Ambient Light Guiding System for the Mobility Support of Elderly People

Implementation report

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The project (Guiding Light) no AAL-2011-4-033 is fanded ander AAL JP

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 (**has produced)** 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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Content

0. Introduction

The main aim of this deliverable is a comprehensive documentation of the implementation of Guiding Light into all field test households. This deliverable describes exactly all technical details, the initial situation within the rooms, design steps and manufacturing and installation processes in order to bring Guiding Light into initial operation within all field test households. This deliverable has *a clearly technical character* and is *sharply separated* from the deliverable *"D5.1 Field test report"* which describes in detail the test persons' typical personal and individual characteristics (e.g. daily personal structure) and executed re-programming of lighting parameters and their correlated effects onto the assessed mobility parameters.

#	**Location**	**Partner**	**Lum.**	**PIR**
VP1	Vatterstetten (DE)	Youse		
VP2	Vatterstetten (DE)	Youse		
VP3	Vatterstetten (DE)	Youse		
VP4	Wolfratshausen (DE)	Youse		
VP5	Götzis (AT)	FHV		
VP6	Götzis (AT)	FHV		
VP7	Wörgl (AT)	BB		
VP8	Wörgl (AT)	BB		
VP9	Zürich (CH)	MVA		
VP10	Neumarkt (ITA)	Apollis		
VP11	Vatterstetten (DE)	Youse		
VP12	Götzis (AT)	FHV		
VP13	Wörgl (AT)	BB		
VP14	Hard (AT)	MVA		
VP15	Hard (AT)	MVA		
VP16	Hard (AT)	MVA		
VP17	Neumarkt (ITA)	Apollis		
VP18	Bozen (ITA)	Apollis		
VP19	Bozen (ITA)	Apollis		

Two households are equipped with the wired solution. These are the households of VP5 and VP6 in Götzis. Within these households the first implementation activities were carried out and these two households started with initial operation in August 2013.
All other households are equipped with the wireless (EnOcean) solution. Preliminary to the implementation (of the wireless solution into private households) a test run, in order to prove the integration and interaction of all single system components to each other, was necessary ander real condition. Therefore a prototype installation was successfully carried

out in October 2013 at the premises of Bartenbach. The households with the complete wireless Guiding Light system were implemented in the period of February 2014 (Wörgl) to July 2014 (Bozen, last installation). The time gap between October 2013 (=approval of prototype installation) and February 2014 (=continuation of implementation into field test households) resulted from a delivery problem by a supplier (delivery of component "Eltako FSG70/1-10V" was postponed several times from originally November 2013 to finally January 2014).
From the table above it can be recognized that a group of households is "just" equipped with the sensor technology, in order to establish a control group according to the field study design.

The following picture gives a geographical overview of the field test household locations. All are located in the area of Central Europe.

1. Prototype installation at premises of Bartenbach

Until October 2013 a prototype installation at the premises of Bartenbach was accomplished in order to validate the overall interaction of all single components to each other (preliminary choice of components according to [4]). With this validation the risk of not foreseeable incompatibilities and errors at the sites of the test persons (especially during installation work) was minimized. This prototype installation was approved by the consortium at a general meeting on July 15th 2013, and was validated by the consortium on October 22nd 2013.

1.1 Object list (for prototype installation)

Ordering by BB at Projektleuchten (delivery on 12.09.2013)

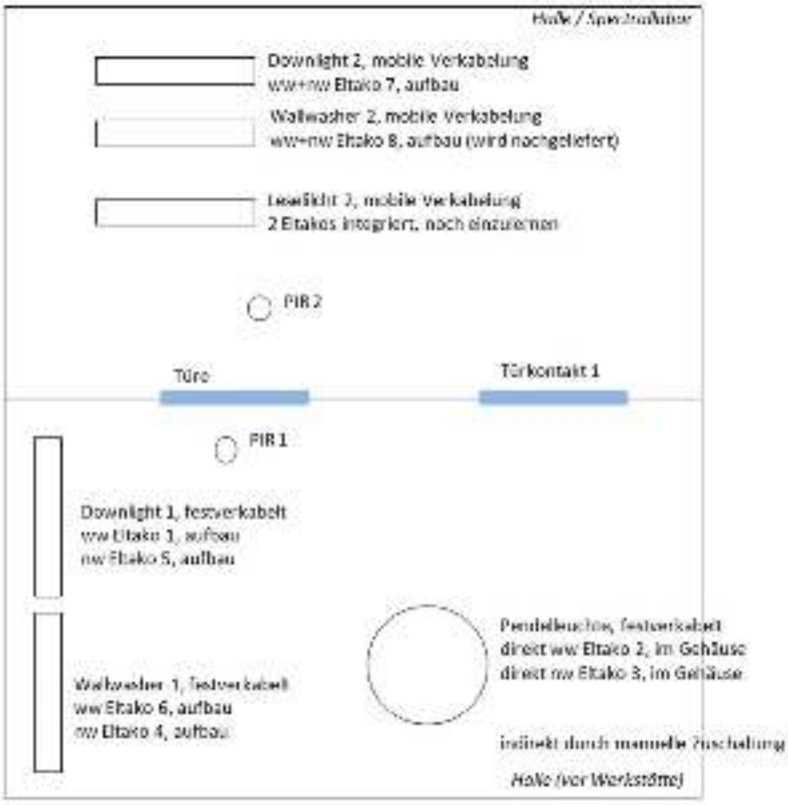
- 2 x Downlight with Jolly Slim
- 2 x Wallwasher with Jolly Slim
- 1 x Reading light mit Jolly Slim with already mounted Eltako-Actuator
- 3 x Wall unit light

Enocean-Material (ordering by MVA, delivery on 08.10.2013)

- 2 x PIR
- 2 x door contact
- 4 x Enocean switch
- 1 x Gateway
- 8 x Eltako actuator

1-10V power supplies provided by TKG

1.2 Layout (scheme of prototype installation)



1.3 Control specification (for the prototype installation)

Event	Action (=response to event)
PIR 1 detects	Suspended luminaire direct (Eltako 2+3) + Wallwasher 1 (Eltako 6+4) ON Downlight 2 (Eltako 7) OFF
PIR 2 detects	Downlight 2 (Eltako 7) ON Suspended luminaire direct (Eltako 2+3) + Wallwasher 1 (Eltako 6+4) OFF
Door contact 1 detects	Wallwasher 1 (Eltako 6+4) ON, all others OFF
Switch T1: Push left side	Downlight 1 ww (Eltako 1) + Suspended luminaire direct ww (Eltako 2) ON / OFF
Switch T1: Push right side	Downlight 1 nw (Eltako 5) + Suspended luminaire direct nw (Eltako 3) ON / OFF
Switch T2: Push left side	Wallwasher 1 ww (Eltako 6) ON / OFF
Switch T2: Push right side	Wallwasher 1 nw (Eltako 4) ON / OFF
Switch T3: Push left side	Reading light 2 ww (Eltakos to be programmed) ON / OFF
Switch T3: Push right side	Reading light 2 nw (Eltakos to be programmed) ON / OFF
Switch T4: Push left side	Downlight 2 nw+ww (Eltako 7) ON / OFF
Switch T4: Push right side	Everthing OFF

These control specifications were implemented into the cloud based development environment by MVA (accordingly to description of [2]).

1.4 Photographical documentation of the prototype installation in Aldrans

Installation of a prototype of the suspended luminaire within the R&D department of Bartenbach.

Luminaire names and their technical characteristics are documented in [4].

Installation of a wallwasher and a downlight.

Photometrical characteristics were evaluated and validated in detail with the lighting measurement equipment of Bartenbach. This is sumarized written into [4], comprehensive measurement reports are within the project documentation.

Same wallwasher and downlight from another angle.

All luminaires were controlled wireless via internet access and the cloud based control specification.

The wireless range was tested. Also with actuators mounted inside the metal based housing. Luminaires were wireless switched from other rooms and building areas which were within a direct distance of approx. 20m and were separated with one concrete wall.

Test of cabling of the wireless actuators with the luminaires.

Integration of PIR and door contact sensors into the system. Monitoring of PIR signals onto a tablet PC. Gaining PIR data onto the cloud.
Testing sensitivity of PIR sensors and lag time in data acquisition.

1.5 Experiments and results of the prototype installation in Aldrans

The interplay of all planned system components could be demonstrated and tested. The radio range was found to be very robust, so there are no problems expected for the Guiding Light Test apartments.

Aesthetically disadvantage is the necessity of partially external mounting of EnOcean actuators. In this regard, a close coordination with electricians and test persons is necessary to avoid aesthetic problems.
(Remark: This esthetical issue will be solved in future as soon as direct EnOcean-compatible electrical ballast is available. Prototypes were already presented by industry in 2013[1].)

A first sampling of the PIR sensors demonstrated the qualitative suitability for detecting a door passage (accordingly to preliminary results [2]). The detection rate is not under 5s and is even closer to check. A limitation of the detection range of a PIR sensor could not be successfully implemented or validated - efforts in this regard are planned to detect the monitoring or the circumscribed localization of stays in space zones[2].

All components of the prototype installation were subsequent used for the implementation into the field test households.

[1]e.g.: http://www.bilton.at/product-category/enocean more manufacturer are under observation by the consortium
[2] This issue was finally solved by a quite smart sensor positioning which used topographical advantages (e.g. walls, furniture, ...) of the apartments in order to realize the specified room zone detection. Positioning guidelines are described in [4].

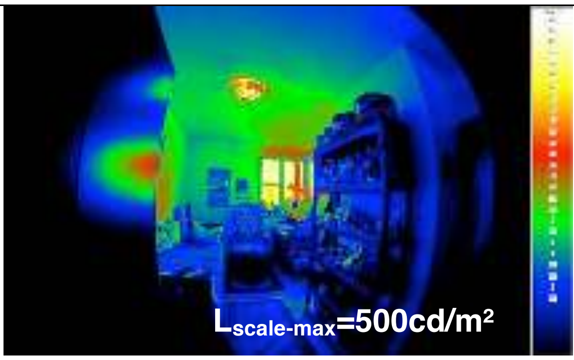
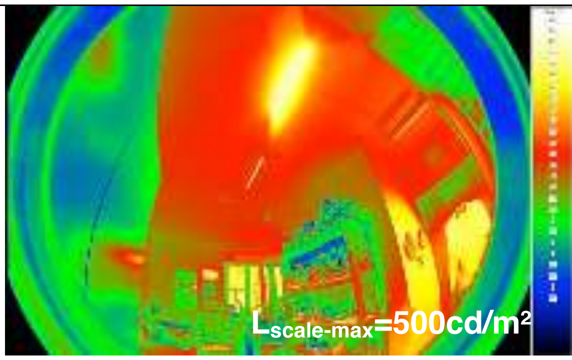
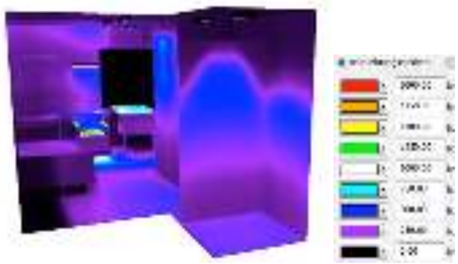
2. Implementation Guiding Light

This chapter documents with photos, photometrical measurements and with the lighting design drawings the implementation of Guiding Light into the field test households. All photometrical measurements show the artificial lighting situation. Daylighting was photometrically characterized too but is documented within the project documentation, in order to keep this deliverable in a readable size.

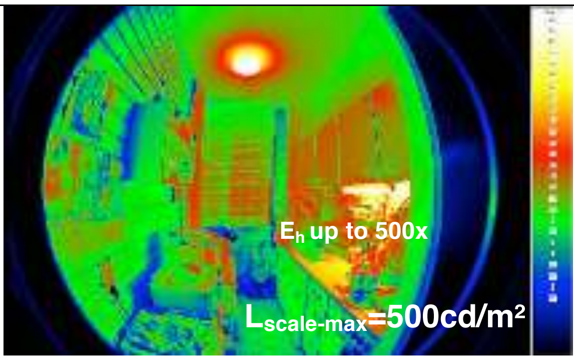
2.1 Apartment of test person VP1 - YOUSE (Vatterstetten, DE)

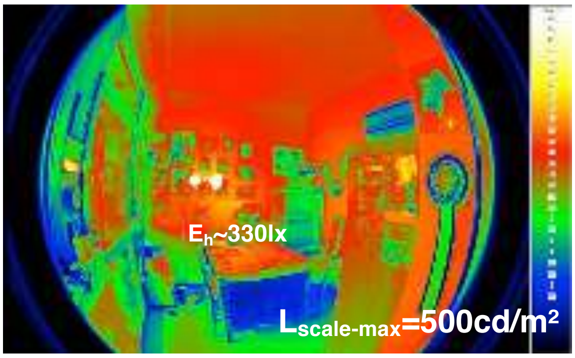
Photometrical Situation

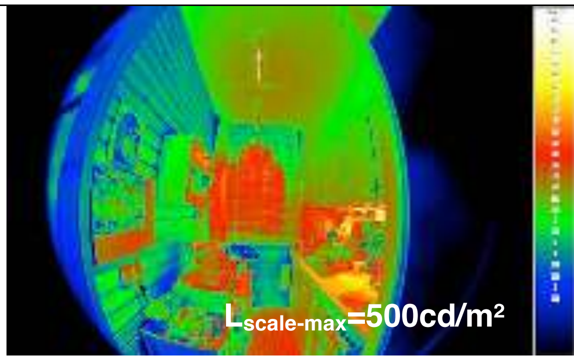
Bedroom

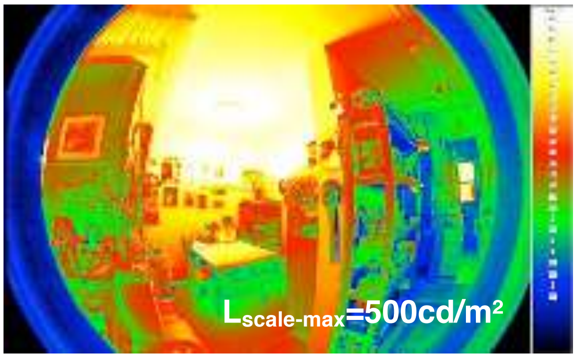
Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Living room / Kitchen



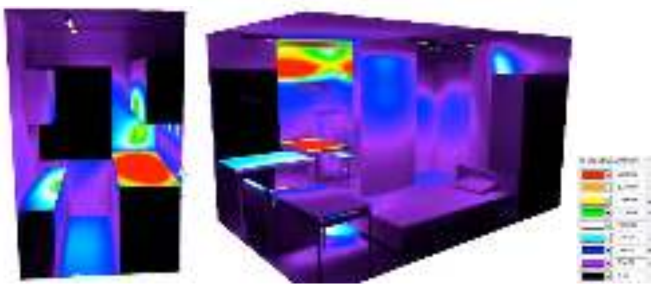




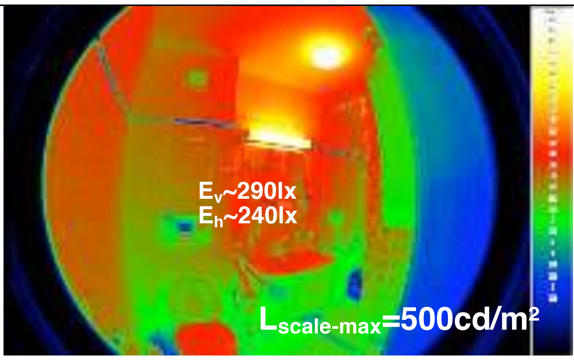
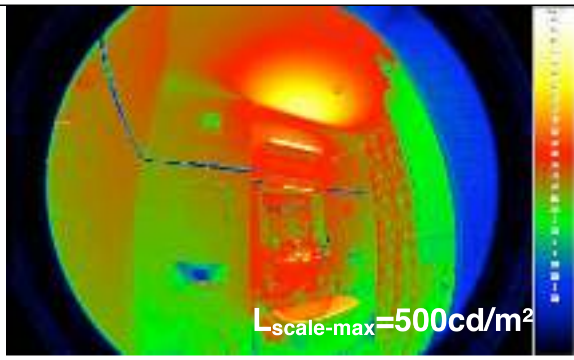
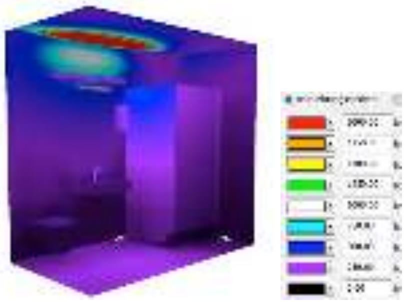


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx] , to the right



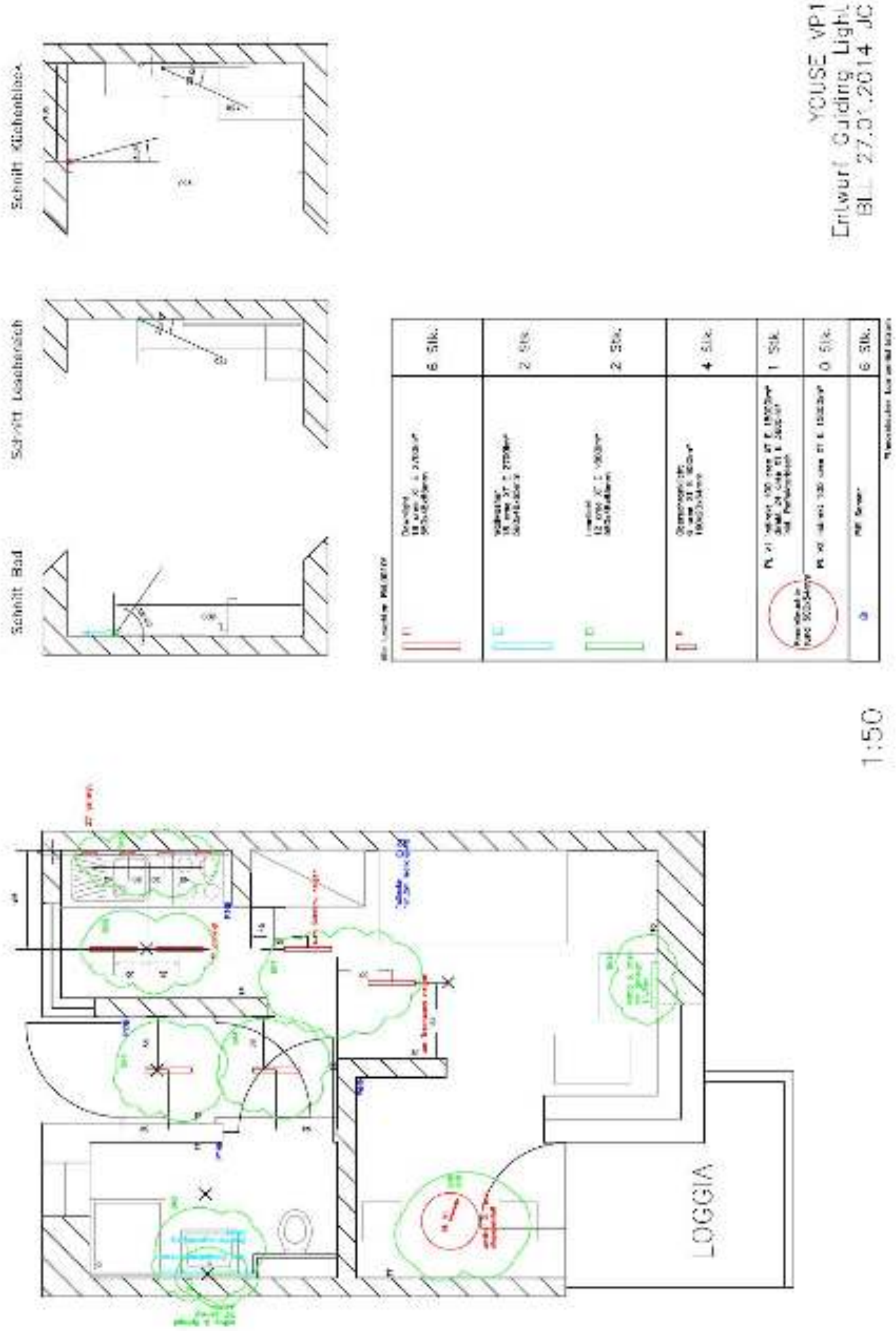
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx] , to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

<u>Lighting design and sensor positioning</u>



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 1 (Bathroom, mirror) (Actuator E1.1 and E1.2)
Switch 1 (right side)	Group 2 (Bathroom, general) (Actuator E2.1 and E2.2)
Switch 2 (left side)	Group 3 (Corridor door) (Actuator E3.1 and E3.2)
Switch 2 (right side)	Group 4 (Corridor general) (Actuator E4.1 and E4.2)
Switch 3 (left side)	Group 3 (Corridor door) (Actuator E3.1 and E3.2)
Switch 3 (right side)	Group 4 (Corridor general) (Actuator E4.1 and E4.2)
Switch 4 (left side)	Group 5 (Kitchen Downlights) (Actuator E5.1 and E5.2)
Switch 4 (right side)	Group 6 (Kitchen Wall unit) (Actuator E6.1 and E6.2)
Switch 5 (left side)	Group 7 (Living area Dowlight) (Actuator E7.1 and E7.2)
Switch 5 (right side)	Group 10 (Living area, Reading light) (Actuator E10.1 and E10.2)
Switch 6 (left side)	Group 7 (Living area Dowlight.) (Actuator E7.1 and E7.2)
Switch 6 (right side)	Group 10 (Living area, Reading light) (Actuator E10.1 and E10.2)
Switch 7 (left side)	Group 8 (Suspended luminaire Direct) (Actuator E8.1 and E8.2)
Switch 7 (right side)	Group 9 (Suspended luminaire Indirect) (Actuator E9.1 a. E9.2)
Switch 8 (left side)	For test issues.
Switch 8 (right side)	For test issues.
Switch 9 (left side), since 28.10.14	Group 9 (Suspended luminaire Indirect) (Actuator E9.1 a. E9.2)
Switch 9 (right side), since 28.10.14	Group 8 (Suspended luminaire Direct) (Actuator E8.1 and E8.2)

PIR-Sensor allocation (29.10.2014):

PIR#	Zone	Luminaire	Remark
1	Bathroom	SK1/2	
2	Entrance	SK3	
3	Kitchen	SK5/6	
4	Sleeping room	SK7	
5	-		Originally planned 1.5m above, not installed do to mechanical situation on site
6	Living room	SK8/9	

PIR-Sensors are mounted with screws, without the white aesthetical PMMA ring

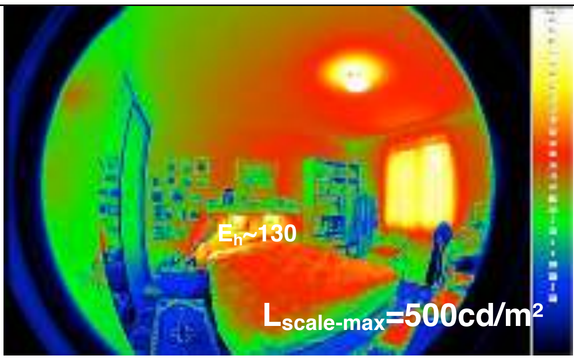
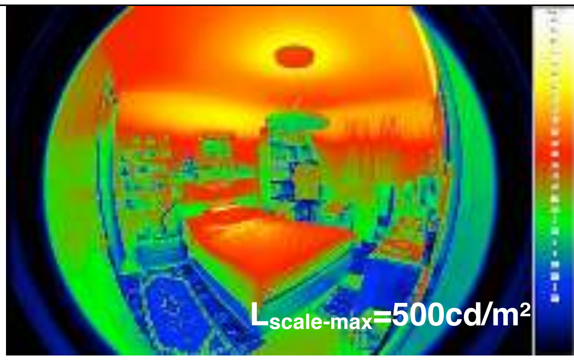
The apartment of VP1 already had an adequate zonally task light in the kitchen with a horizontal illuminance of up to 500lx. The illumination value of approx. 330lx at the desk in the living area is a medium value (in the course of the experiences and knowledge of private homes).

