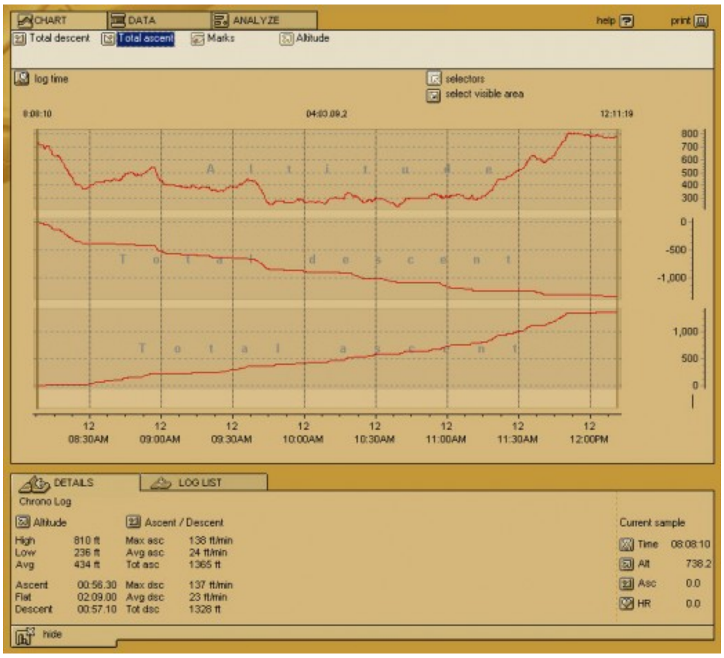


Fig. 24. Activity monitoring from Suunto (www.suunto.com).

Fig. 25. Actigraphy application from Actigraph (http://www.actigraphcorp.com).

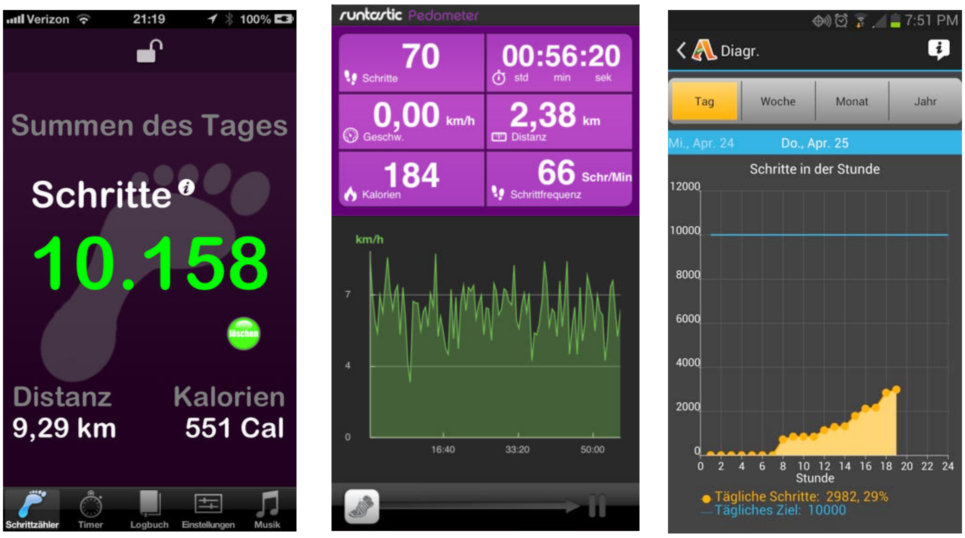


Fig. 26. Different activity monitoring applications for iPhone.

The commercial applications we found show very complicated representations of different activity parameters. This might be too complicated for older persons as end users. Therefore, we decided to develop an application with an easy to use and easy to understand information visualization for primary end users only showing a single overall parameter of mobility for freely selectable time intervals.

6.4. Alternative concepts of motion data analysis

If we look on signals from passive infrared motion/presence sensors (PIR-sensors) within an apartment for several days, we can see that more than one sensor indicates presence at the same time. However, this is not surprising, because a person can stay at different room zones at the same time of day but at different days. The following figure shows that a person may stay during the time interval between 10 a.m. and 15 p.m. in the bathing room, the sleeping room or the living room. At low temporal and spatial solution of monitoring it seems, that the probability to be present in a two different rooms at the same may be nearly the same.

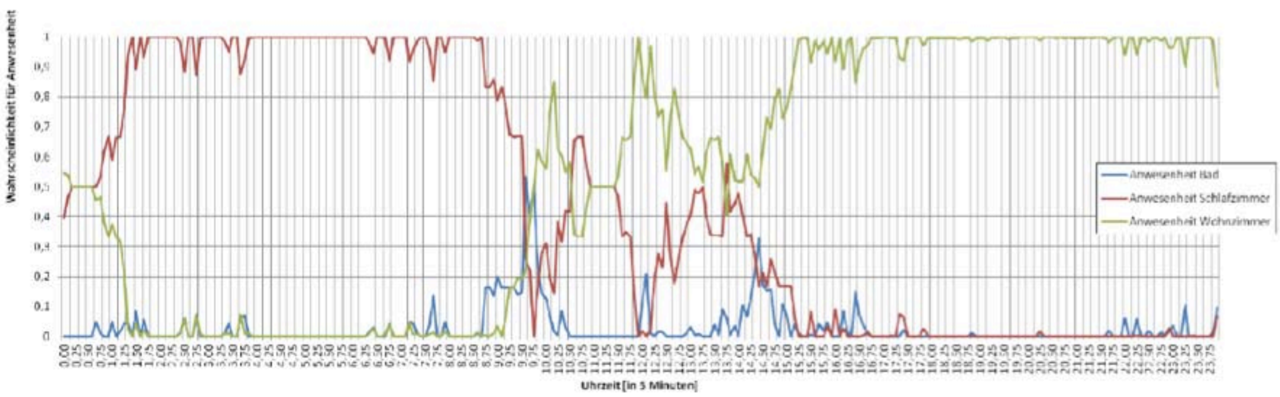


Fig. 27. Signals from three different motion sensors within an apartment.

Furthermore, we will receive motion or presence information from more than one sensor at the same time because the sensitive range of PIR-sensors might overlap each other. This might be problematic, if we want to refer activity of a person to specific room zones. In this case, we will check solutions to restrict the sensitive range of a motion sensor.

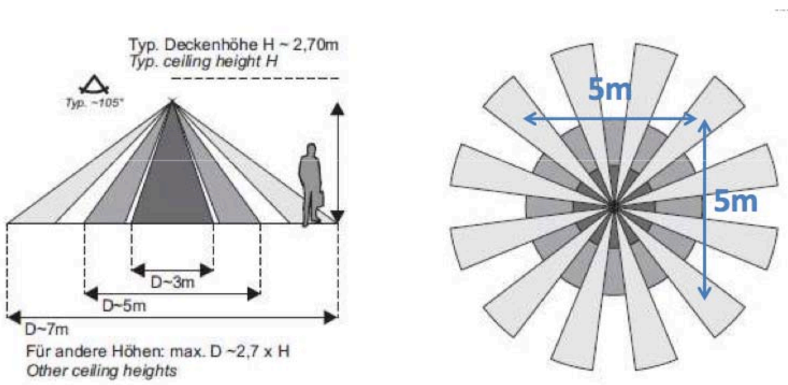


Fig. 28. Restricting sensitive range of a motion sensor.

In some cases we can use information about overlapping sensitive range of a motion sensor in order to define more room zones than PIR-sensors installed within an apartment. The following figure shows overlapping and non-overlapping zones. If we combine information from all sensors, we are able to detect presence within 13 different room zones.

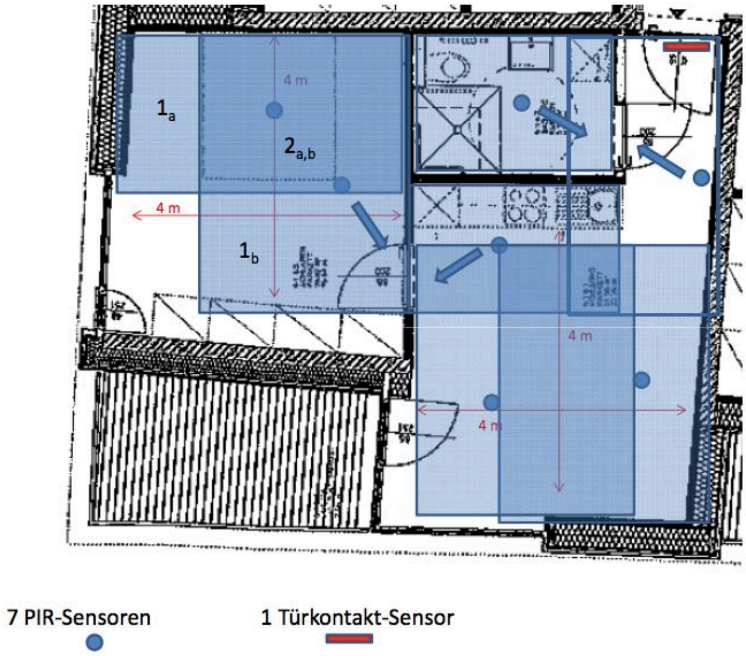


Fig. 29. Interpretative logic of overlapping sensitive range of a motion sensor.

7. Daily structure monitoring

7.1. Relevance of daily structures

The harmonised European time use survey shows that people normally have a well established daily structure because they are engaged in several activities during specific times of a day (see following figure).

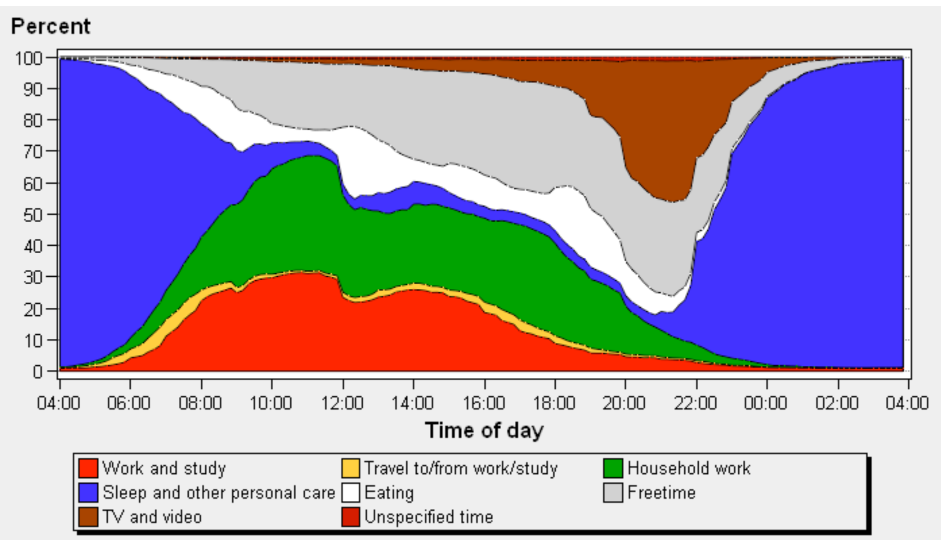


Fig. 30. Results from Harmonised European time use survey (Eurostat, 2007).