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initially finalized on 23.04.2014.

2.2 Apartment of test person VP2 - YOUSE (Vatterstetten, DE)

Photometrical Situation

Bedroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td>
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<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
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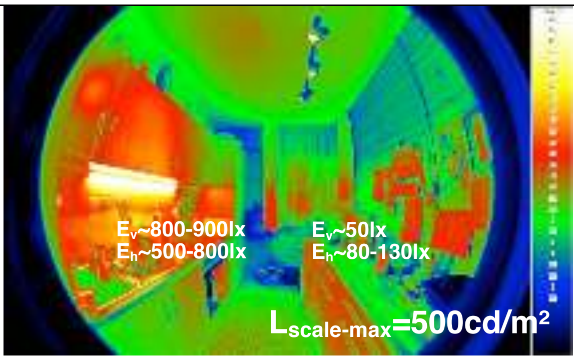
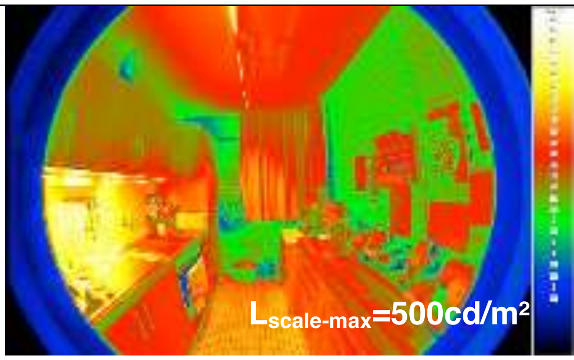
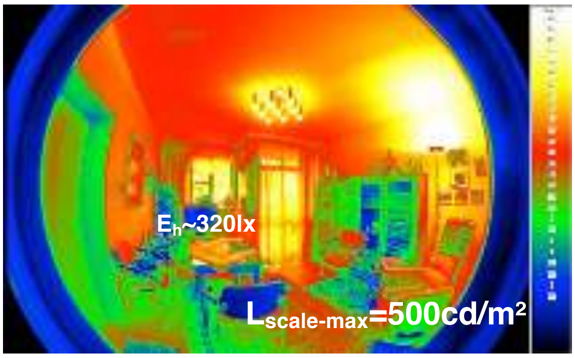
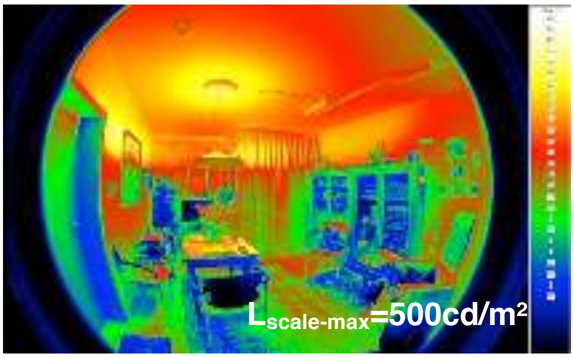
Living room / Kitchen



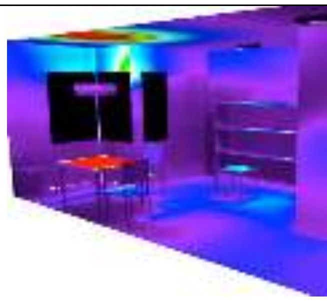




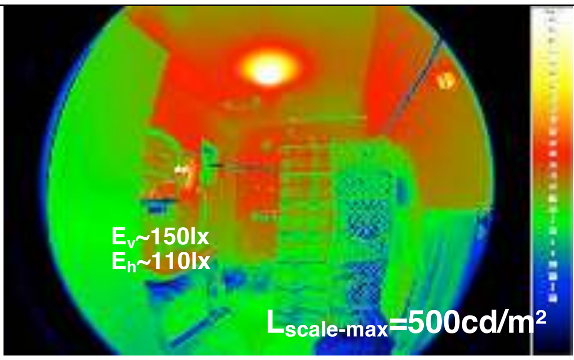
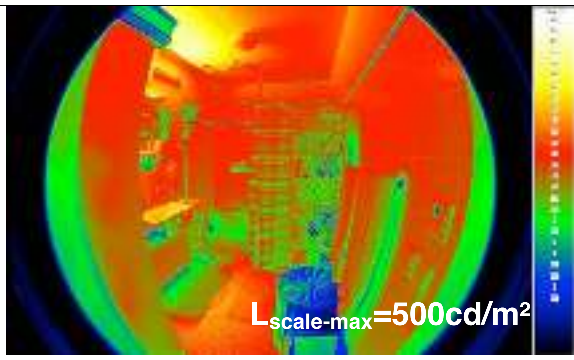
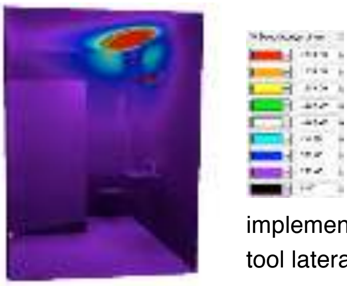


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right



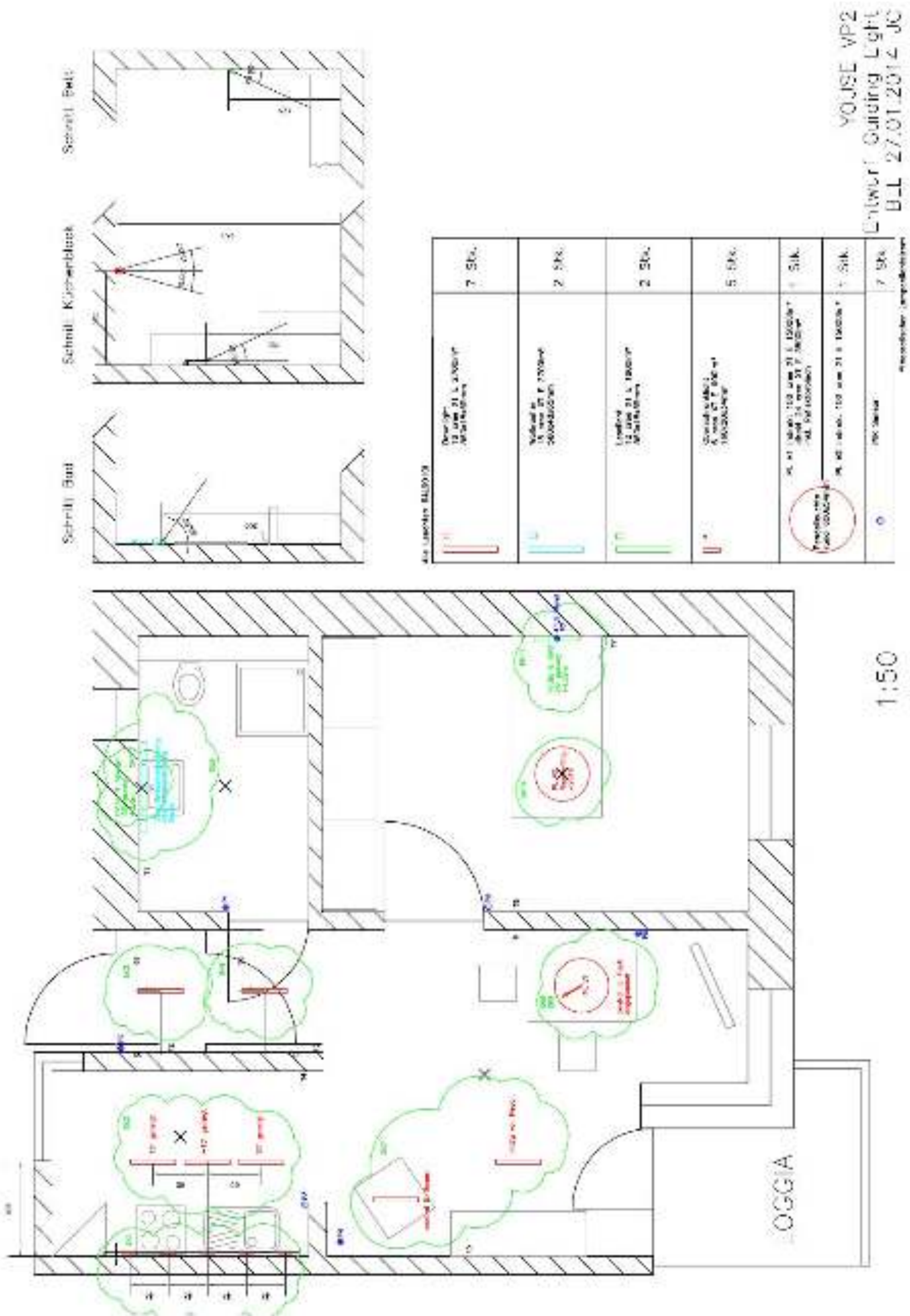
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	 CAD of bathroom implemented in simulation tool laterally reversed

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 5 (Bathroom, mirror) (Actuator E5.1 and E5.2)
Switch 1 (right side)	Group 6 (Bathroom, general) (Actuator E6.1 and E6.2)
Switch 2 (left side)	Group 3 (Corridor door) (Actuator E3.1 and E3.2)
Switch 2 (right side)	Group 4 (Corridor general) (Actuator E4.1 and E4.2)
Switch 3 (left side)	Group 3 (Corridor door) (Actuator E3.1 and E3.2)
Switch 3 (right side)	Group 4 (Corridor general) (Actuator E4.1 and E4.2)
Switch 4 (left side)	Group 2 (Kitchen Downlights) (Actuator E2.1 and E2.2)
Switch 4 (right side)	Group 1 (Kitchen Wall unit) (Actuator E1.1 and E1.2)
Switch 5 (left side)	Group 7 (Living area Downlights) (Actuator E7.1 and E7.2)
Switch 5 (right side)	For test issues.
Switch 6 (left side)	Group 8 (Suspended luminaire Direct) (Actuator E8.1 and E8.2)
Switch 6 (right side)	Group 9 (Suspended luminaire Indirect) (Actuator E9.1 and E9.2)
Switch 7 (left side)	Group 10 (Suspended luminaire Indirect Sleeping room) (Actuator E10.1 and E10.2)
Switch 7 (right side)	Group 11 (Reading light Sleeping room) (Actuator E11.1 and E11.2)
Switch 8 (left side)	Group 10 (Suspended luminaire Indirect Sleeping room) (Actuator E10.1 and E10.2)
Switch 8 (right side)	Group 11 (Reading light Sleeping room) (Actuator E11.1 and E11.2)

PIR-Sensor allocation (29.10.2014):

PIR#	Zone	Luminaire	Remark
1	Bathroom	SK5/6	Movement on toilet isn't detected
2	Entrance	SK3	
3	Kitchen	SK1/2	
4	Living room	SK7	Detection of reading/TV chair and pass through to kitchen
5	Living room	SK8/9	Dining table and workplace detection
6	-	-	Entrance area of sleeping room, not operating
7	Sleeping room	SK10/11	Mounted at the bed-head
8	Slpeeping room	SK10/11	Entrance area of sleeping room, replacement of PIR6
9	Living room	SK8/9	Additional for presence detection at table

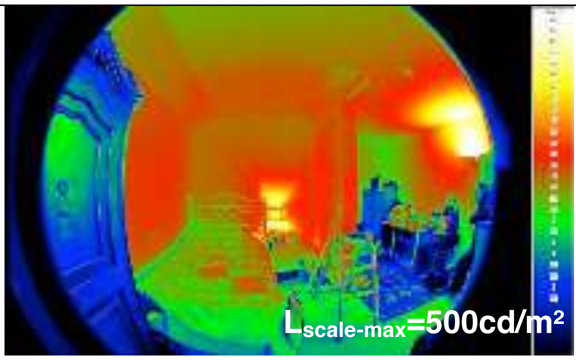
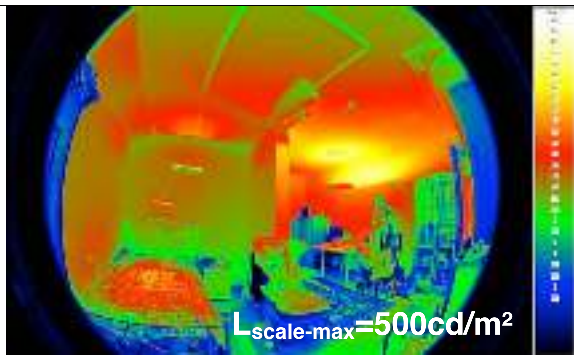
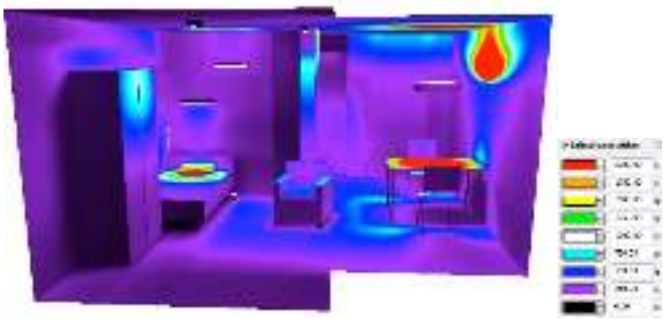
Except one side of the kitchen area, which shows up to 800lx of horizontal illuminance (zonally) the illuminance values of the initial situation showed typically low values (<200lx).

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized on 28.04.2014.

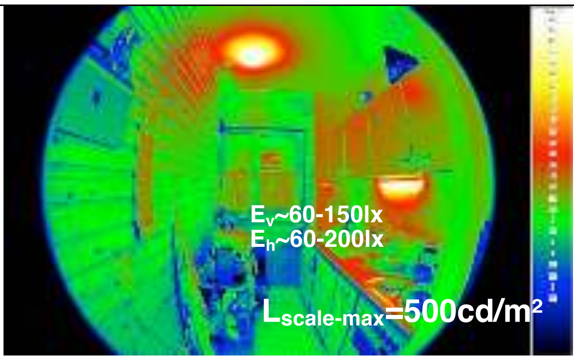
2.3 Apartment of test person VP3 - YOUSE (Vatterstetten, DE)

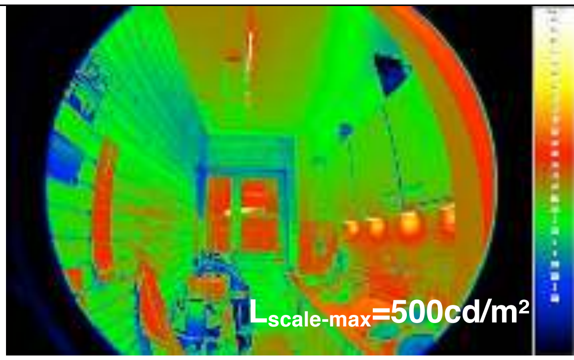
<u>Photometrical Situation</u>

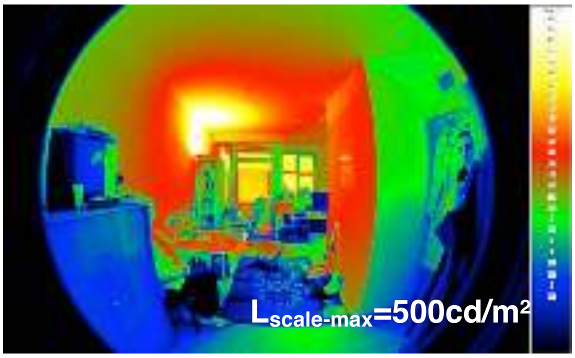
Bedroom

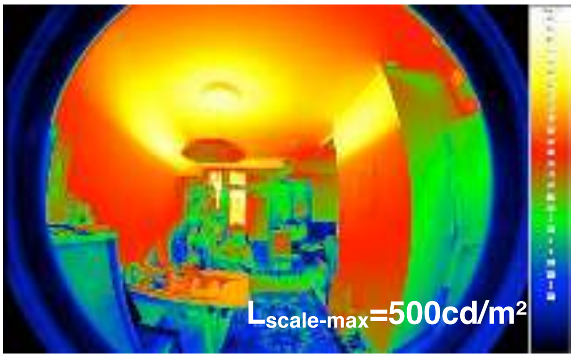
Initial situation (was documented on that day when installation has started)	Implemented Guiding Light
	
 	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Living room / Kitchen





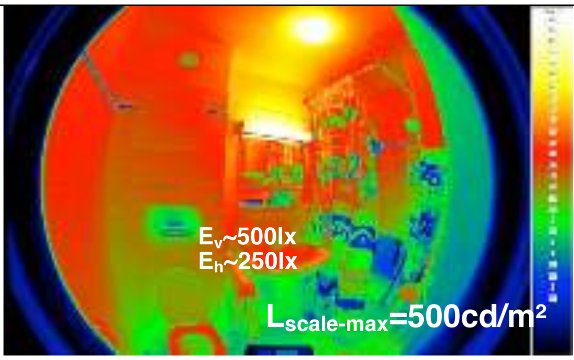
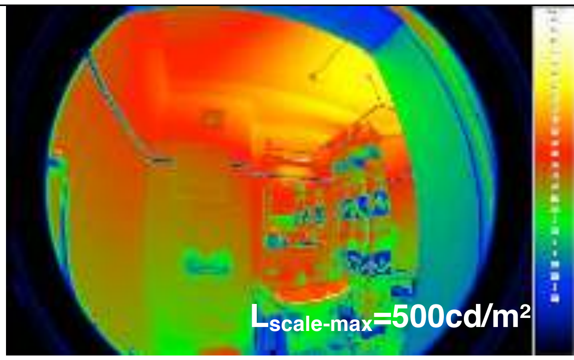
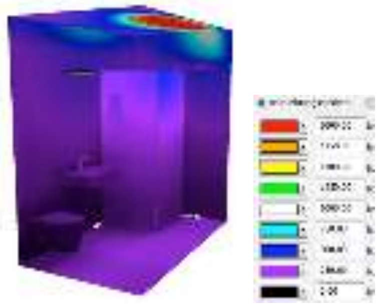




Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right

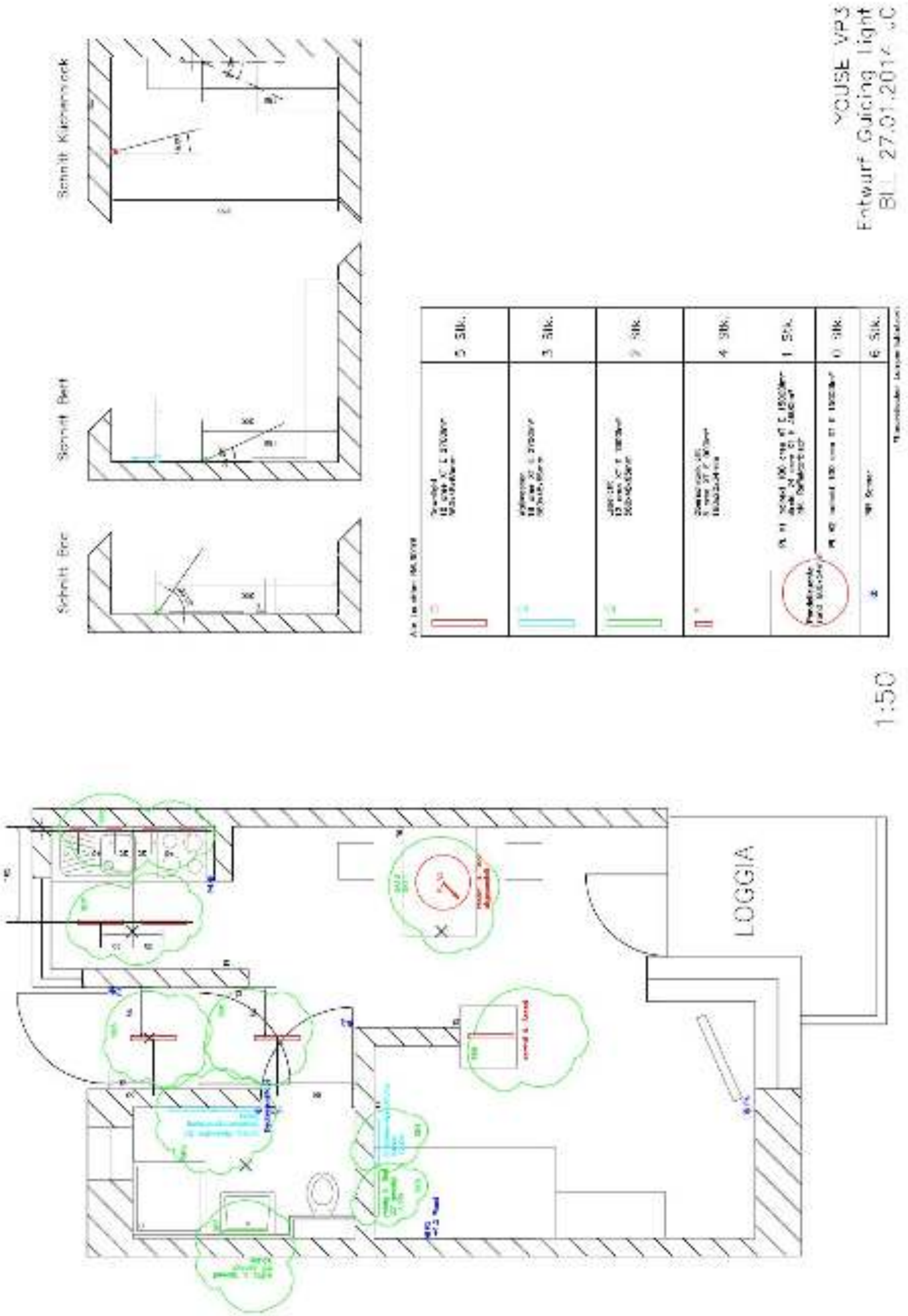
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 1 (Bathroom, mirror) (Actuator E1.1 and E1.2)
Switch 1 (right side)	Group 2 (Bathroom, general) (Actuator E2.1 and E2.2)
Switch 2 (left side)	Group 6 (Corridor door) (Actuator E6.1 and E6.2)
Switch 2 (right side)	Group 5 (Corridor general) (Actuator E5.1 and E5.2)
Switch 3 (left side)	Group 6 (Corridor door) (Actuator E6.1 and E6.2)
Switch 3 (right side)	Group 5 (Corridor general) (Actuator E5.1 and E5.2)
Switch 4 (left side)	Group 7 (Kitchen Downlights) (Actuator E7.1 and E7.2)
Switch 4 (right side)	Group 8 (Kitchen Wall unit) (Actuator E8.1 and E8.2)
Switch 5 (left side)	Group 9 (Living area Downlights) (Actuator E9.1 and 9.2)
Switch 5 (right side)	Group 11 (Suspended luminaire Indirect) (Actuator E11.1 and E11.2)
Switch 6 (left side)	Group 10 (Suspended luminaire Direct) (Actuator E10.1 and E10.2)
Switch 6 (right side)	Group 11 (Suspended luminaire Indirect) (Actuator E11.1 and E11.2)
Switch 7 (left side)	Group 3 (Reading light at bed) (Actuator E3.1 and E3.2)
Switch 7 (right side)	Group 4 (Living area, Ceilingwasher) (Actuator E4.1 and E4.2)
Switch 8 (left side)	For test issues.
Switch 8 (right side)	For test issues.

PIR-Sensor allocation (29.10.2014):

PIR#	Zone	Luminaire	Remark
1	Bathroom	SK1/2	
2	Living room	SK10/11	
3	Entrance	SK6	
4	Kitchen	SK7/8	
5	Sleeping room	SK3/4	
6	Dressing zone	?	TV/Radio on/off switching is detected, dressing at reading chair isn't detected

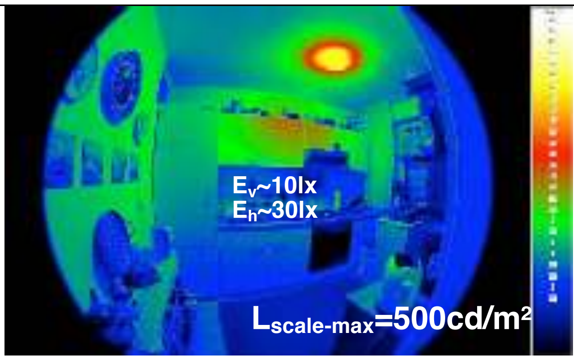
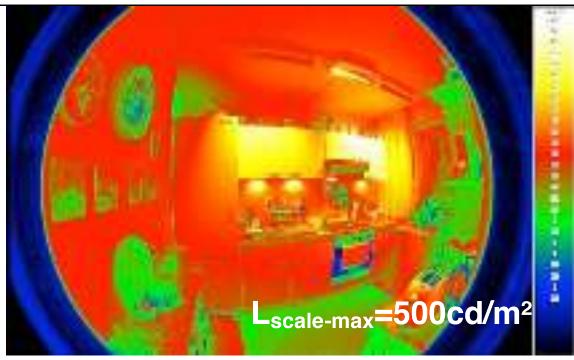
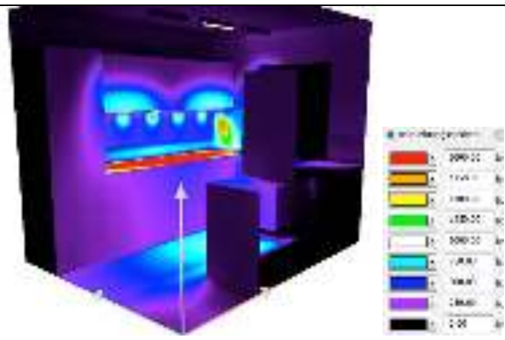
The initial situation of apartment of VP3 had a little higher illuminance value at the mirror area within the bathroom, in comparison to the other test person in the same retirement home (VP1 and VP2). This was probably due to a quite new lamp within the mirror luminaire.
There was no stationary lighting in the living / sleeping areas and we measured typically low illumination values (<200lx).

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized on 12.03.2014.

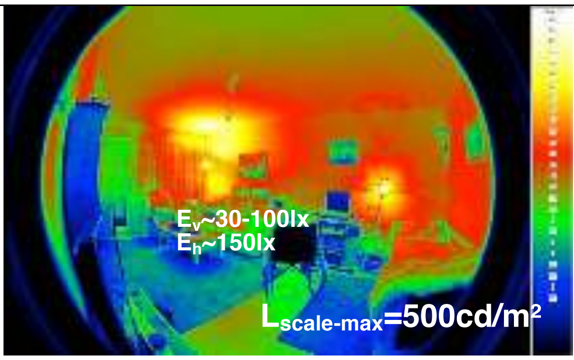
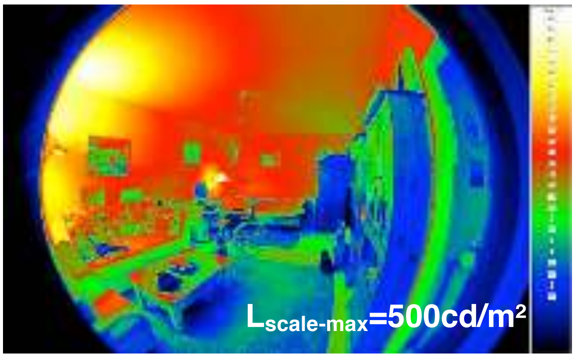
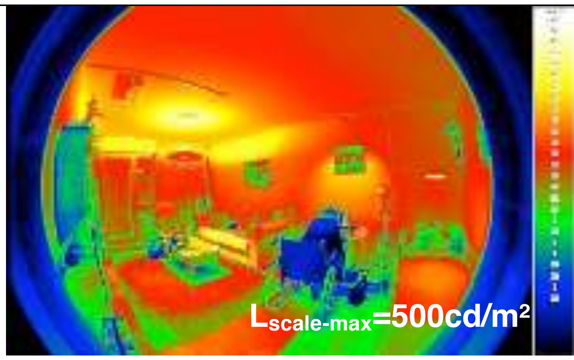
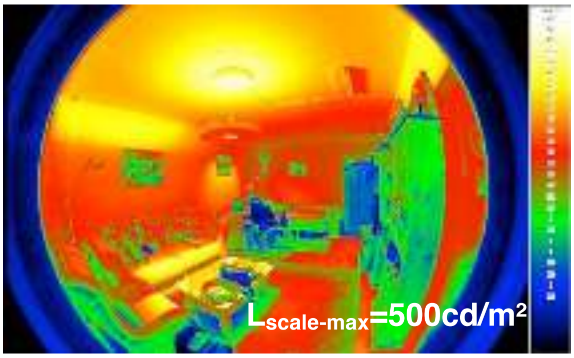
2.4 Apartment of test person VP4 - YOUSE (Wolfratshausen, DE)

Photometrical Situation

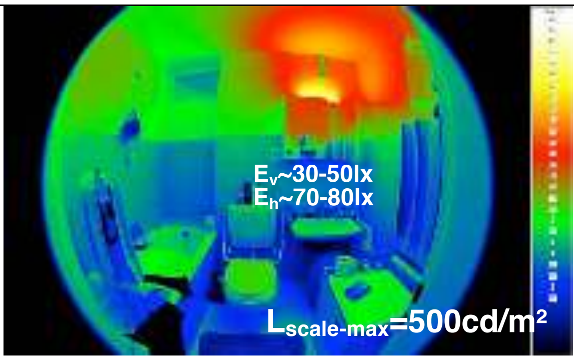
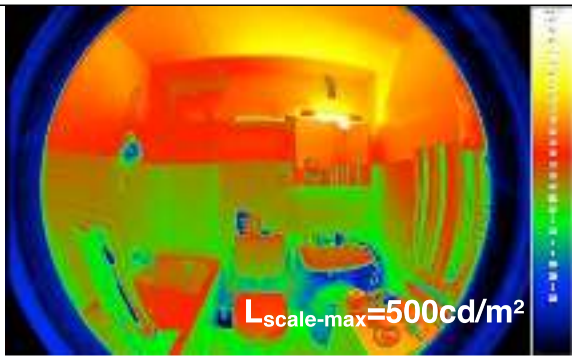
Kitchen

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Bedroom / Living room

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td> </td></tr>
</table>

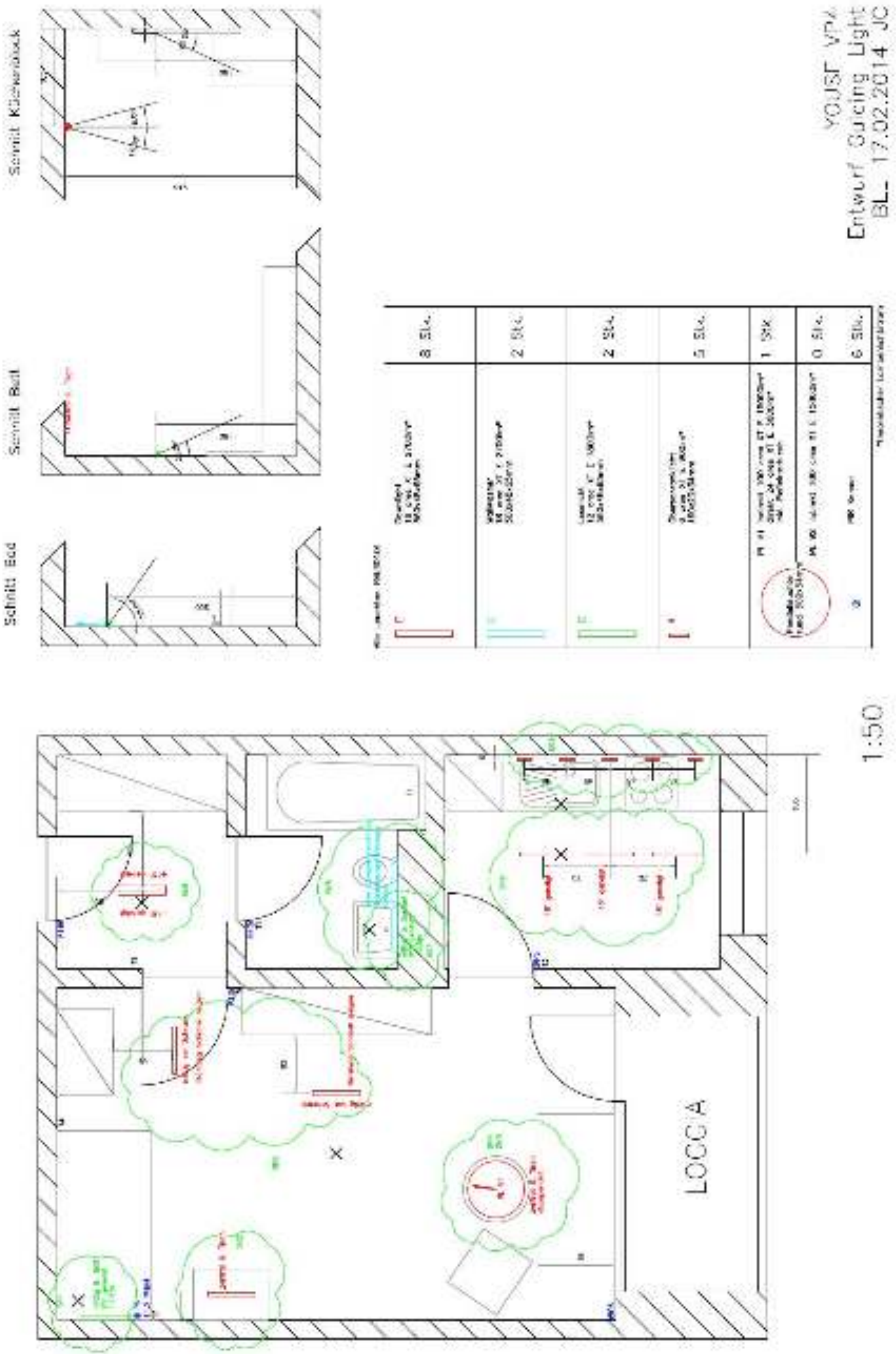
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 7 (Bathroom, mirror) (Actuator E7.1 and E7.2)
Switch 1 (right side)	Group 8 (Bathroom, general) (Actuator E8.1 and E8.2)
Switch 2 (left side)	Group 6 (Corridor) (Actuator E6.1 and E6.2)
Switch 2 (right side)	For test issues.
Switch 3 (left side)	Group 9 (Kitchen Downlights) (Actuator E9.1 and E9.2)
Switch 3 (right side)	Group 10 (Kitchen Wall unit) (Actuator E10.1 and E10.2)
Switch 4 (left side)	Group 2 (Downlight at desk area) (Actuator E2.1 and E2.2)
Switch 4 (right side)	For test issues.
Switch 5 (left side)	Group 3 (Living area Downlights) (Actuator E3.1 and E3.2)
Switch 5 (right side)	Group 5 (Suspended luminaire Indirect) (Actuator E5.1 and E5.2)
Switch 6 (left side)	Group 4 (Suspended luminaire Direct) (Actuator E4.1 and E4.2)
Switch 6 (right side)	Group 5 (Suspended luminaire Indirect) (Actuator E5.1 and E5.2)
Switch 7 (left side)	Group 1 (Reading light at bed) (Actuator E1.1 and E1.2)
Switch 7 (right side)	For test issues.
Switch 8 (left side)	For test issues.
Switch 8 (right side)	For test issues.

PIR-Sensor allocation (29.10.2014):

PIR#	Zone	Luminaire	Remark
1	Entrance	SK6	
2	Bathroom	SK7/8	
3	Dressing zone	SK3	Situated at area in front of wardrobe
4	Sleeping room	SK1/2	Detects also movement at PC table
5	Kitchen	SK9	
6	Living room	SK4/5	

Apartment of VP4 showed a very poor task light within the kitchen due to a damaged cooker light. Also the bathroom lighting was poor with illumination values below 100lx. The living / sleeping room was illuminated with moveable and adjustable floor lamps. One fix installed bulb fitting in the centre of the room was out of order.

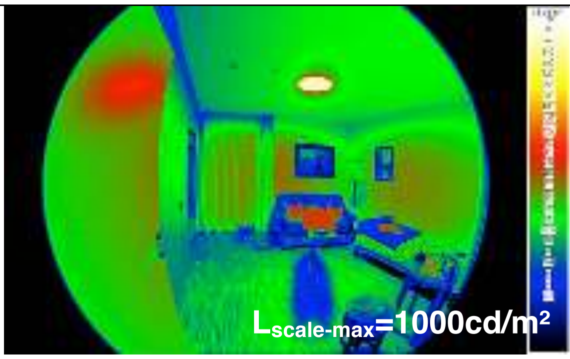
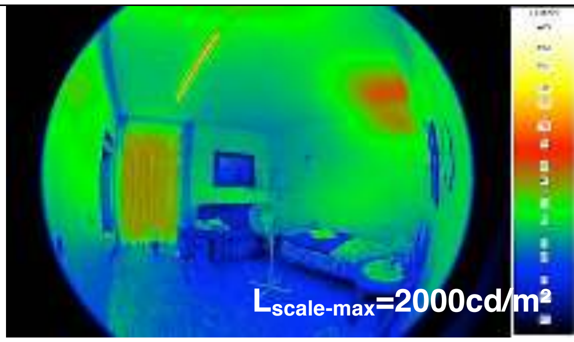
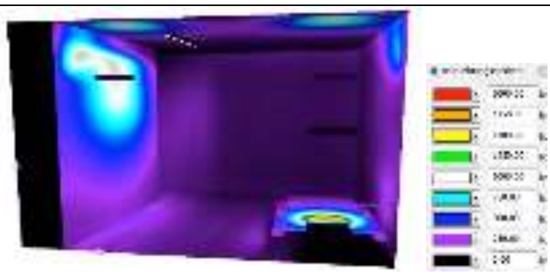
The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initially finalized by the end of May 2014.

2.5 Apartment of test person VP5 - FHV (Götzis, AT)

The field test apartments in Götzis were chosen in a very early project phase and this retirement home was already equipped with a wired home automation system. This situation lead to the decision to install the wired version of Guiding Light (detailed description in [4])[3]

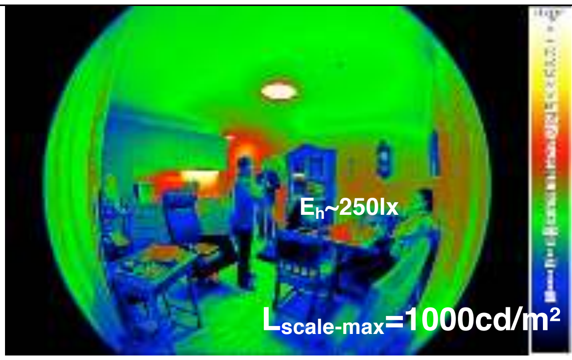
Photometrical Situation

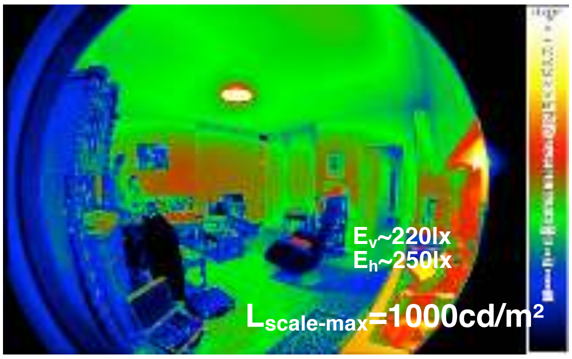
Bedroom

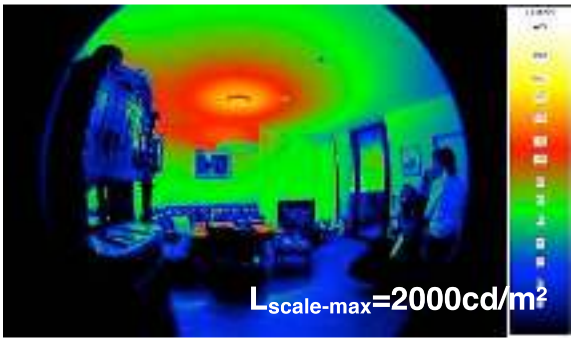
Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

[3] In general a wired solution is aligned with higher material and installation costs (for Götzis this was not the case due to the existing home automation system). On the other hand wired solutions are broadly established on the market of lighting management systems, therefore it was not necessary to wait for the results of the prototype installation (see chapter 1.), i.e. it was possible to install Guiding Light hardware components in a very early implementation phase of the project.