Many older persons have problems in structuring their daily life. They only get up at noon, spend a lot of time in front of the television or on the computer, and meet friends or family members less frequently than in the past. In this manner, one easily allows the entire day to pass by without accomplishing or achieving anything. For some who are affected, this leads them long-term to hardly leaving the house at all, and to having fewer and fewer social relationships. Loss in daily structure at an advanced age often leads to relocation into assisted living facilities (Schäper et al., 2010). Day-structuring measures are highly significant interventions within care activity for older people (Greving & Remke, 2012).

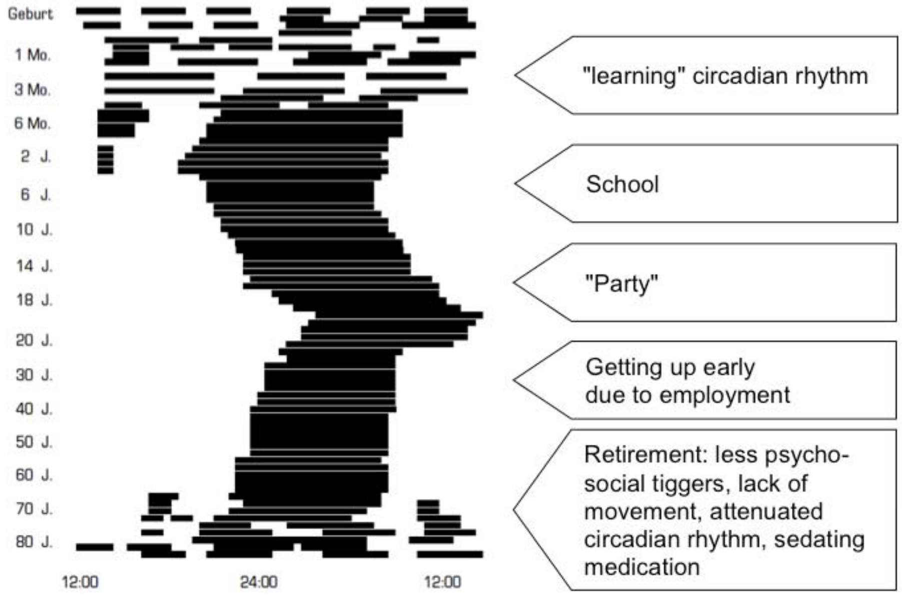


Fig. 31. Age dependent time of inactivity during a day (prototypical view from Staedt & Riemann, 2007).

7.2. Approaches for data analysis

Improving mobility of older persons by means of Guiding Light also includes a better structuring of activities of daily living within ageing population. To see if we could deduce daily structure parameters from the logged data, we evaluated data collected from PIR-sensors over a period of six month. The following figure shows a daily activity profile of four PIR-sectors in the living room on sundays averaged over 6 month. The x-axis shows the time whereas the y-axis the number of individual activations in a sector per 15 minutes time slot. One can clearly see the lack of activity from 11:45 to 12:15 hinting at a lunch break.

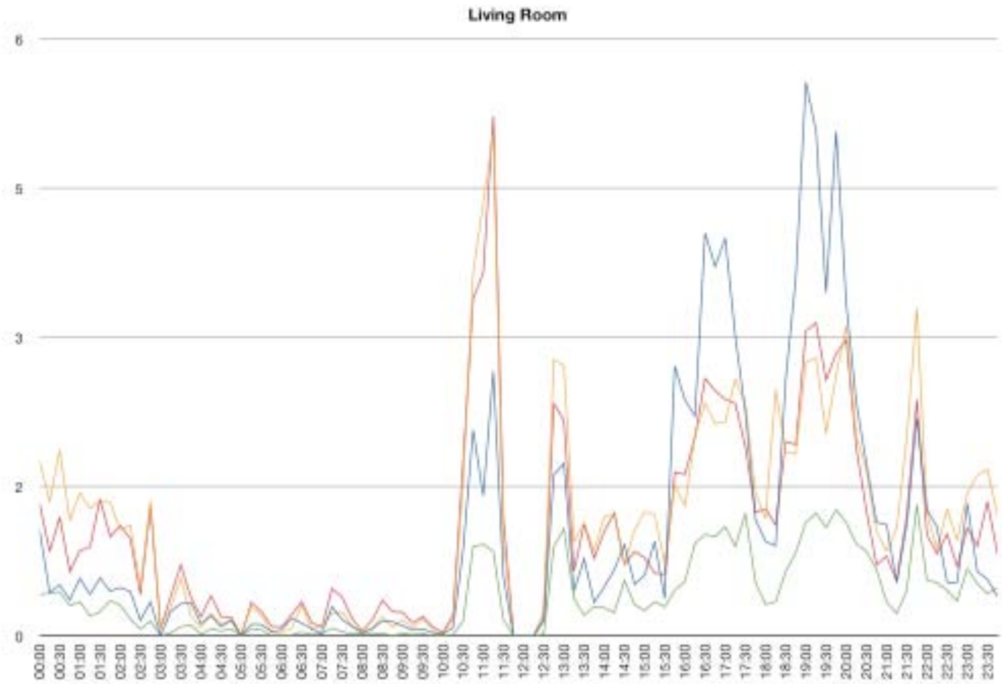


Fig. 32. Activity profile of the 4 PIR-sectors in living room for sundays averaged over 6 month.

The following figure shows a daily activity profile for two typical days for one apartment. The maximum activity distribution in the separate sectors of the apartment indicate different daily actions on weekends (left side) and weekdays (right side). The x-axis shows the time whereas the y-axis shows the sector-number. Data for this chart has been aggregated over a period of 6 month.