Living room / Kitchen

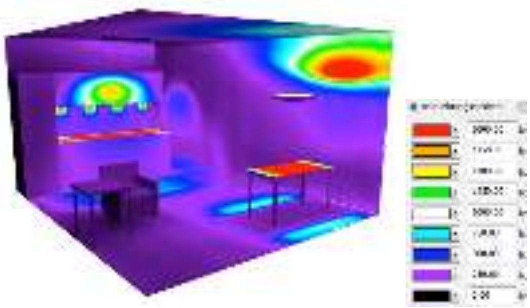




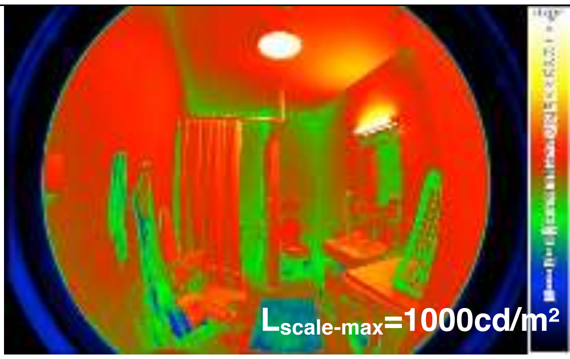
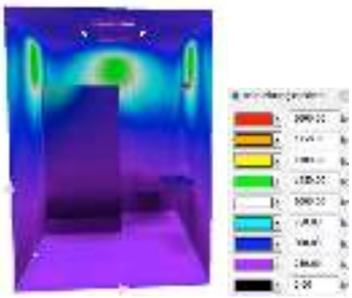


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right



Bathroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

Corridor / entrance area

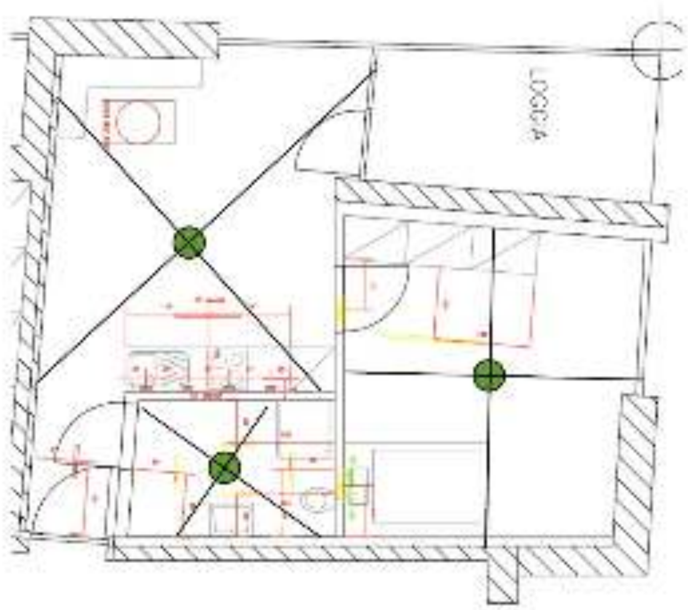
<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
</table>

<u>Lighting design and sensor positioning</u>

Installation, initial operation and photometrical approval

The initial control specification followed already available (cable based) switches. The switches were programmed accordingly to the new installed luminaires in every room area.

PIR-Sensor allocation:



Every room is equipped with a centred (cable-based) PIR-sensor which shows four sectors.

The apartment of VP5 showed single diffuse luminaires in the centre of every room. I.e. illuminance and luminance for the bathroom (smaller room) is comparatively high however values are low in the sleeping room.

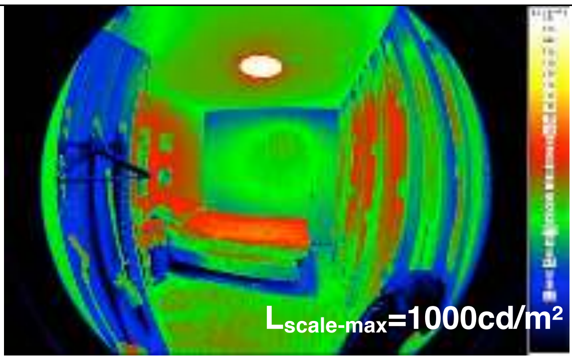
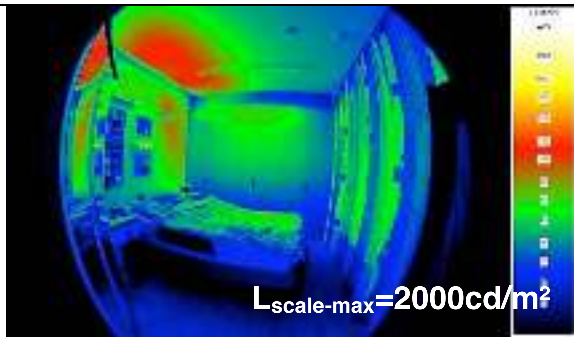
The illuminance values (horizontal) of approx. 250lx within the zonally areas of kitchen working space and living room desk are typical for such apartments.

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized on of 19.08.2013.

2.6 Apartment of test person VP6 - FHV (Götzis, AT)

Photometrical Situation

Bedroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td>
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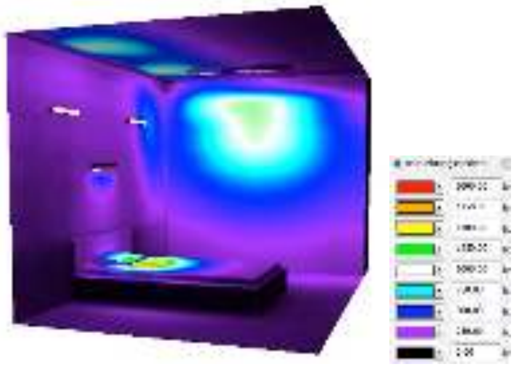
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
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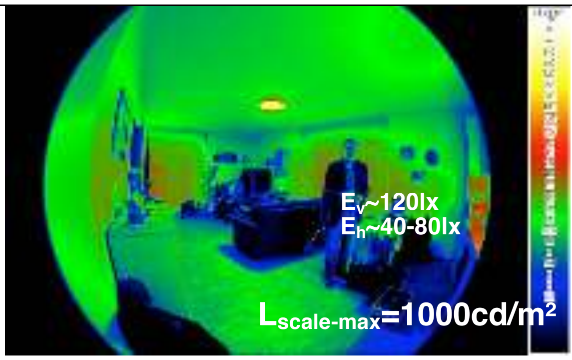
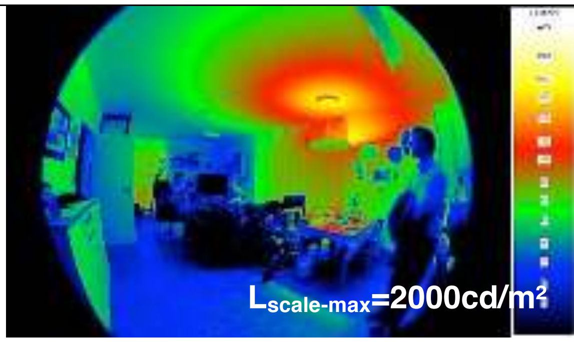
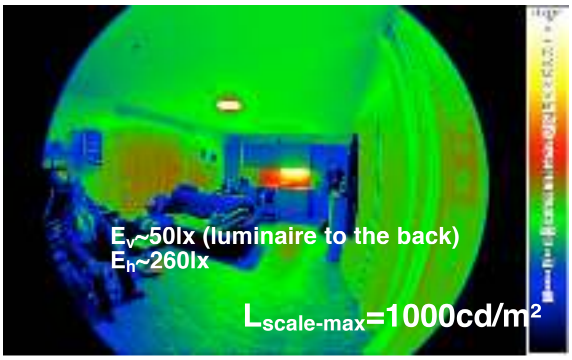
Living room / Kitchen

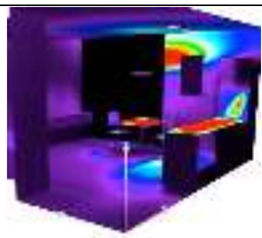




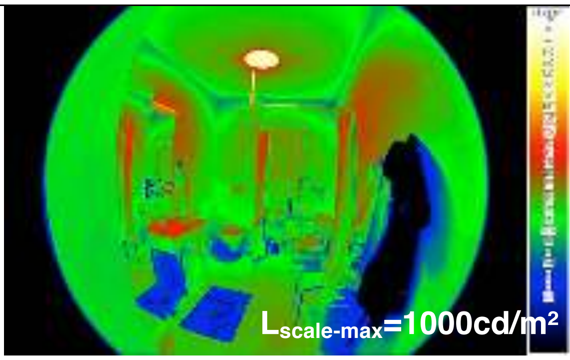
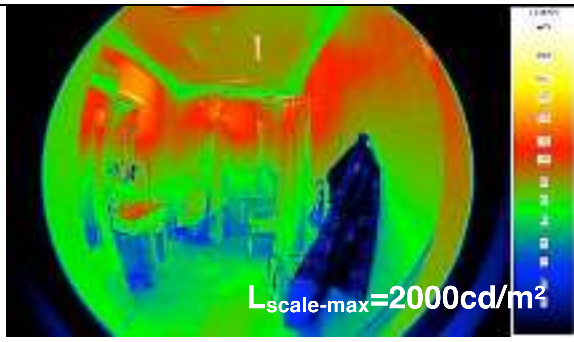


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right



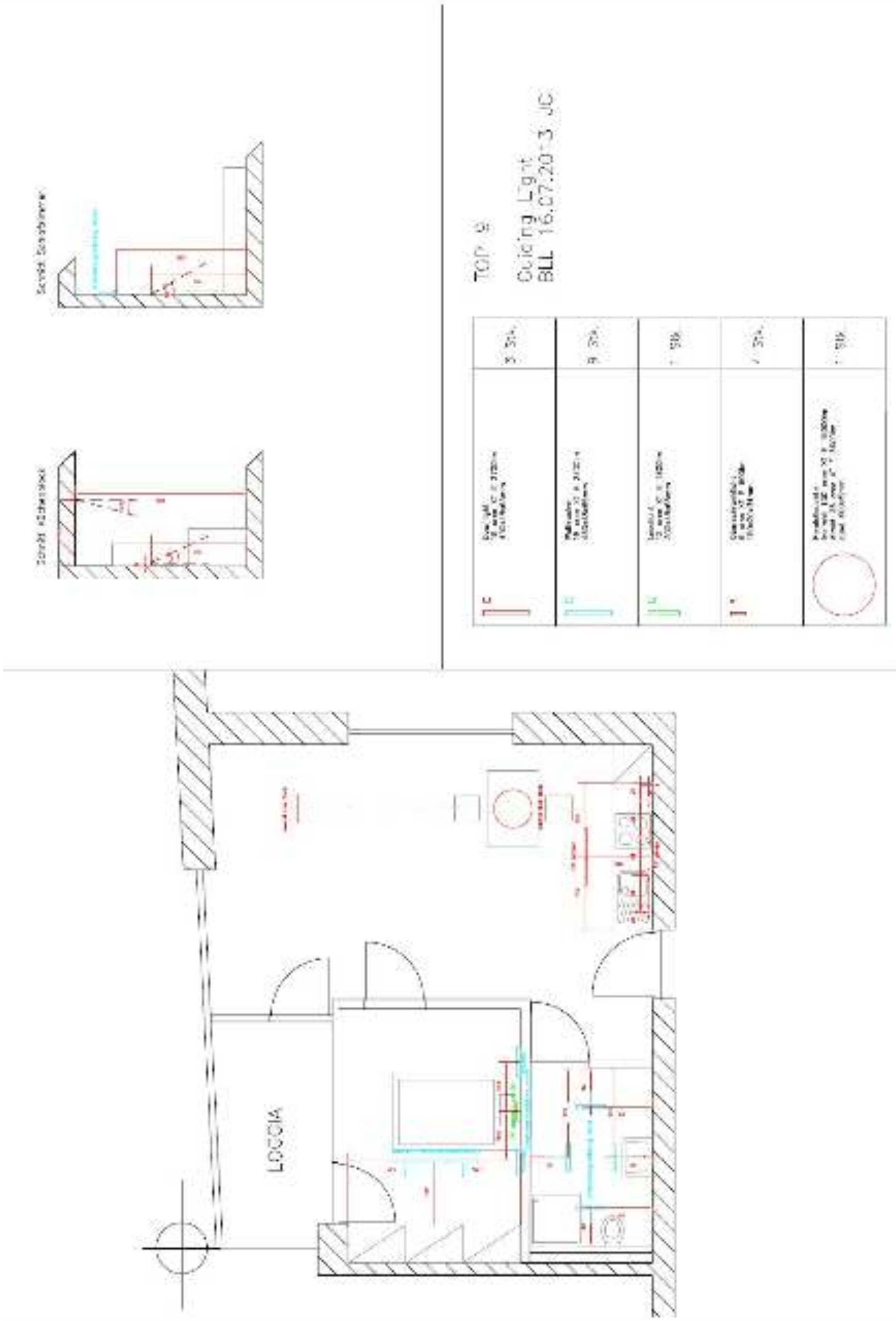
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	  CAD of bathroom implemented in simulation tool laterally reversed

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

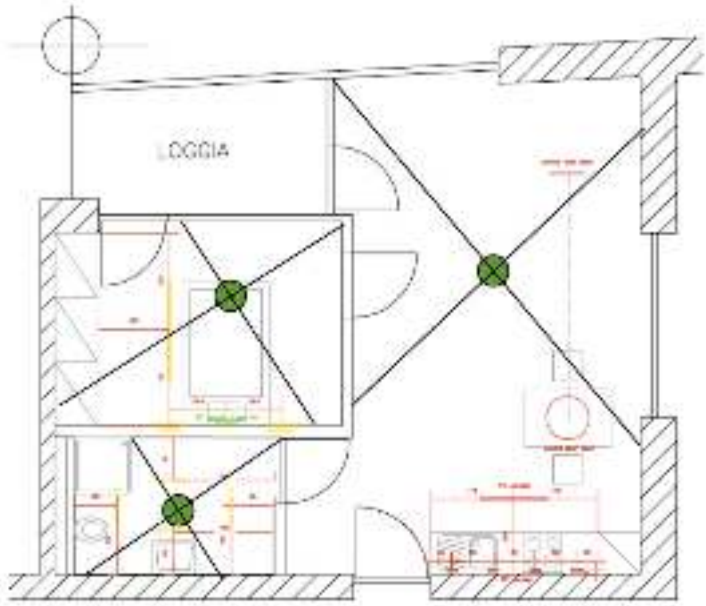
Lighting design and sensor positioning



<u>Installation, initial operation and photometrical approval</u>

The initial control specification followed already available (cable based) switches. The switches were programmed accordingly to the new installed luminaires in every room area.

PIR-Sensor allocation:



Every room is equipped with a centred (cable-based) PIR-sensor which shows four sectors.

The apartment of VP6 shows similarities to the apartment of VP5: single diffuse luminaires in the centre of every room, with the same illuminance result.
The illuminance values (horizontal) of approx. 250lx within the zonally areas of kitchen working space and living room desk are typical (and low) for such apartments.
The hardware installation was initial finalized with end of 19.08.2013.

Remark to apartment of VP5 and VP6:

In a first installation during June 2013 Guiding Light luminaires were on-wall mounted, unfortunately with a not justifiable appearance (see photo to the left). This problem was solved by installing gypsum board ceilings too (see photos above).

2.7 Apartment of test person VP7 - BB (Wörgl, AT)

<u>Photometrical Situation</u>

Bedroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
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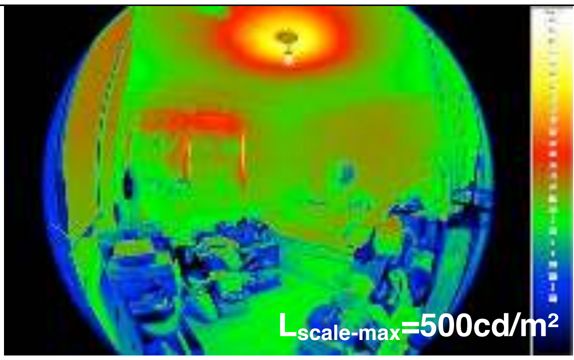
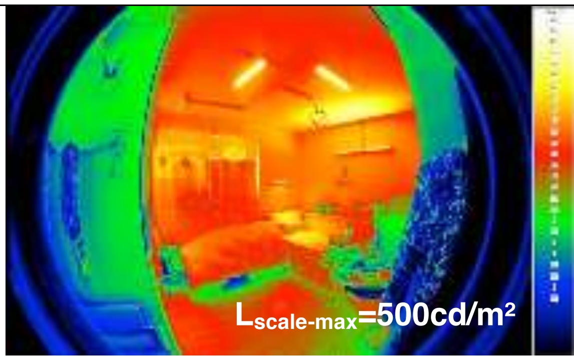
<tr><td>
</td><td>
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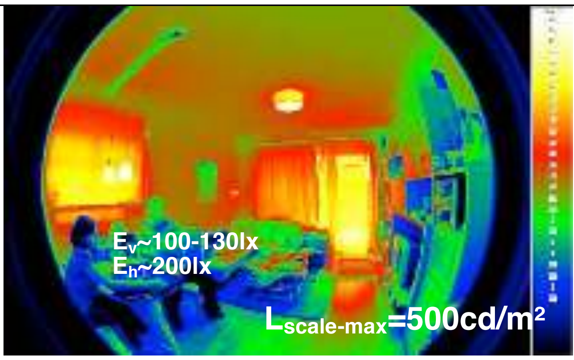
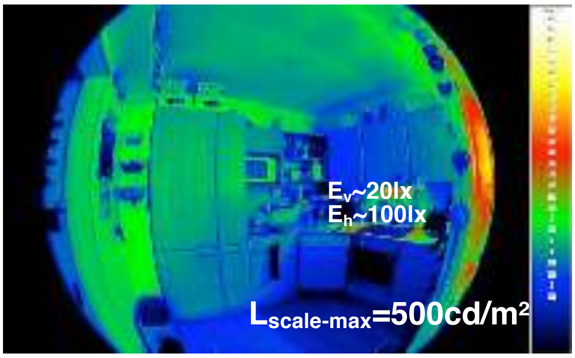
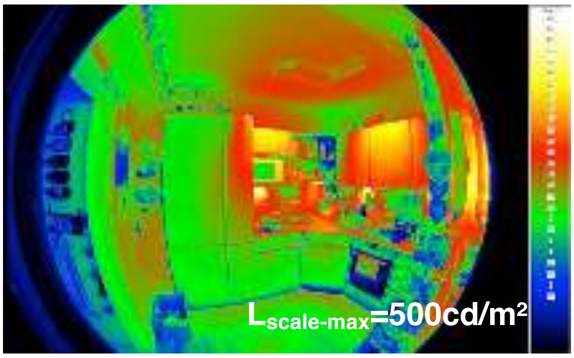
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

Living room / Kitchen

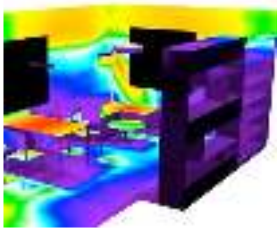


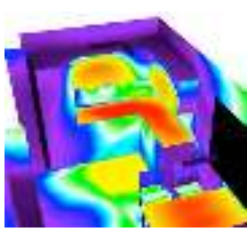




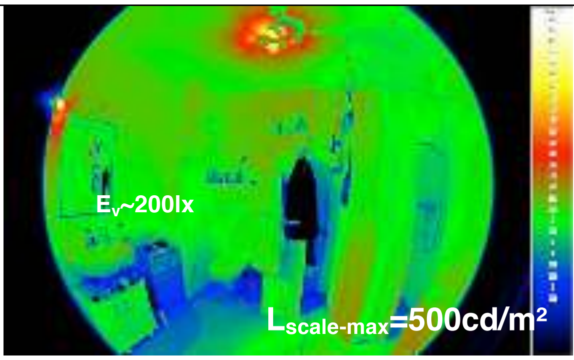
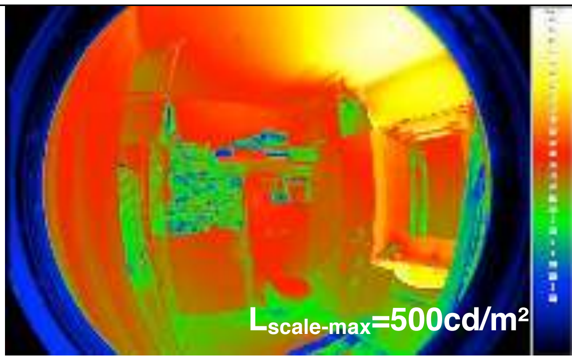
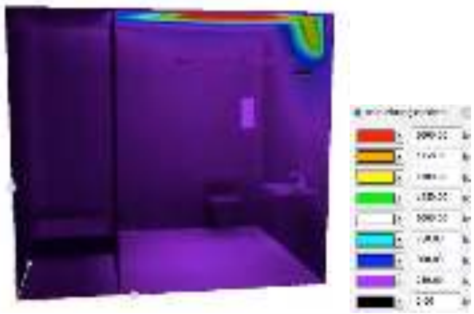
Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right