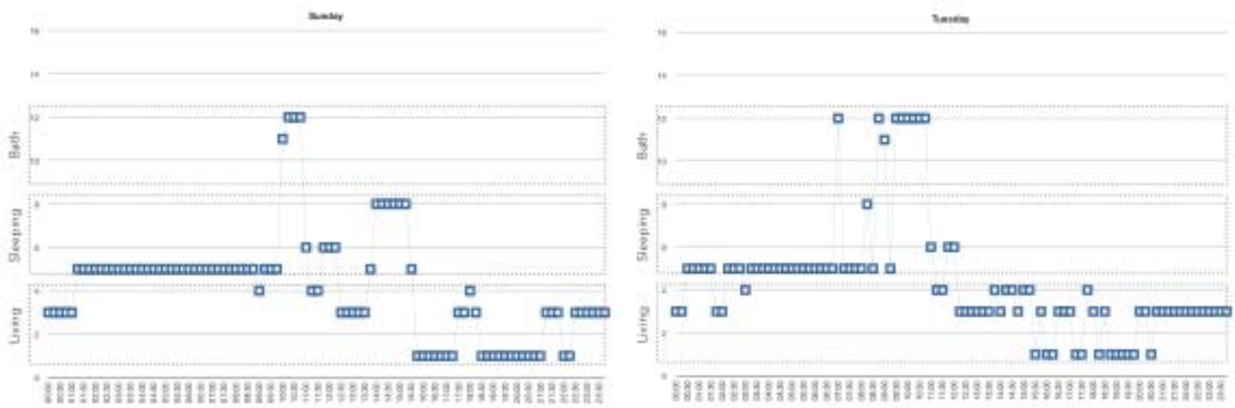


Fig. 33. PIR sector with maximum activity in a time slot of 15 minutes. A comparison between a typical Sunday and Tuesday (averaged over 6 months) show a shift in sleep time by have an hour earlier during weekdays.

Another interesting question was if there would be some detectable change within the daily activity profile between summer- and winter-months, as this is especially relevant in an application using light. The following figure shows a shift in sleep/wake times during two summer months and two winter months, meaning this system can in fact be used for detecting changes to the daily structure of a person, without the need for the person to wear or maintain any sensors at all.

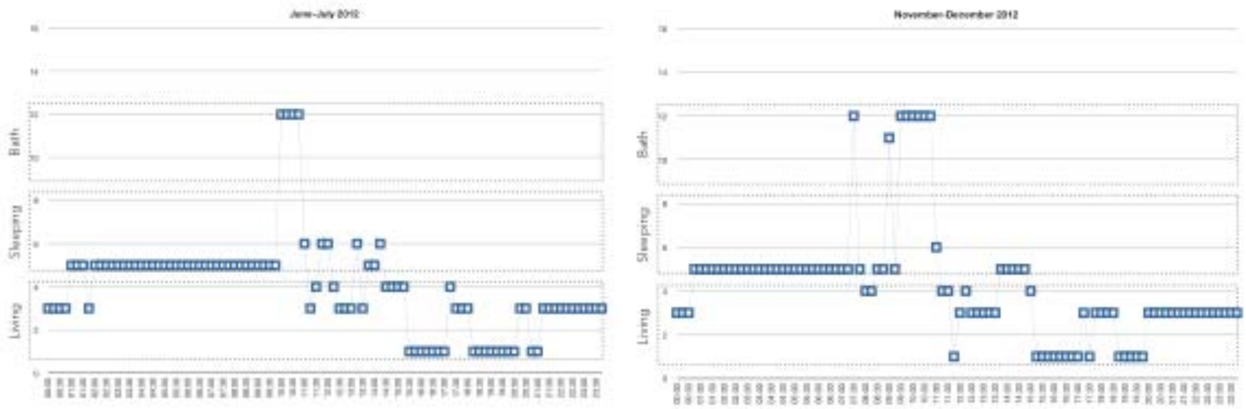


Fig. 34. PIR-sector with maximum activity in a time slot of 15 minutes. A comparison between summer and winter periods shows a shift of sleep-time by 15-30 minutes earlier in winter.

If we compare the likelihood of presence within sleeping room for two persons, we can detect important individual differences. We can illustrate this in the following figure, where this likelihood is showed for two persons and for one week observation time. While person one shows a clear circadian rhythm, the sleeping time of person 2 is displaced and shows no clear wakeup time in the morning. Furthermore, person 2 might sleep some times in the afternoon too.

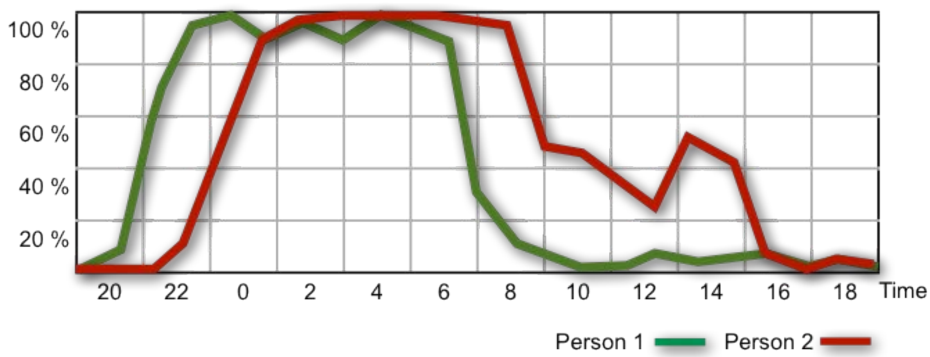


Fig. 35. Likelihood of presence within sleeping room (one week).

If we look at the sensor sector data within an apartment of a person for six month, we can see a clear daily structure, independently from the differences of week day and seasons mentioned above. The green areas show the time intervalls where inhabitants normally stay within this area of a room.

Time	PIR zones	p
0	W3	21 %
1	S2	15 %
2	S1	18 %
3	S1	20 %
4	S1	19 %
5	S1	22 %
6	S1	21 %
7	S1	19 %
8	S1	15 %
9	B4	13 %
10	B4	16 %
11	W3	13 %
12	W3	27 %
13	W3	21 %
14	S1	13 %
15	W1	16 %
16	W1	21 %
17	W1	21 %
18	W3	24 %
19	W1	32 %
20	W1	28 %
21	W3	34 %
22	W3	35 %
23	W3	31 %

Fig. 36. June to December 2012 - room zones with most frequent PIR triggerings per hour.

Among the parameters that can be deduced from activity data we recorded in this field study are sleep-/wake times (indicator of circadian rhythm), the time at which various sectors of an apartment feature the most presence (and therefore might be candidates for special light treatments), nightly actions like visiting the toilet or getting something from the kitchen, or the time at which a participant leaves the apartment or comes back (e.g. for getting lunch), and many more.

Despite these promising results, there are two obvious major drawbacks of PIR-sensor based approach: First, it’s only suitable for single person households without pets. Any additional heat-sources would cause additional actuations not related to the main person’s actions. In our case, one workaround for this could be to automatically track situations where more than one person is present (e.g. by light barriers that allow for people counting at the entrance, or by observing other room parameters like CO2 levels) and exclude those from data evaluation.

Second, activity that’s happening outside the apartment that might have a big effect on a person’s health state cannot be tracked in this way. One way to overcome this issue would be to have optional wearable accelerometers that could deliver additional input when worn, but with the core system remaining still functional without them. In the Guiding Light project, we intend to use both solutions to these two drawbacks mentioned here.

Our pre-studies show, that we are able to detect individual daily structure within private residence by implementing standard passive infrared (PIR) presence sensors within rooms. Knowing about the individual daily structure of a person we are able to install a room lighting system, which follows the individual needs of an inhabitant. In the next phase we are able to discover whether our zonal and ambient lighting installation can help strengthening individual daily structure or is able to change structure of daily routines if required. Within our project we will evaluate whether these assumptions are valid in practice.

7.3. Calculating presence from PIR sensors

In our context presence corresponds with the statement that a person either stays in different room zones or outside of the apartment. For presence detection we will use commercial PIR sensors within our project. PIR sensors are primarily built for detecting presence of people within a well defined area of space. Normally, PIR sensors are used for switching light on in case of presence. Nearly any area where people only occasionally walk or move through and which is not required to be continuously lit, could benefit from the installation of a PIR sensor. But this is not the one and only use case for PIR sensors.

All PIR sensors detect changes in infra-red radiation, in the form of heat emitted by a number of bodies including people. In a standard use case each relevant room zone is constantly monitored by one or more PIR sensors. When a person (or other heat source) enters such a zone, the level of infra-red radiation in that zone increases. This change is detected and processed by the sensor, switching on, for example, the connected lighting and starting the in-built ‘timeout’ process. Providing the heat source (presence of a person) continues to move in detection zone, the PIR sensor will keep processing the changes in infra-red radiation and the lighting, in this case, will stay on. If a person stands still in the field of view or moves out of the detection area, the sensor will not detect any changes in infra-red radiation between the zones and the lights will go out after the “‘timeout“ period is complete.

Basically, we decided to localize presence of persons in those room zones where PIR-sensors are triggered by body motion. In some cases, however, this interpretation of presence is not correct because PIR-sensor does not send a presence telegram if a person stands still in the field of view for a prolonged period of time. Therefore we have to implement an extended logic for presence detection. This logic could be that, for example, within sleeping zone respective PIR senor(s) are triggered at the moment t1 but with no more triggerings until t130. In this case we will assume presence of person within sleeping zone for t1 to t130. It might be irrelevant if a sensor from another room zone than sleeping zone is triggered at t130 (normally again PIR sensor form sleeping zone will be triggered).

We will apply this logic to PIR sensors of all other room zones (e.g. at t1there might be a PIR sensor trigger within kitchen zone and at t130 t1there might be a PIR sensor trigger within living zone) but only in such cases where an additional logic for data analysis does not indicate that occupant is staying outside of the apartment. For the latter logic, a door contact and two motion detector sections are used: the door-contact attached to the entrance-door into the apartment, a motion-detector located near the entrance area, and all other motion-detectors from the apartment grouped together. This logic in the discrimination of whether there is just no movement inside an apartment or if there are actually no persons present. The internal logic of this node is implemented using a simple state machine (see next figure).