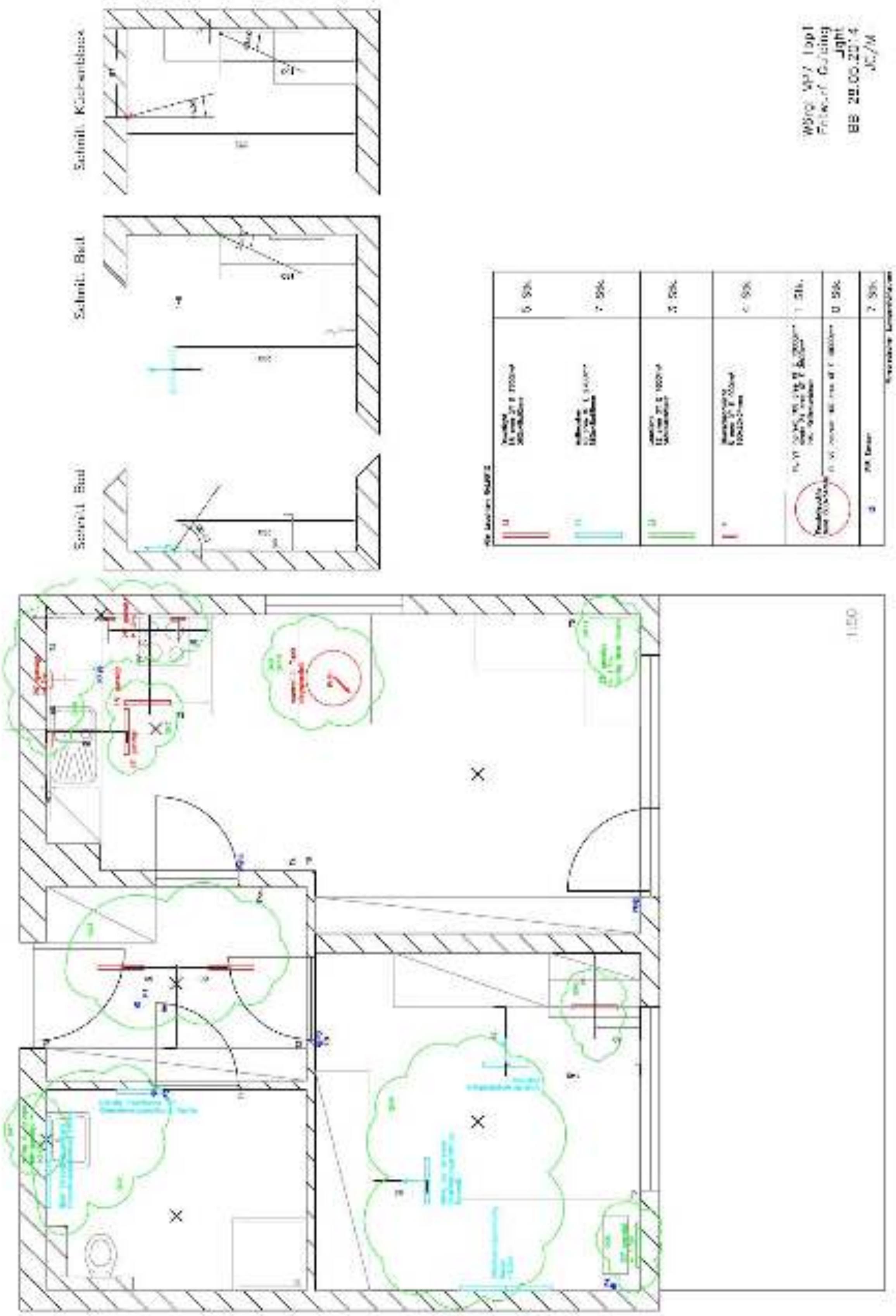
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 1 (Bathroom, mirror) (Actuator E1.1 and E1.2)
Switch 1 (right side)	Group 2 (Bathroom, general) (Actuator E2.1 and E2.2)
Switch 2 (left side)	Group 3 (Corridor) (Actuator E3.1 and E3.2)
Switch 2 (right side)	For test issues.
Switch 3 (left side)	Group 3 (Corridor) (Actuator E3.1 and E3.2)
Switch 3 (right side)	For test issues.
Switch 4 (left side)	Group 7 (Kitchen Downlights) (Actuator E7.1 and E7.2)
Switch 4 (right side)	Group 8 (Kitchen Wall unit) (Actuator E8.1 and E8.2)
Switch 5 (left side)	Group 11 (Wohnen Reading light) (Actuator E11.1 and E11.2)
Switch 5 (right side)	Group 10 (Suspended luminaire Indirect) (Actuator E10.1 and E10.2)
Switch 6 (left side)	Group 9 (Suspended luminaire Direct) (Actuator E9.1 and E9.2)
Switch 6 (right side)	Group 10 (Suspended luminaire Indirect) (Actuator E10.1 and E10.2)
Switch 7 (left side)	Group 5 (Reading light at bed) (Actuator E5.1 and E5.2)
Switch 7 (right side)	Group 4 (Sleeping room general) (Actuator E4.1 and E4.2)
Switch 8 (left side)	Group 6 (Downlight Sleeping room / PC-workplace) (Actuator E6.1 and E6.2)
Switch 8 (right side)	Group 4 (Sleeping room general) (Actuator E4.1 and E4.2)

PIR-Sensor allocation:

P1	Entrance
P2	Bathroom
P3	Sleeping room, entrance area
P4	Sleeping rom, bed area
P5	Living room, entrance area
P6	Living room, couch
P7	Kitchen
PIR-Test	For testing, directly mounted beside P3

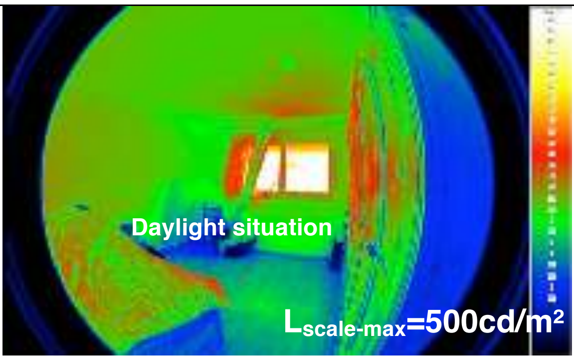
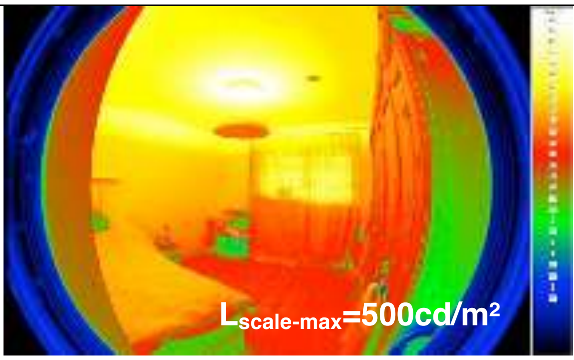
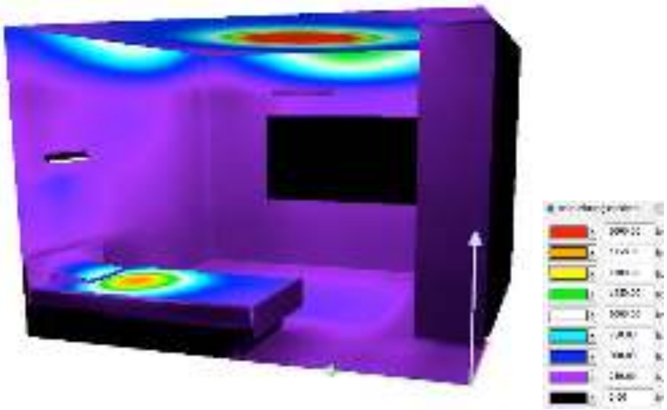
The kitchen zone of VP7 was not equipped with a ceiling based luminaire, only the cooker was equipped with a single lamp. Therefore the whole kitchen area had very low illuminance values. Within the living zone there were home-made luminaires, which achieved approx. 200lx of zonally horizontal illuminance. The sleeping room was illuminated with a room centred incandescent bulb. Person VP7 explained that new luminaires were planed, but this was refused due to the participation within the Guiding Light project. The bathroom was illuminated quite adequate.

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized with 03.03.2014.

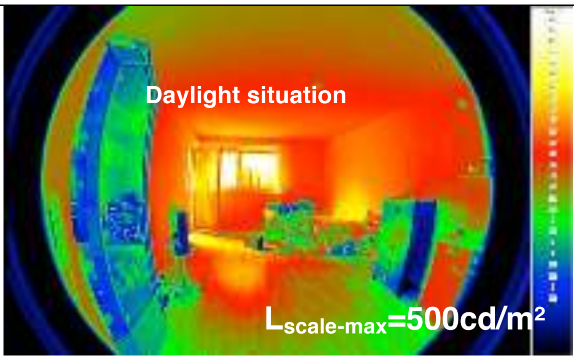
2.8 Apartment of test person VP8 - BB (Wörgl, AT)

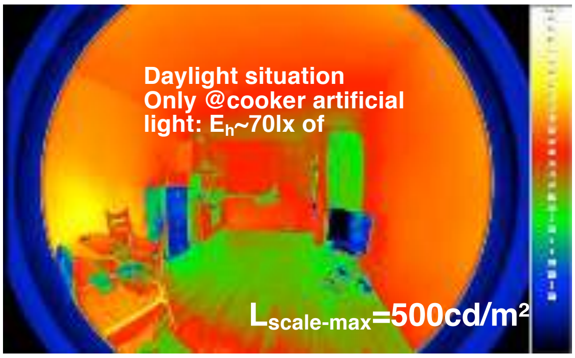
<u>Photometrical Situation</u>

Bedroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

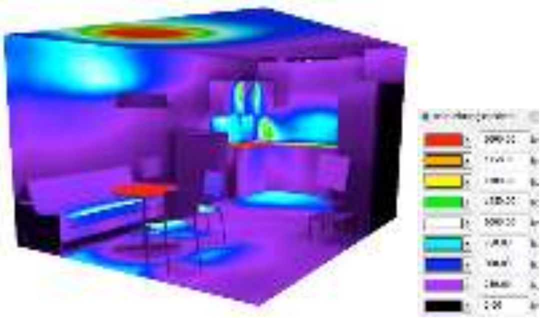
Living room / Kitchen



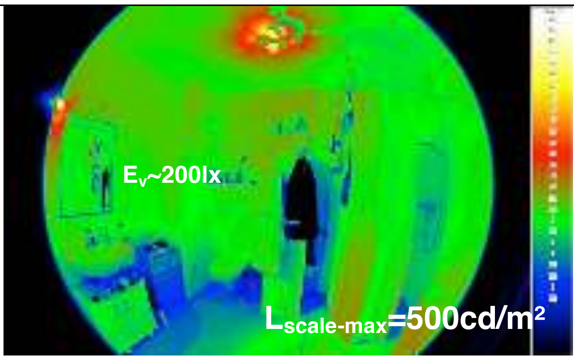
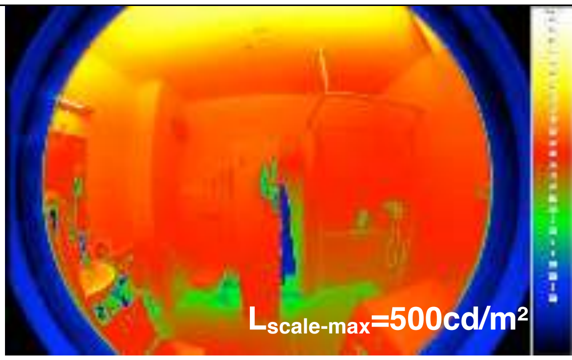


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right



Bathroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td>
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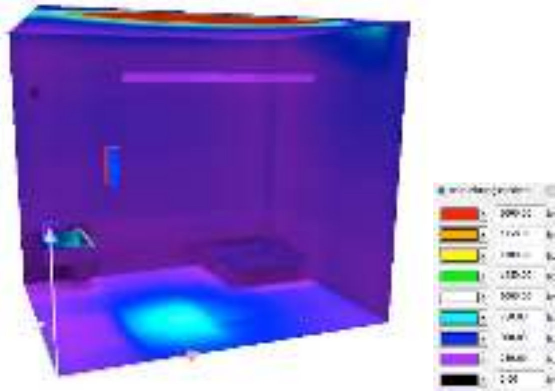
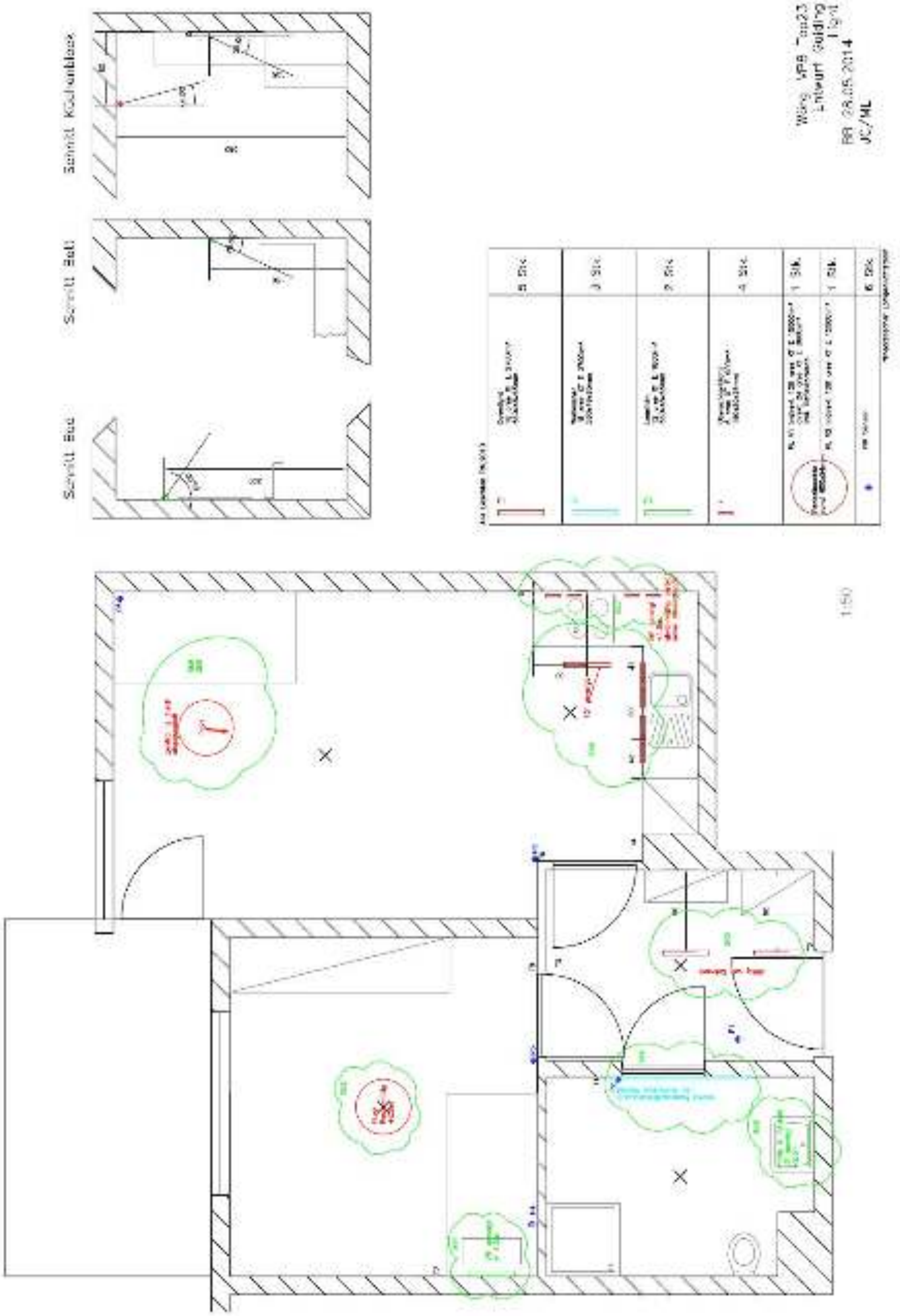
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

Corridor / entrance area

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
</table>

<u>Lighting design and sensor positioning</u>



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group 3 (Bathroom, mirror) (Actuator E3.1 and E3.2)
Switch 1 (right side)	Group 4 (Bathroom, general) (Actuator E4.1 and E4.2)
Switch 2 (left side)	Group 5 (Corridor) (Actuator E5.1 and E5.2)
Switch 2 (right side)	For test issues.
Switch 3 (left side)	Group 5 (Corridor) (Actuator E5.1 and E5.2)
Switch 3 (right side)	For test issues.
Switch 4 (left side)	Group 6 (Kitchen Downlights) (Actuator E6.1 and E6.2)
Switch 4 (right side)	Group 7 (Kitchen Wall unit) (Actuator E7.1 and E7.2)
Switch 5 (left side)	Similar to Switch 6
Switch 5 (right side)	Similar to Switch 6
Switch 6 (left side)	Group 8 (Suspended luminaire Direct) (Actuator E8.1 and E8.2)
Switch 6 (right side)	Group 9 (Suspended luminaire Indirect) (Actuator E9.1 and E9.2)
Switch 7 (left side)	Group 1 (Reading light at bed) (Actuator E1.1 and E1.2)
Switch 7 (right side)	Group 2 (Sleeping room general) (Actuator E2.1 and E2.2)
Switch 8 (left side)	Group 2 (Sleeping room general) (Actuator E2.1 and E2.2)
Switch 8 (right side)	For test issues.

PIR-Sensor allocation:

P1	Entrance, corridor
P2	Bathroom
P3	Sleeping room, entrance area
P4	Sleeping room, bed area
P5	Living room
P6	Kitchen

Test person VP8 had moved into this apartment with August 2013, i.e. only a cooker lamp and a bathroom luminaire were installed. Test person VP8 had some moveable floor lamps which were moved and adjusted every day (also between rooms or rather room zones).
The initial lighting situation of apartment of VP8 was very poor (except the bathroom which was illuminated adequate).

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized on 20.03.2014.

Within this apartment it was possible for the first time (and approved by the test person) to realize exactly all details of the lighting design guidelines [4]. From special interest is the ("modified", i.e. without direct component) suspended luminaire for the sleeping room illumination. Within the summary of this deliverable a comparison is made to the other sleeping room lightings (of the other field test apartments).

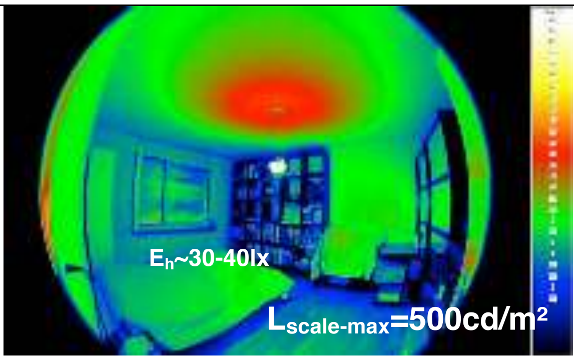
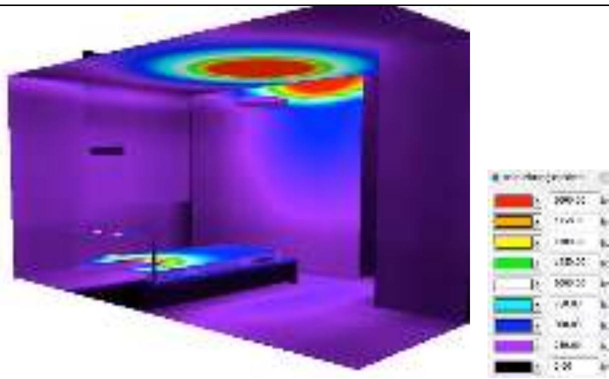
2.9 Apartment of test person VP9 - MVA (Zürich, CH)

For the apartment of VP9 (and also of VP10 and VP18) the market offered in the meantime a hardware upgrade for the EnOcean-actuator. This enhancement was implemented.