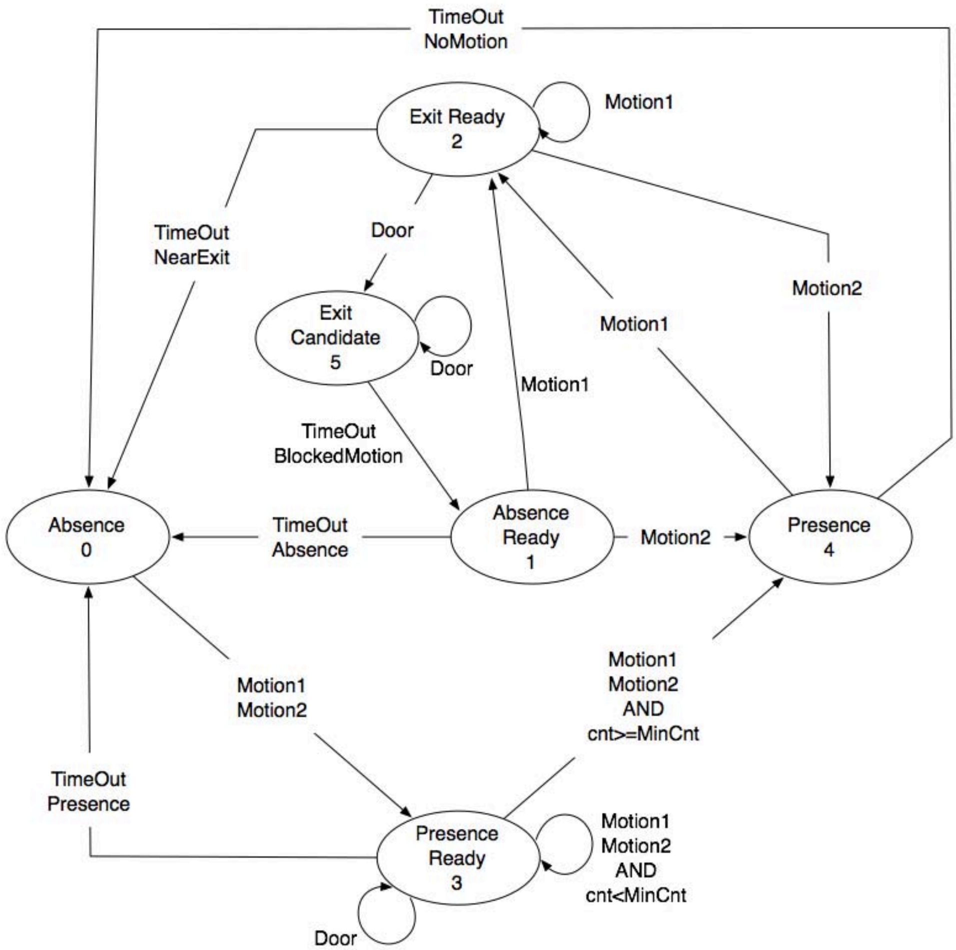


Fig. 37. State-diagram for presence/absence detection. Door: a door contact event occurred, motion1: a motion event of the detector closes to the main entrance occurred, mition2: a motion event of other detectors occurred, timeout: after a specific amount of time of no events this toute is taken.

In our standard use case there is only one person present within an apartment. This means that we will focus on single person apartments within our project. Nevertheless, at some times there will be more than one person within the apartment (e.g. if there are visitors). This mean we have to discriminate if there are more then one persons in an apartment. Our logic for data analysis observes if there are more than one motion detection sectors active at the same time. The more often the output is switched to on, the higher the chance of more people being present in the apartment. The clearer the sections of the motion detectors are separated, the better the results for this logic will be. Therefore it's recommended to only use clearly separated sectors for this logic. Note that this logic will only give a hint on the presence of multiple persons in an apartment. If all persons are within the same motion detector sector, this logic will not be able to tell if there are multiple persons present. Also if sectors are not clearly separated, one person can invoke multiple motion detectors at the same time.

7.4. Calculating mobility from PIR sensors

In our context mobility concerns to locomotion of people respectively to spatio-temporal parameters of daily living (Wingenefeld, 2011). For most human, the typical mode of locomotion is to walk from one place to the other. Low mobility concerns to people, who stay for the most part of the day within the same area or let's say room zone. High mobility concerns to people, who change their localization several times a day or let's say are very often in different room zones respectively are more outside of the apartment.

Taking into consideration the above mentioned logic for PIR sensor data analysis we may assume, that the a single person is present in the room zone with highest triggerings of respective PIR sensor(s). If we focus a single time period of 24 hours a day (starting at 00:00), we will obtain a kind of daily structure for this person. We can apply this logic for a single day but also for summarizing a longer period of time within a 24 hours observation time slot. In the latter case we are calculating mean values for the daily structure. Following this approach we may find different mobility patterns for different periods of time as shown in the following figure.

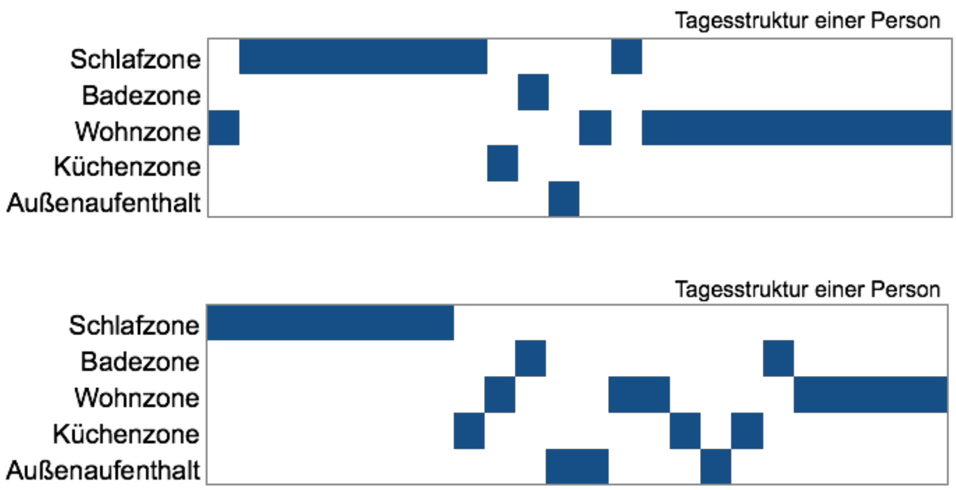


Fig. 38. Two different mobility patterns of a person during 24 hours of a day (starting with 00:00) applying means values for a time period of two months.

Mobility does not exclusively mean that a person is very often in different room zones. In addition to variability it is equally important to focus directed mobility. In our context directed mobility means that a person consistently follows his individual daily structure respectively spatio-temporal parameters, which is not dysfunctional in accordance to health science. At the beginning of Guiding Light intervention we might define a functional daily structure together with single end user and secondary end user. Thereafter, we observe all kinds deviation and adaption of actual daily structure to commonly predefined daily structure.