With the new actuator "SRC-AO MULTI" from Thermokon [5] wiring work (wiring actuator to luminaire at site) for the electrician was significantly decreased and due to the fact that this actuator has two outputs the number of needed actuators is cut into half.[4]

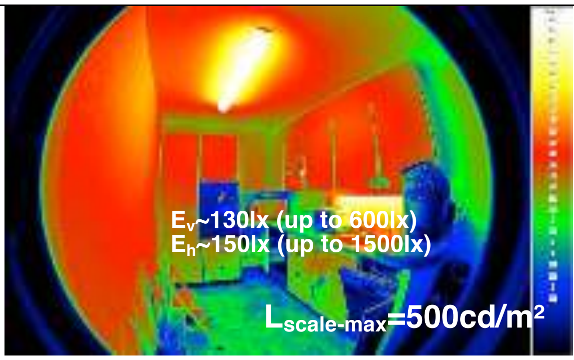
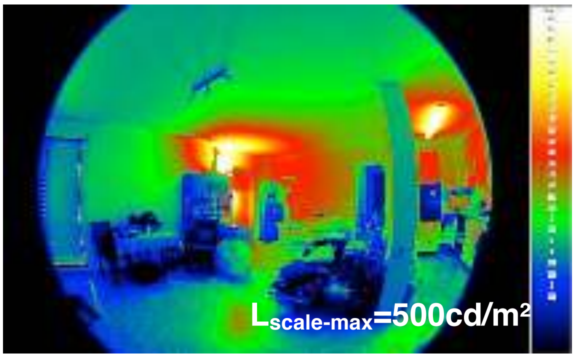
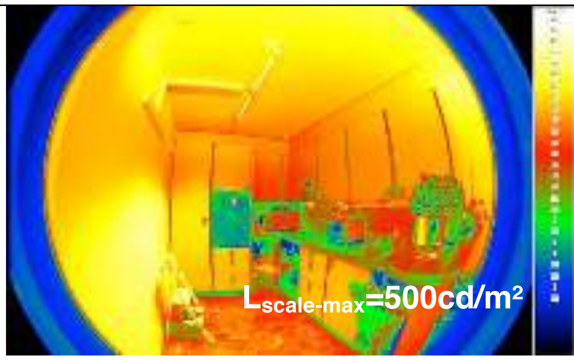
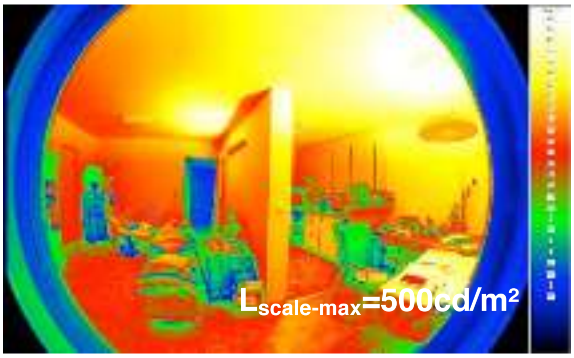
<u>Photometrical Situation</u>

Bedroom

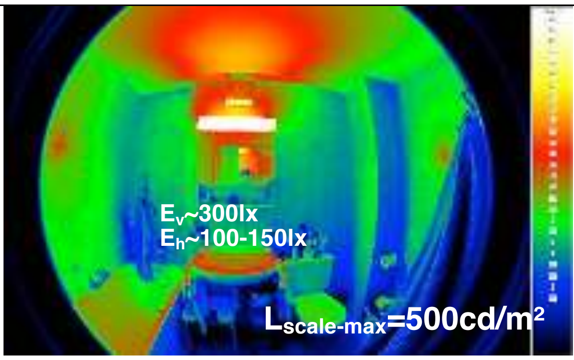
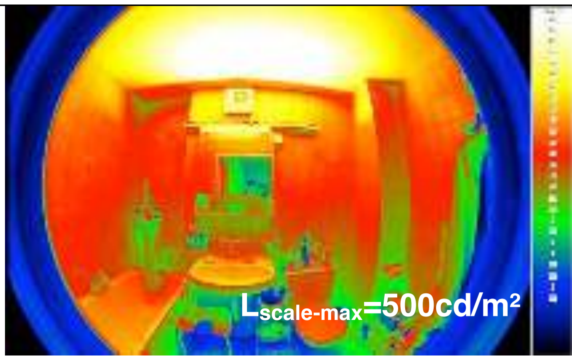
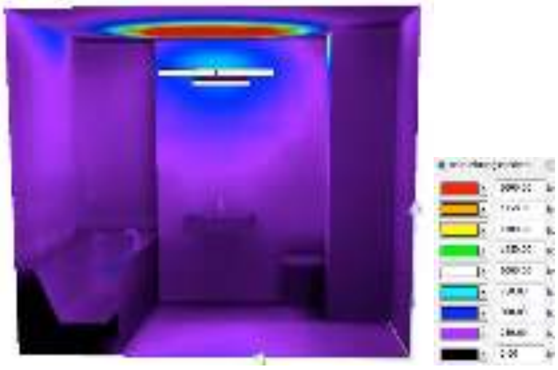
<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Legend:
• HDR picture
• Luminance picture [cd/m²]
• Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

[4] Remark: As soon as the market offers electrical ballast which is directly EnOcean controlled no more "actuators" are needed for the technical Guiding Light system approach. This is an important technical detail for the business model and further technical enhancements.

Living room / Kitchen

 	 
 	 
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

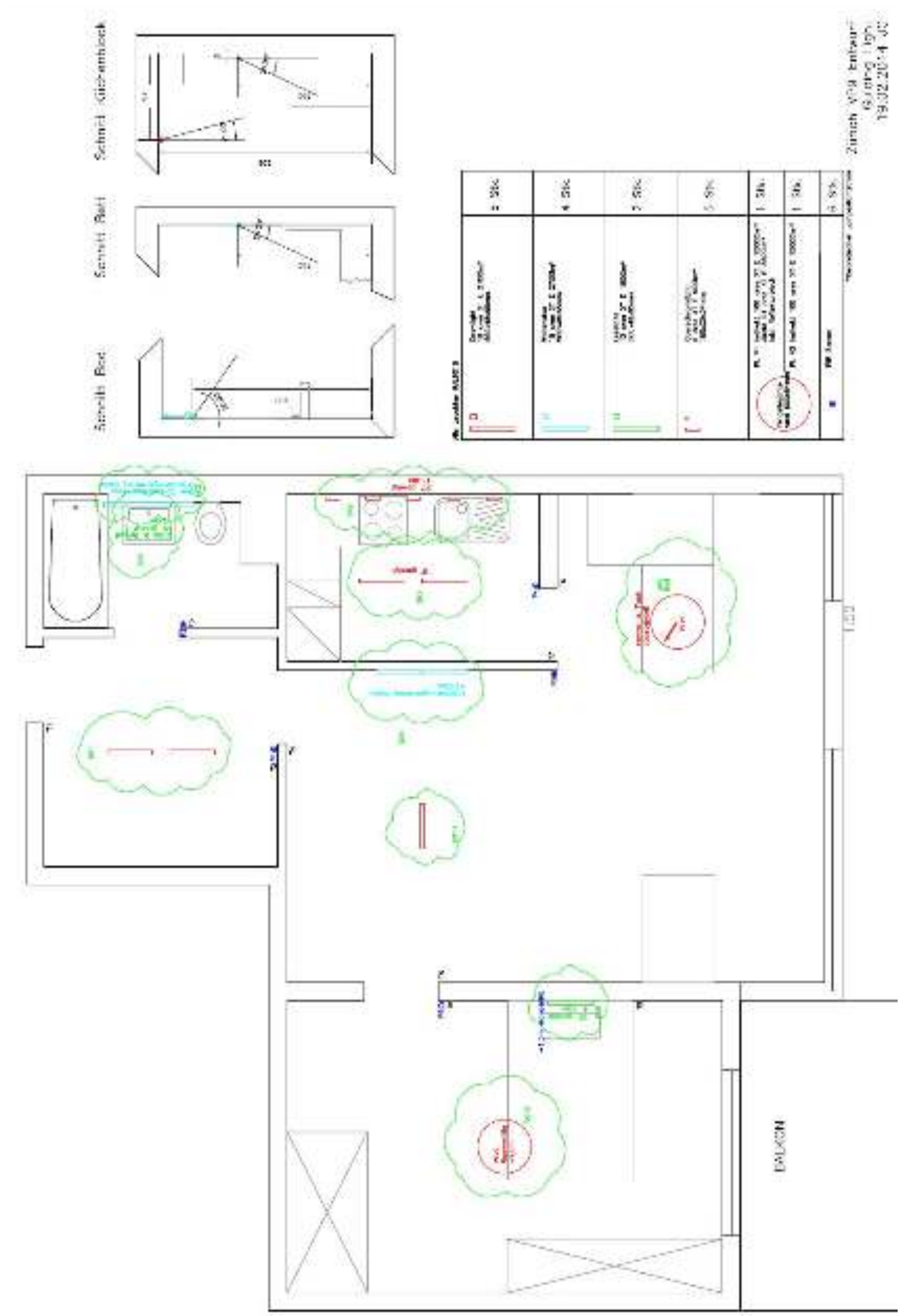
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group SK1 (Corridor) (Actuator E1.1 and E1.2)
Switch 1 (right side)	For test issues.
Switch 2 (left side)	Group SK1 (Corridor) (Actuator E2.1 and E2.2)
Switch 2 (right side)	For test issues.
Switch 3 (left side)	Group SK2 (Bathroom, mirror) (Actuator E2.1 and E2.2)
Switch 3 (right side)	Group SK3 (Bathroom, general) (Actuator E3.1 and E3.2)
Switch 4 (left side)	Group SK4 & SK11 (Living area general) (Actuator E4.1 and E4.2 & Actuator E11.1 and E11.2)
Switch 4 (right side)	Group SK6 (Suspended luminaire Indirect) (Actuator E6.1 u. E6.2)
Switch 5 (left side)	Group SK4 & SK11 (Living area general) (Actuator E4.1 and E4.2 & Actuator E11.1 and E11.2)
Switch 5 (right side)	Group SK6 (Suspended luminaire Indirect) (Actuator E6.1 u. E6.2)
Switch 6 (left side)	Group SK5 (Suspended luminaire Direct) (Actuator E5.1 and E5.2)
Switch 6 (right side)	Group SK6 (Suspended luminaire Indirect) (Actuator E6.1 u. E6.2)
Switch 7 (left side)	Group SK7 (Kitchen Downlights) (Actuator E7.1 and E7.2)
Switch 7 (right side)	Group SK8 (Kitchen Wall unit) (Actuator E8.1 and E8.2)
Switch 8 (left side)	Group SK9 (Sleeping area Suspended luminaire) (Actuator E9.1 and E9.2)
Switch 8 (right side)	Group SK10 (Sleeping area Reading light) (Actuator E10.1 and E10.2)
Switch 9 (left side)	Group SK9 (Sleeping area Suspended luminaire) (Actuator E9.1 and E9.2)
Switch 9 (right side)	Group SK10 (Sleeping area Reading light) (Actuator E10.1 and E10.2)

PIR-Sensor allocation:

P1	Entrance, corridor
P2	Bathroom
P3	Living room
P4	Kitchen
P5	Sleeping room, entrance area
P6	Sleeping room, bed area

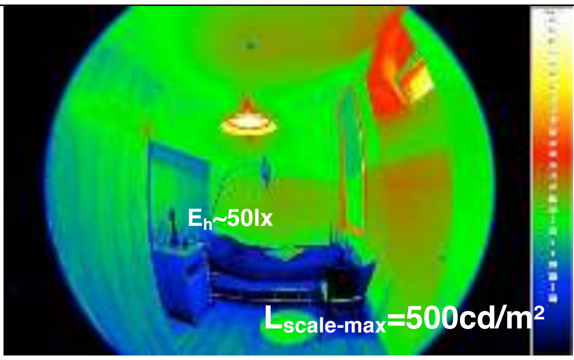
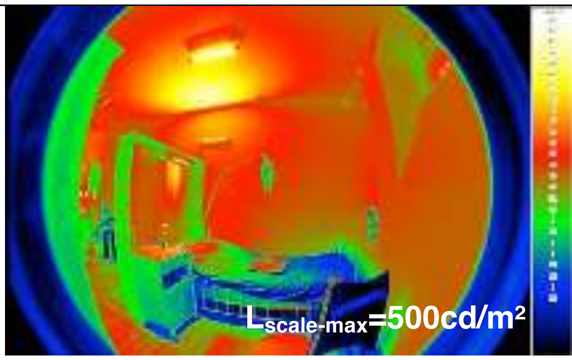
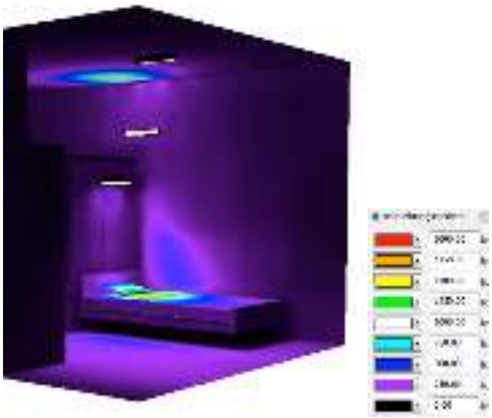
Apartment of VP9 showed partially in the kitchen area (at the washing sink) a significantly high illuminance (horizontal up to 1500lx). The desk in the living room area, the bathroom and especially the sleeping room and the entrance area showed a low illuminance with values below 200lx (mostly below 100lx). Within the living room there were damaged luminaires which were not been repaired and it was not foreseen to repair it.

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized with end of June 2014.

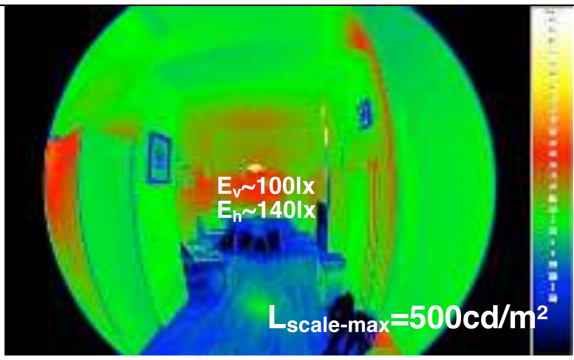
2.10 Apartment of test person VP10 - Apollis (Neumarkt, ITA)

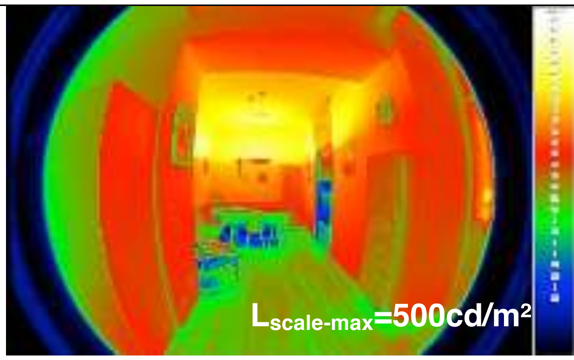
<u>Photometrical Situation</u>

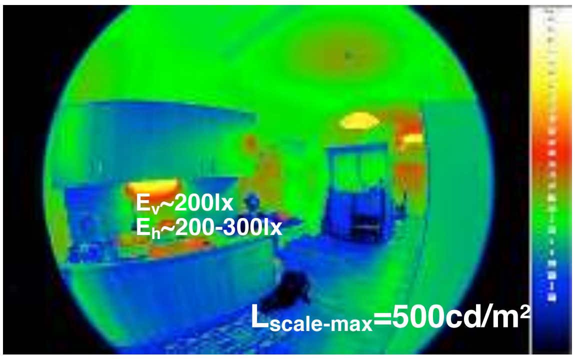
Bedroom

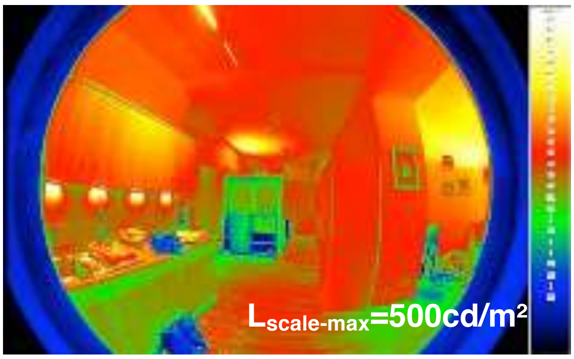
Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Living room / Kitchen



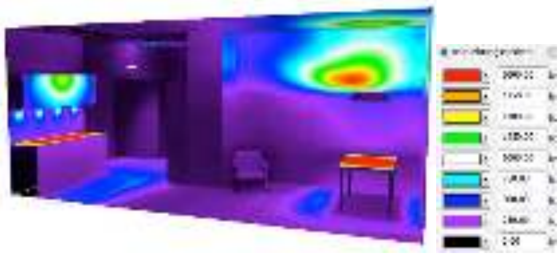




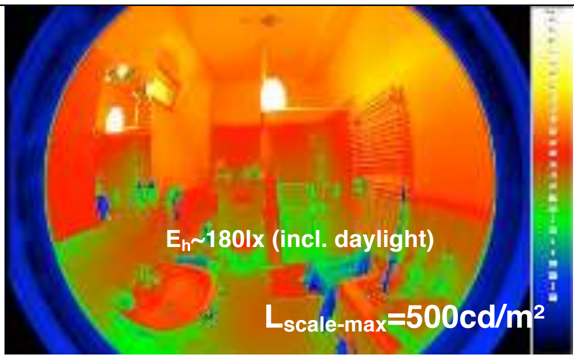
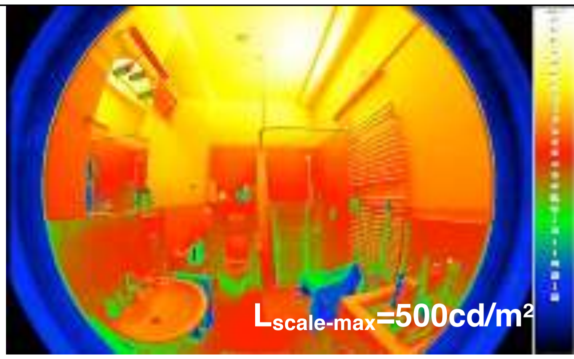
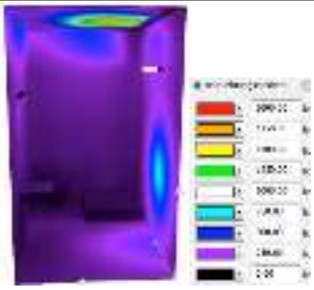


Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right



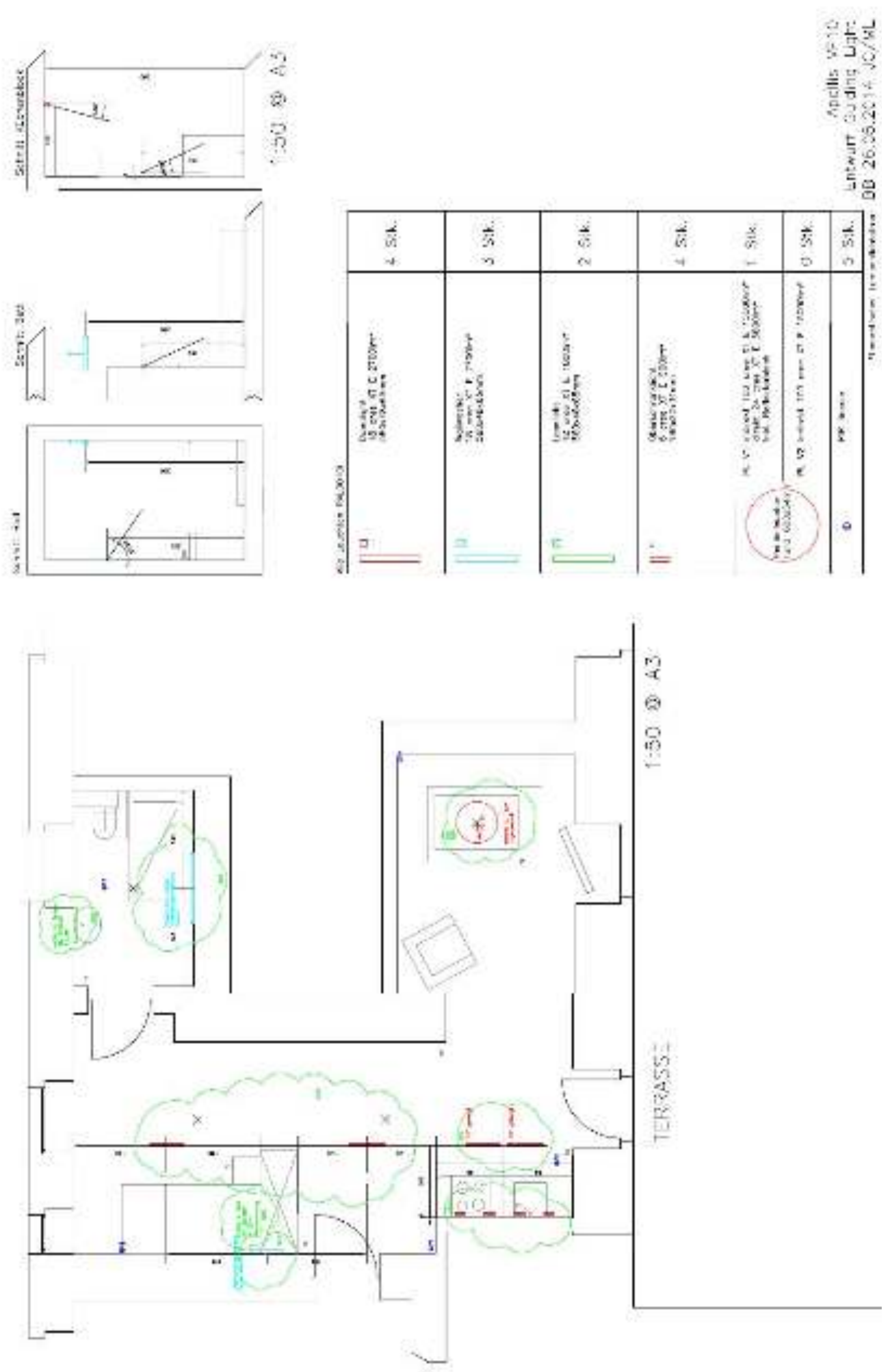
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

Lighting design and sensor positioning



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (left side)	Group SK3 (Corridor) (Actuator E3.1 and E3.2)
Switch 1 (right side)	Group SK4 (Wallwasher entrance area Actuator E4.1 and E4.2)
Switch 2 (left side)	Group SK3 (Corridor) (Actuator E3.1 and E3.2)
Switch 2 (right side)	Group SK4 (Wallwasher entrance area Actuator E4.1 and E4.2)
Switch 3 (left side)	Group SK6 (Bathroom, mirror) (Actuator E6.1 and E6.2)
Switch 3 (right side)	Group SK7 (Bathroom, general) (Actuator E7.1 and E7.2)
Switch 4 (left side)	Group SK8 (Suspended luminaire Direct) (Actuator E8.1 and E8.2)
Switch 4 (right side)	Group SK9 (Suspended luminaire Indirect) (Actuator E9.1 u. E9.2)
Switch 5 (left side)	For test issues.
Switch 5 (right side)	For test issues.
Switch 6 (left side)	Group SK1 (Kitchen Downlights) (Actuator E1.1 and E1.2)
Switch 6 (right side)	Group SK2 (Kitchen Wall unit) (Actuator E2.1 and E2.2)
Switch 7 (left side)	Group SK3 (Corridor) (Actuator E3.1 and E3.2)
Switch 7 (right side)	Group SK5 (Sleeping area Reading light) (Actuator E5.1 and E5.2)
Switch 8 (left side)	Without current setting.
Switch 8 (right side)	Without current setting.