The analyses and discussions required parametrisation of mobility have not yet been completed. We will need this kind of parametrisation for effect analysis of Guiding Light within this project as well as feedback for primary as well as secondary end users.

7.5. Secondary enduser GUI for mobility monitoring

Mobility analysis for secondary end users (e.g. experts for care) will receive more detailed information. This application should give insight to current daily structure of older persons as well as modifications in daily structure. At the starting point we searched for similar applications, which are available from other providers. The supply for this objective is very limited but we found an example for visualizing daily structures (see following figure).

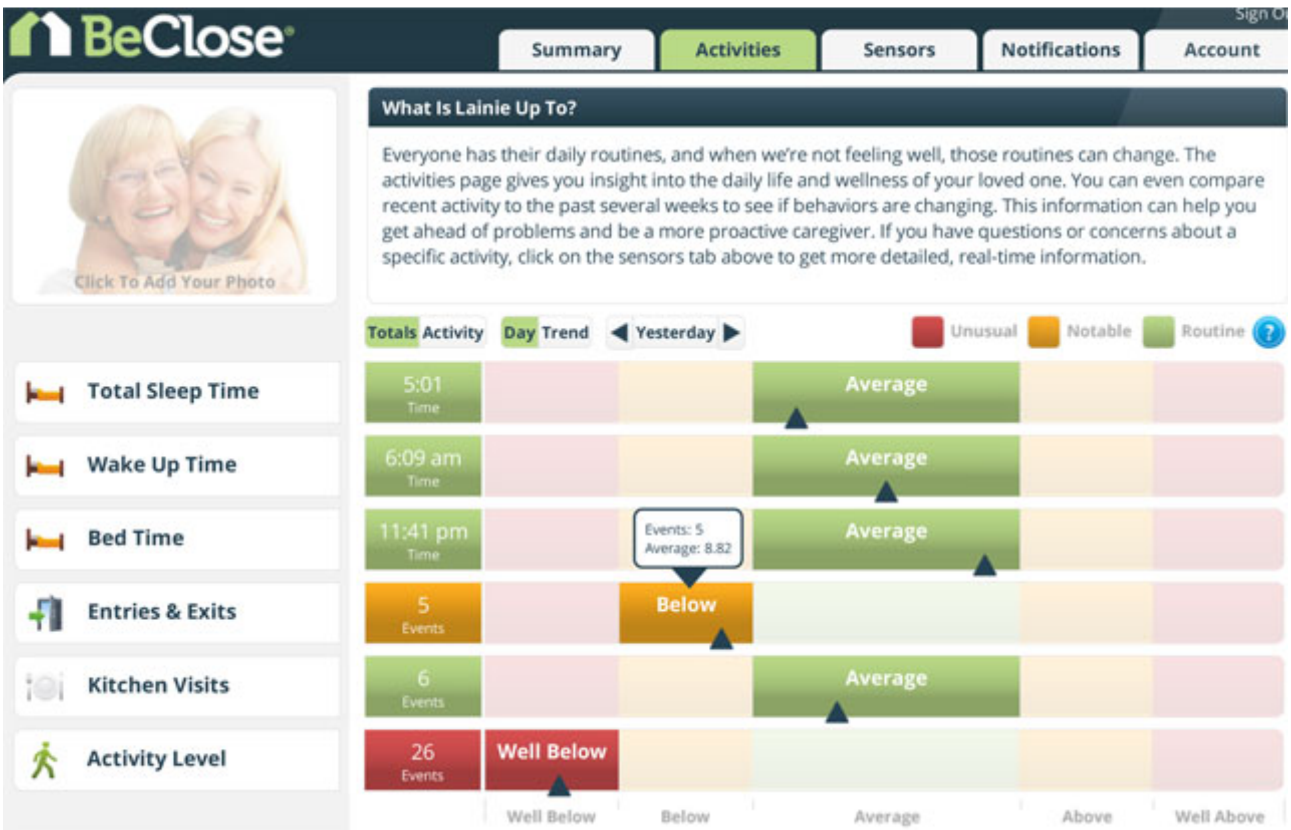


Fig. 39. Example for visualizing daily structures (Source: www.BeClose.com)

In order to build a basis for design decision, we designed three different version for expert user GUI (see following figures). Version 1 shows time lines of activity for each room zone. Version 2 shows circle charts of activity for each room zone. Version 3 integrates all activity information in one singe circle chart. Each version distinguishes between PIR-signals, analysed daily structure from PIR-signals and predetermined daily structure. We will compare analysed daily structure from PIR-signals with predetermined daily structure in order to detect exceptions from the typical daily structure or effects of Guiding Light.

Fig. 40. Screen for expert user GUI Version 1.

Fig. 41. Screen for expert user GUI Version 2.