PIR-Sensor allocation:

P1	Entrance
P2	Kitchen
P3	Living room
P4	Sleeping room
P5	Bathroom

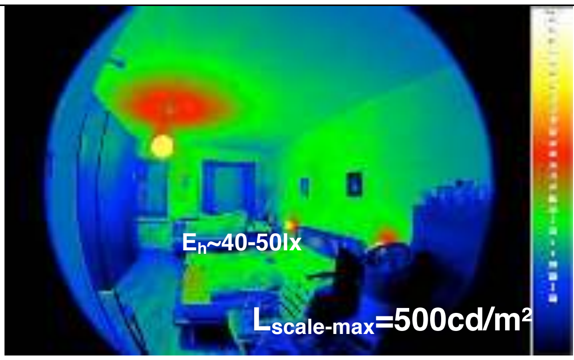
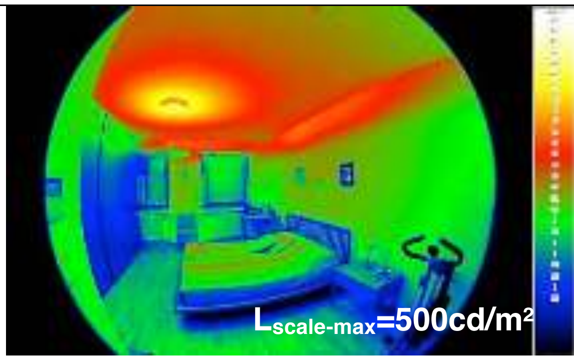
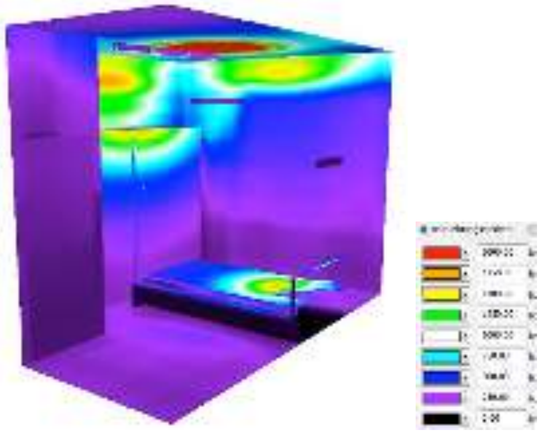
The whole apartment of test person VP10 showed a poor illumination situation. All areas showed low illuminance values within the initial situation.
Due to the fact that VP10 used originally several suspended luminaires this apartment showed already low glare in the initial situation.

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized with 18.06.2014.

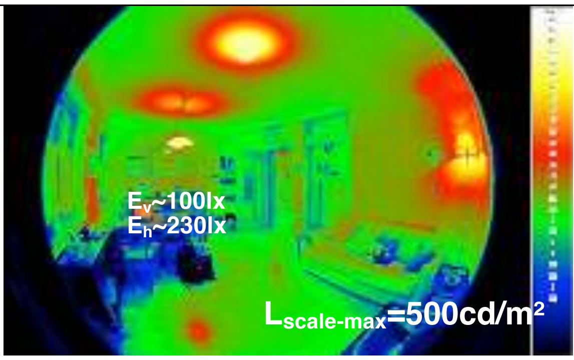
2.11 Apartment of test person VP18 - Apollis (Bozen, ITA)

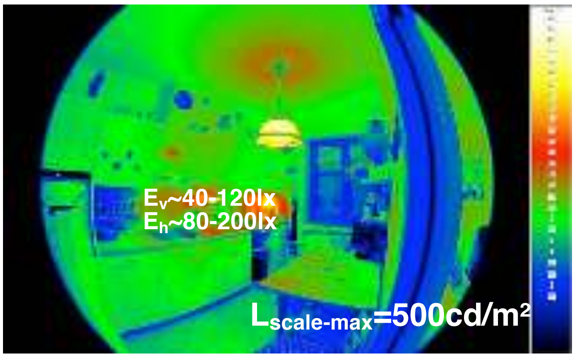
<u>Photometrical Situation</u>

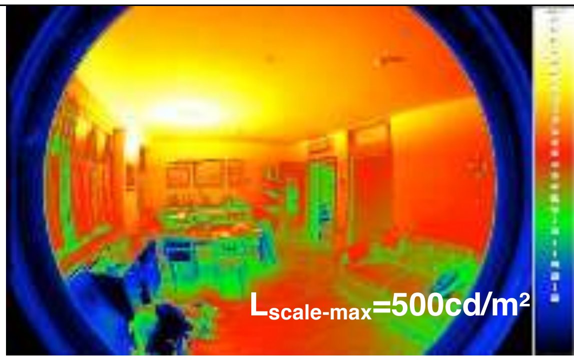
Bedroom

<table>
<tr><th>Initial situation</th><th>Implemented Guiding Light</th></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Legend:
HDR picture
Luminance picture [cd/m²]
Simulation (illuminance) [lx], to the right</td><td></td></tr>
</table>

Livingroom / Kitchen



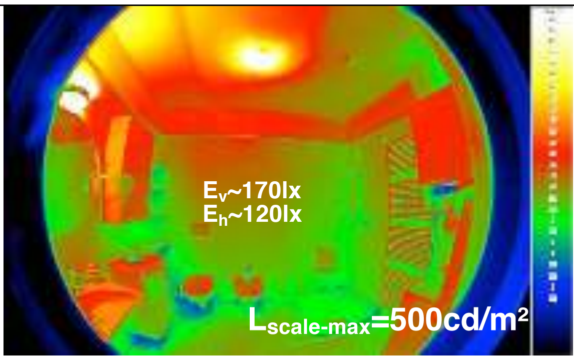
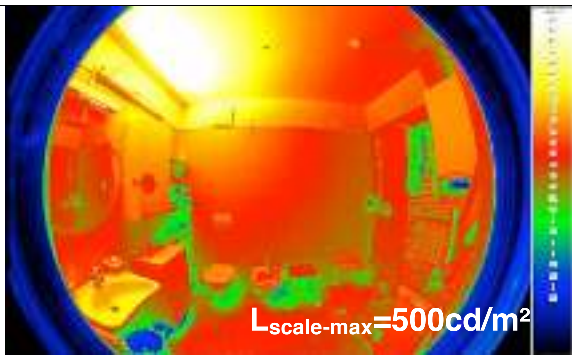
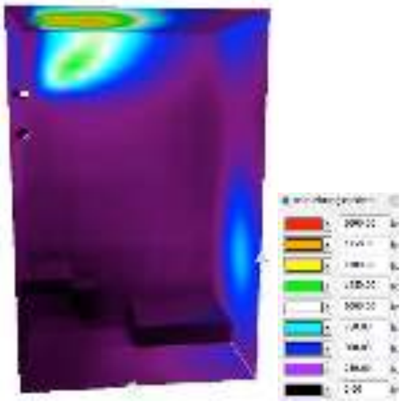




Legend:

- HDR picture
- Luminance picture [cd/m²]
- Simulation (illuminance) [lx], to the right

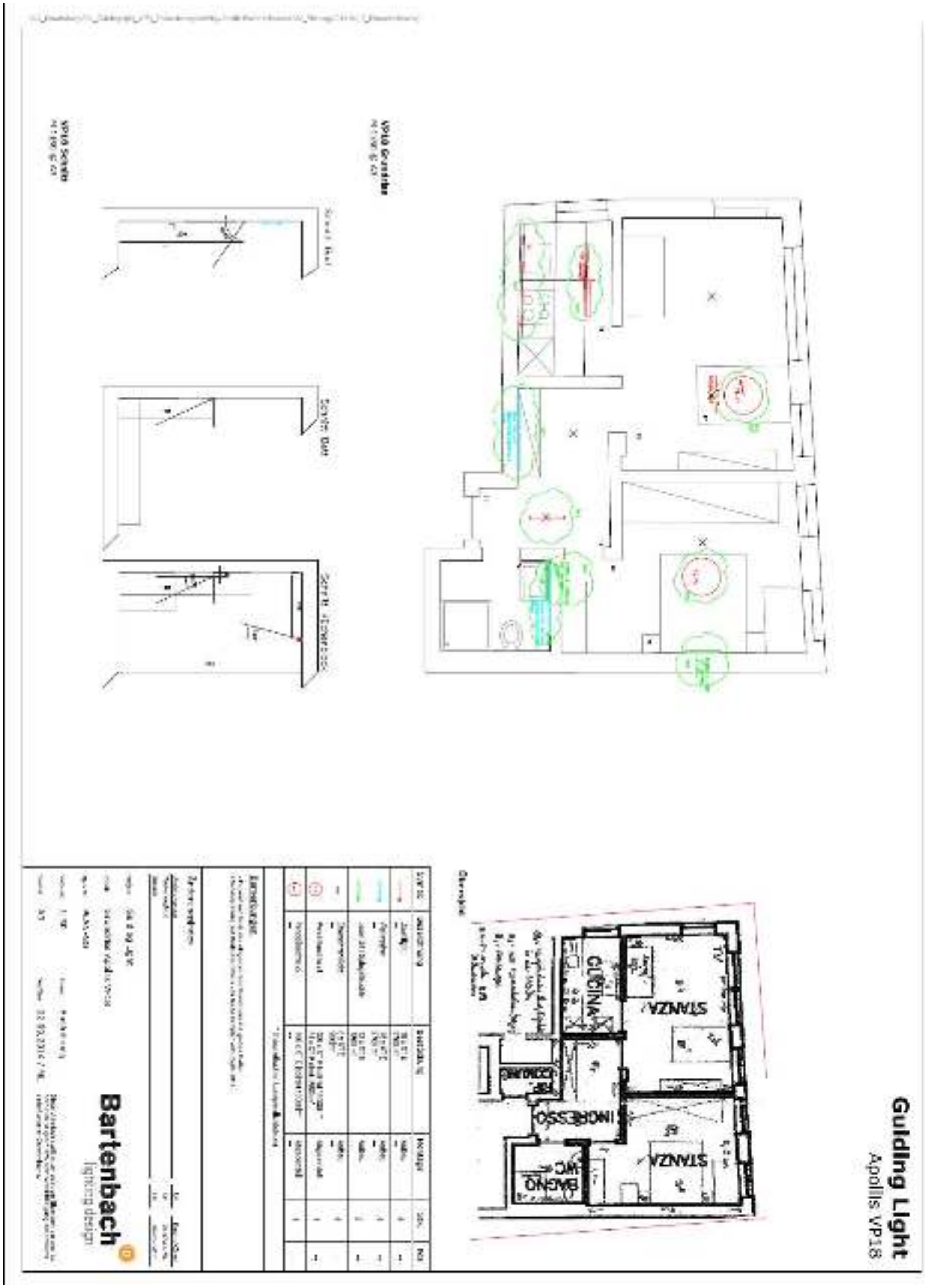
Bathroom

Initial situation	Implemented Guiding Light
	
	
Legend: • HDR picture • Luminance picture [cd/m²] • Simulation (illuminance) [lx], to the right	

Corridor / entrance area

Initial situation	Implemented Guiding Light
	

<u>Lighting design and sensor positioning</u>



Installation, initial operation and photometrical approval

Initial control specification:

Switch 1 (no special side)	Group SK8 (Corridor) (Actuator A8.1 and A8.2)
Switch 2 (no special side)	Group SK8 (Corridor) (Actuator A8.1 and A8.2)
Switch 3 (left side)	Group SK2 (Suspended luminaire Direct) (Actuator E2.1 and E2.2)
Switch 3 (right side)	Group SK3 (Suspended luminaire Indirect) (Actuator E3.1 u. E3.2)
Switch 4 (left side)	Group SK9 (Bathroom, mirror) (Actuator E9.1 and E9.2)
Switch 4 (right side)	Group SK10 (Bathroom, general) (Actuator E10.1 and E10.2)
Switch 5 (left side)	Group SK4 (Sleeping area Suspended luminaire) (Actuator E4.1 and E4.2)
Switch 5 (right side)	Group SK5 (Sleeping area Reading light) (Actuator E5.1 and E5.2)
Switch 6 (left side)	Group SK4 (Sleeping area Suspended luminaire) (Actuator E4.1 and E4.2)
Switch 6 (right side)	Group SK5 (Sleeping area Reading light) (Actuator E5.1 and E5.2)
Switch 7 (left side)	For test issues.
Switch 7 (right side)	For test issues.
Switch 8 (left side)	Group SK6 (Kitchen Downlights) (Actuator E6.1 and E6.2)
Switch 8 (right side)	Group SK7 (Kitchen Wall unit) (Actuator E7.1 and E7.2)

PIR-Sensor allocation:

P1	Kitchen
P2	Living room, at desk area
P3	Living room, couch
P4	Living room, sensor centred
P5	Entrance area in living room direction
P6	Entrance area - door
P7	Sleeping room
P8	Bathroom

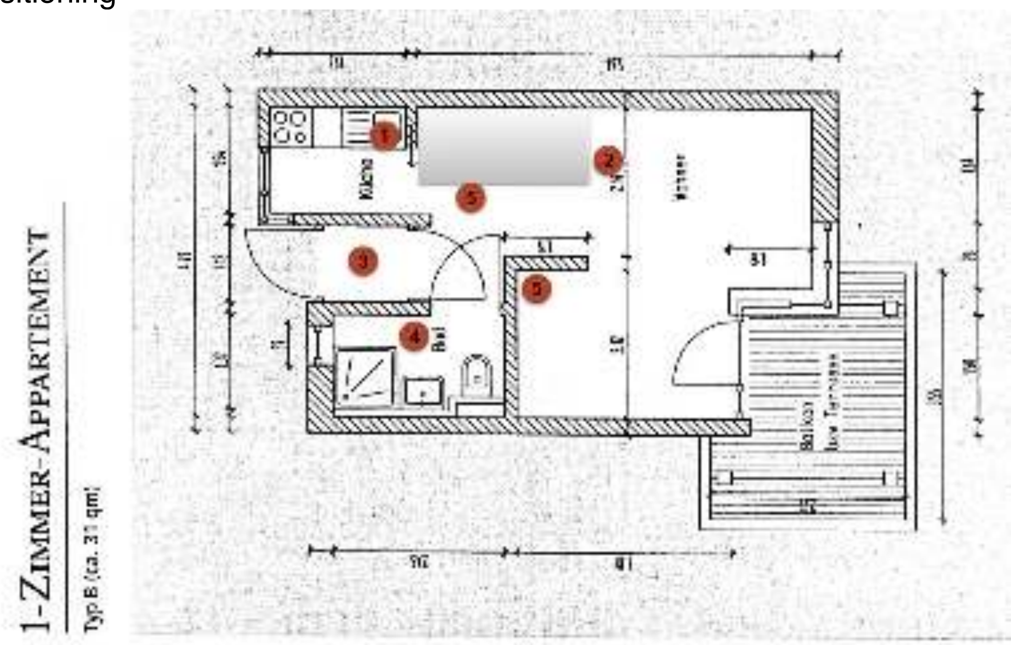
Apartment of test person VP18 reached partially illuminance >200lx of artificial light at important zones (desk, kitchen working area). The illuminance within the sleeping room is very low with values not exceeding approx. 50lx.

The Guiding Light hardware installation (ambient light up to 300lx and zonally task light up to 2000lx) was initial finalized with 25.07.2014.

3. Implementation Guiding Light control group

3.1 Apartment of test person VP11 - YOUSE (Vatterstetten, DE)

Sensor positioning



1: Küchenzone, 2: Wohnzone, 3: Eingangszone, 4: Badezone, 5: Schlafzone, optional 6: Flurzone

PIR#	Zone	Remark
1	Kitchen	
2	Living room	Central at dining table mounted, most stays are expected there
3	Entrance	
4	Bathroom	Also used as smoker room
5	Sleeping room	+ Passage to balcony
6	-	Omitted since before cabinet no "dressing area"

PIR1	PIR2
	

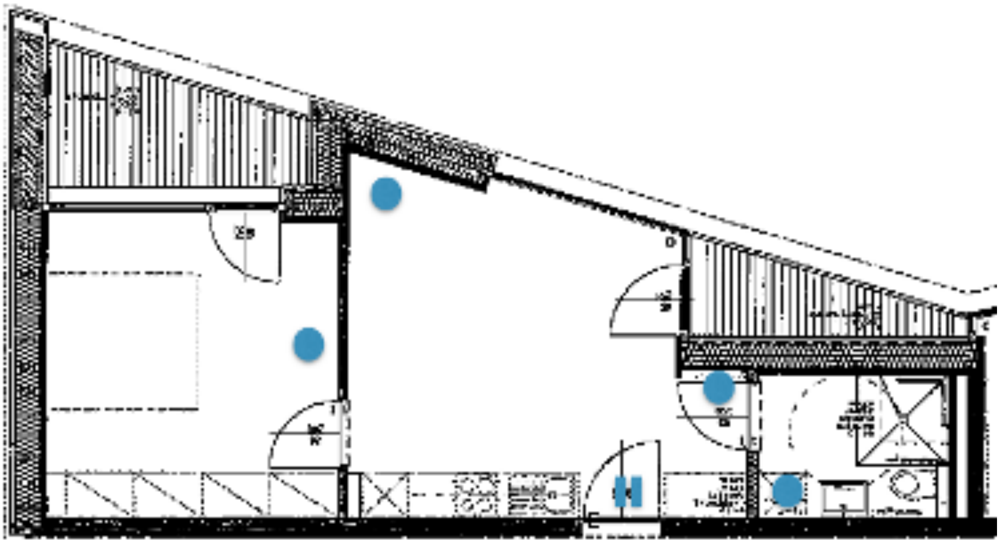
PIR3	PIR4	PIR5
		

The optimal positions of the PIR sensors were determined during an on-site visit on 28.10.2014. Hardware implementation was finalized until 03.11.2014.

3.2 Apartment of test person VP12 - FHV (Götzis, AT)

VP12 is physically handicapped and uses a wheelchair as well a lifting device to go to bed. The person is able to manage her life independently.