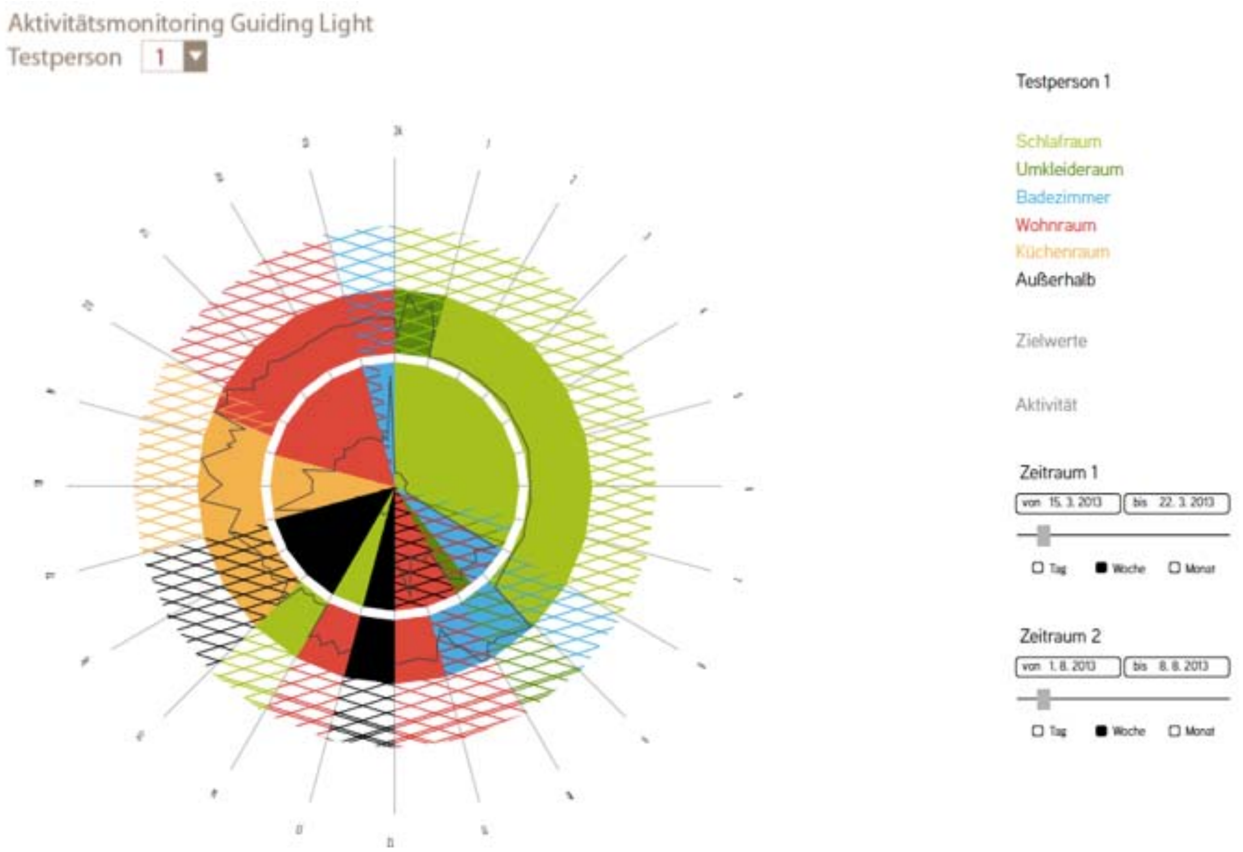


Fig. 42. Screen for expert user GUI Version 3.

We decided to follow version 1 for expert user GUI, because this version follows familiar visualizations of time lines from different information channels. This decision was made with feedback from care experts who will probably use this application. We interviewed care an case manager, nursing manager, and qualified care personnel by using cognitive walkthrough method with real use cases at Garnmarkt in Götzis. We compared versions of expert user GUI on how easy it is for care experts to accomplish tasks with the application. After walking through typical tasks the test users could state their perference for one of three versions.

8. References

Eurostat (2009). Harmonised European time use surveys. Official Publications of the European Communities.

Figueiro, M.G., Plitnick, B., Rea, M.S., Gras, L.Z. & Rea, M.S. (2011). Lighting and perceptual cues: Effects on gait measures of older adults at high and low risk for falls. BMC Geriatrics, 11, 2-10.

Greving, H. & Remke, S. (2012). Tagesstruktur und Gestaltung freier Zeit im Alter: Potentiale zur Teilhabe. In H. Greving, F. Dieckmann, S. Schäper & S. Graumann (Hrsg.). Dritter Zwischenbericht zum Forschungsprojekt „Lebensqualität inklusiv(e): Innovative Konzepte unterstützten Wohnens älter werdender Menschen mit Behinderung“, S. 198-226. Münster: Katholische Hochschule NRW

Hidayetoglu, M.L., Yildirim, K. & Akalin, A. (2012). The effects of color and light on indoor wayfinding and the evaluation of the perceived environment. Journal of Environmental Psychology, 32, 50-58.

Huismann, E.R.C.M., Morales, E., van Hoof, J. & Kort, H.S.M. (2012). Healing environment: A review of the impact of physical environmental factors on users. Building and Environment, 58, 70-80.

Marianne M., Sinoo, M.M., van Hoof, J. & Kort, H.S.M. (2011). Light conditions for older adults in the nursing home: Assessment of environmental illuminances and colour temperature. Building and Environment, 46, 1917-1927.

Schäper, S., Schüller, S., Dieckmann & Greving (2010). Anforderungen an die Lebensgestaltung älter werdender Menschen mit geistiger Behinderung in unterstützten Wohnformen. Münster: Katholische Hochschule NRW.

Staedt, J. & Riemann, D. (2007). Zirkadiane Rhythmik und Chronobiologie. In: Staedt, J. &

Riemann, D. (eds.). Diagnostik und Therapie von Schlafstörungen, 105-126. Stuttgart: Kohlhammer.

Veitch, J.A. & Galasiu, A.D. (2012). The physiological and psychological effects of windows, daylight, and view at home: review and research agenda. NRC-IRC Research Report RR-325.

Wardono, P., Hibino, H. & Shinichi, K. (2012). Effects of interior colors, lighting and decors on perceived sociability, emotion and behavior related to social dining. Procedia Social and Behavioral Sciences, 38, 362-372.

Wingenfeld, K. (2011). Pflegebedürftigkeit, Pflegebedarf und pflegerische Leistungen. In D. Schaeffer & K. Wingenfeld (Hrsg.). Handbuch Pflegewissenschaft, S. 263-290. Weinhem: Juventa.

Annex. Pictures from Guiding Light General Meeting