Sensor positioning

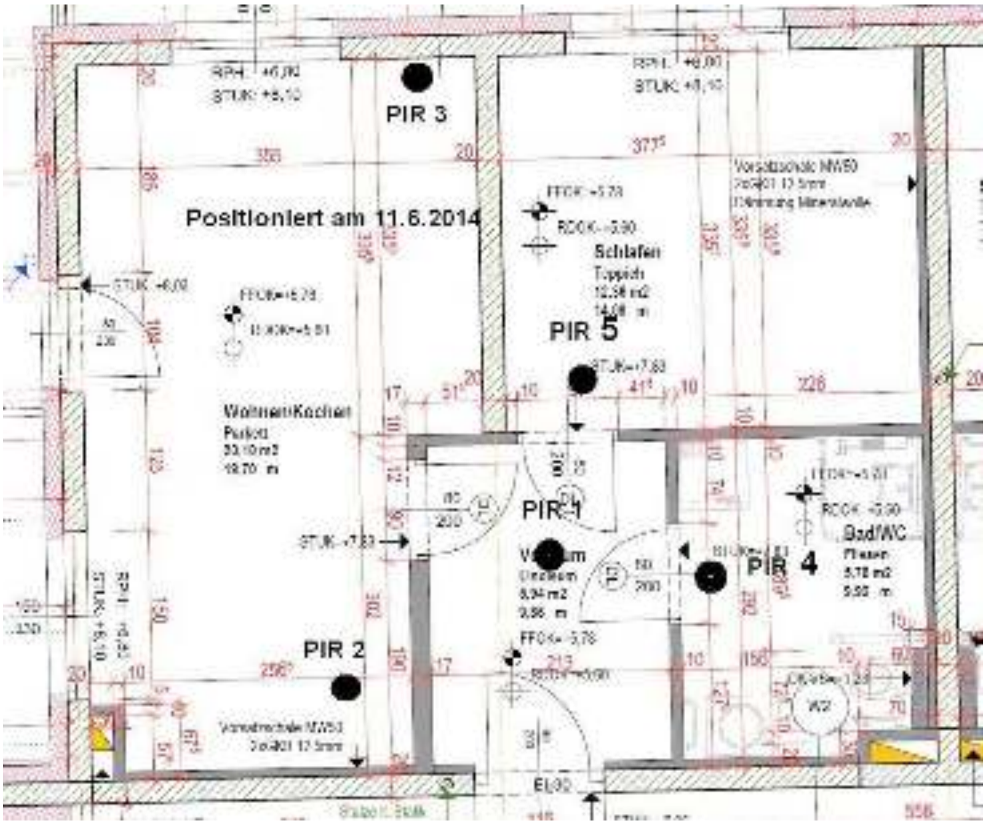


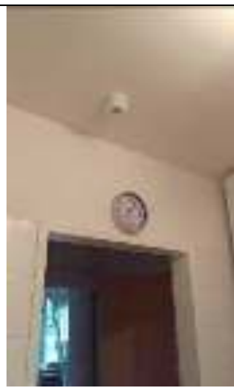
PIR#	Zone	Remark
1	Living room	sensor in the corner covers typical sitting position at table
2	Kitchen	sensor in the living room behind a corner covers only the kitchen unit
4	Bathroom	one sensor covers whole bathroom
5	Sleeping room	one sensors central in front of bed covers the whole room; bed with lifting device
6	Entrance	door contact switches

The hardware implementation was initial finalized on 14.06.2014

3.3 Apartment of test person VP13 - BB (Wörgl, AT)

Sensor positioning



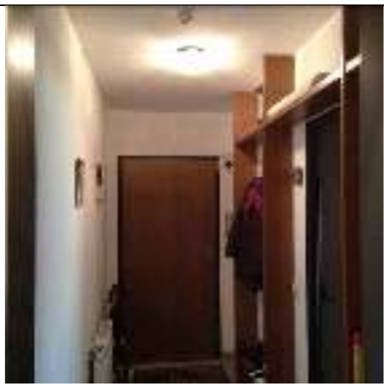
PIR1	PIR2	PIR3	PIR4	PIR5
				

PIR1 = Corridor, entrance
PIR2 = Kitchen
PIR3 = Living room
PIR4 = Bathroom
PIR5 = Sleeping room

The hardware implementation was initial finalized on 11.06.2014

3.4 Apartment of test person VP14 - MVA (Hard, AT)

Sensor positioning

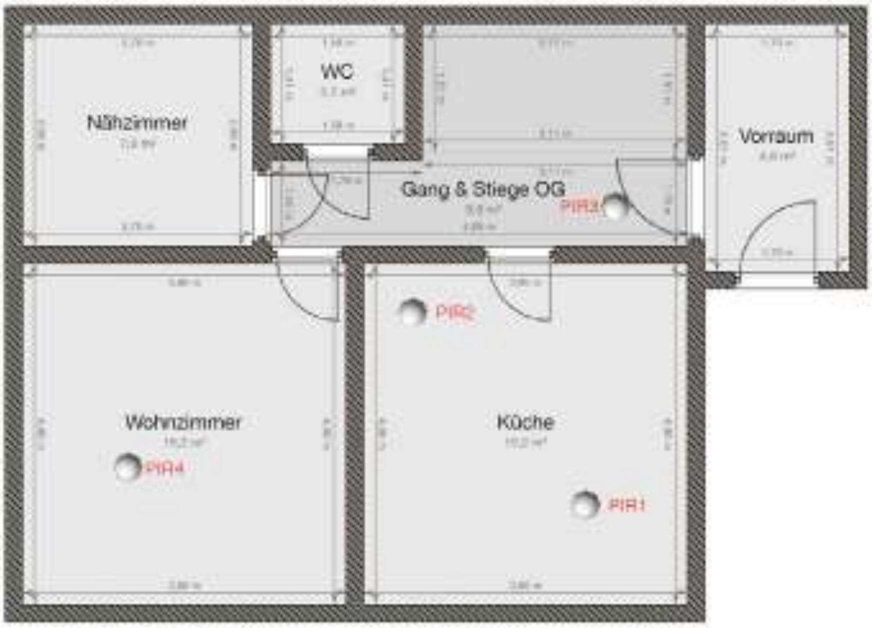
PIR1	PIR2	PIR3
		
PIR4	PIR5	
		

PIR1 = bath room ("Raum 5")
PIR2 = corridor ("Raum 6")
PIR3 = kitchen zone ("Raum 1")
PIR4 = living room ("Raum 2")
PIR5 = sleeping zone ("Raum 3")

The hardware implementation was initial finalized July 10th 2014.

3.5 Apartment of test person VP15 - MVA (Hard, AT)

Sensor positioning - top view 1st floor



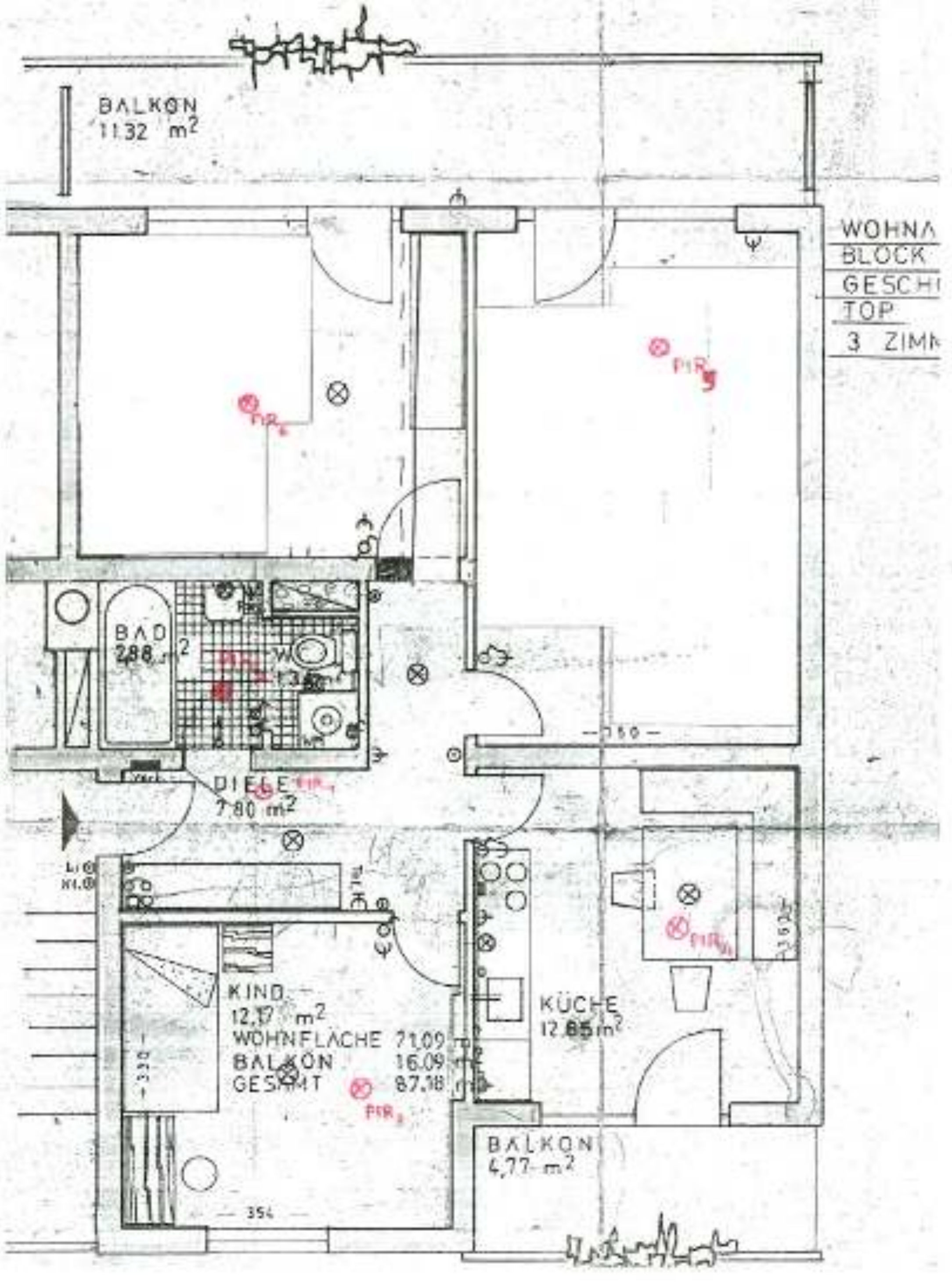
PIR1 = kitchen zone ("Kitchen")
PIR2 = kitchen zone ("Kitchen")
PIR3 = corridor, stairways ("Corridor & Stiege OG")
PIR4 = living room ("Wohnzimmer")
PIR5 = bath room ("Bathroom/WC")
PIR6 = sleeping zone ("Sleeping room")

PIR1	PIR2	PIR3
		
PIR4	PIR5	PIR6
		

The hardware implementation was initial finalized on August 6th 2014.

3.6 Apartment of test person VP16 - MVA (Hard, AT)

Sensor positioning



PIR1	PIR2	PIR3
		

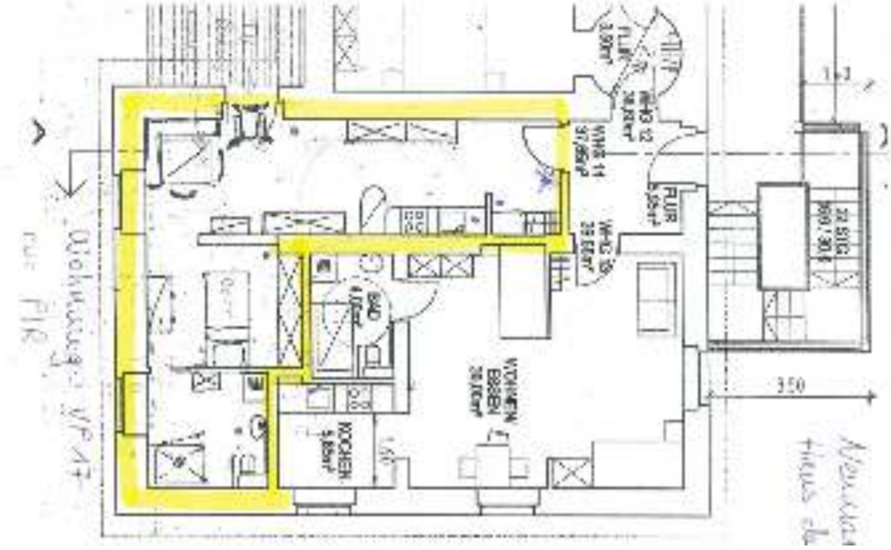
PIR4	PIR5	PIR6
		

PIR1 = entrance area
PIR2 = bathroom
PIR3 = living room
PIR4 = kitchen zone
PIR5 = dinning room
PIR6 = sleeping room

The hardware implementation was initially finalized on August 23rd 2014

3.7 Apartment of test person VP17 - Apollis (Neumarkt, ITA)

Sensor positioning - Installation carried out on 12.06.2014

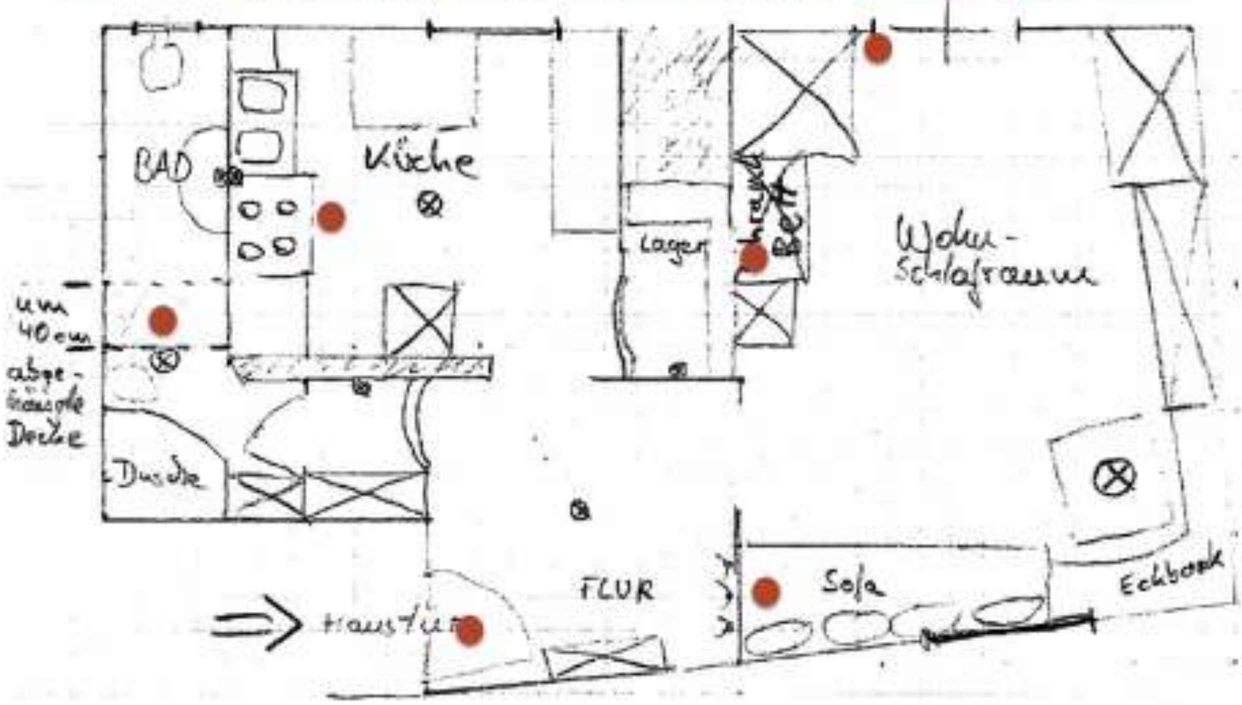


Photographical documentation:

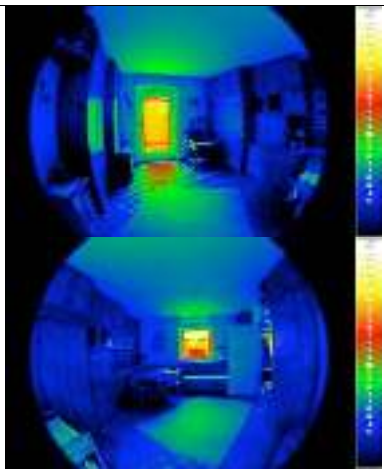
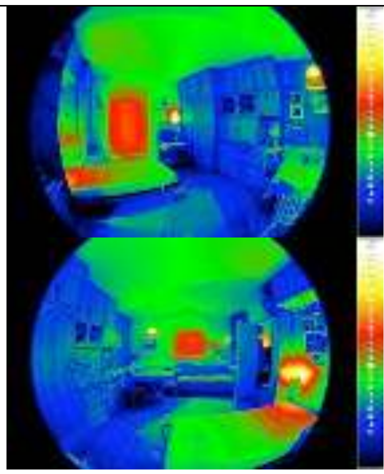
Kitchen view 1	Kitchen view 2 (entrance)
	
Bedroom	Bathroom
	

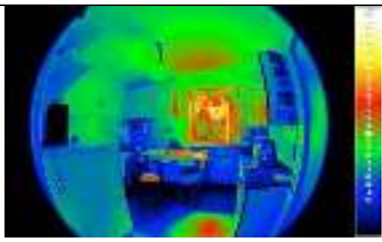
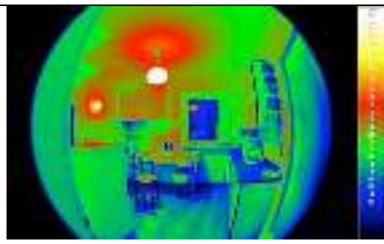
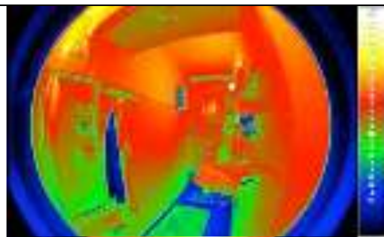
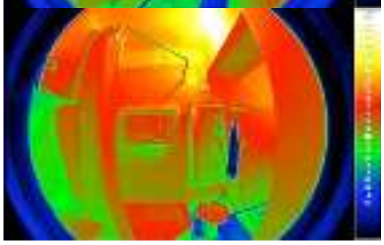
3.8 Apartment of test person VP19 - Apollis (Bozen, ITA)

Sensor positioning - Installation carried out on 18.06.2014



Photometrical documentation (additionally)

	Daylight	Artificial light
Living room		

Entrance		
Kitchen		
Bathroom	n/a	 

Photographical documentation:

4. Software implementation

When developing the user interfaces of Guiding Light, we applied principles of participatory design and iterative design, which means that the end-users was involved at all stages of development. Besides, we apply a design-for-all approach that greatly enhanced the potential for commercial exploitation because it extends the group of potential beneficiaries to include anyone desiring a more usable and joyful experience with AAL home automation. This applies to computer interfaces as well as the home environment. Outcome of the project is an intelligent light wayguidance system consisting a variable set of flexible modules that work together with other heterogeneous home automation systems, information and communication systems as seamlessly as possible. Guiding Light will support spatio-temporal orientation of older people and thus sustain their mobility as long as possible.

Our end-user segments are located along various continua rather than in “locked” categories. Primary end-users, actually using Guiding Light, are older people in post-retirement age but at different stages of individual ageing process reaching from healthy elderly up to multi-morbid elderly. Configuration of our solution packages (e.g. modules of home automation and information system) is different for those needing (professional) care (on a regular basis) - because having problems with mobility and spatio-temporal orientation e.g. due to dementia - and those older people who need no care. Solution packages can always be reconfigured according to individual needs. Nevertheless, we will focus single person households since they are more vulnerable to age related diseases and (stand-alone) emergency cases.

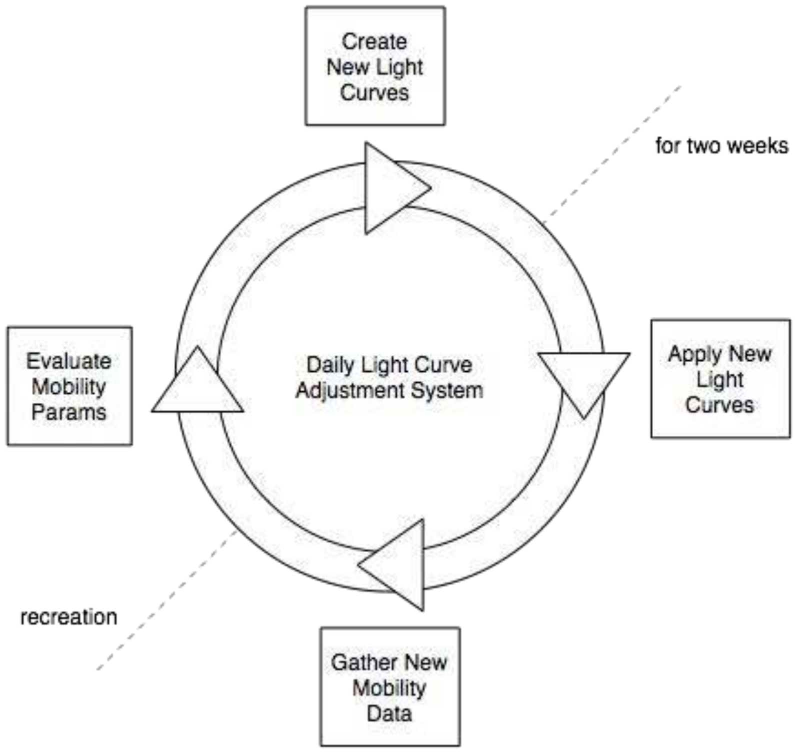
End-user communication will be different for experienced front-runners and digitally challenged people but system will be easy to use in the same way for both user segments since we will follow a design-for-all approach in user interface design. Technological solution of home automation (wireless/field bus system) can be different for those end users who move their flat, e.g. into a new service oriented single apartment, and those who stay at home either entirely reconstructed or adapt only relevant room installations. Secondary end-users, directly being in contact with a primary end-user that uses Guiding Light, are family members, staff from health/care/social services, and/or staff of retirement houses as well as residential care homes.

4.1 Light-Curve Adjustment Processing

One of the goals of the Guiding Light project was to develop and evaluate an algorithm for deducing lighting variations for individual lighting zones and thus establishing a control loop that should ultimately lead to the desired results of improving or at least stabilizing the daily structure of its users.

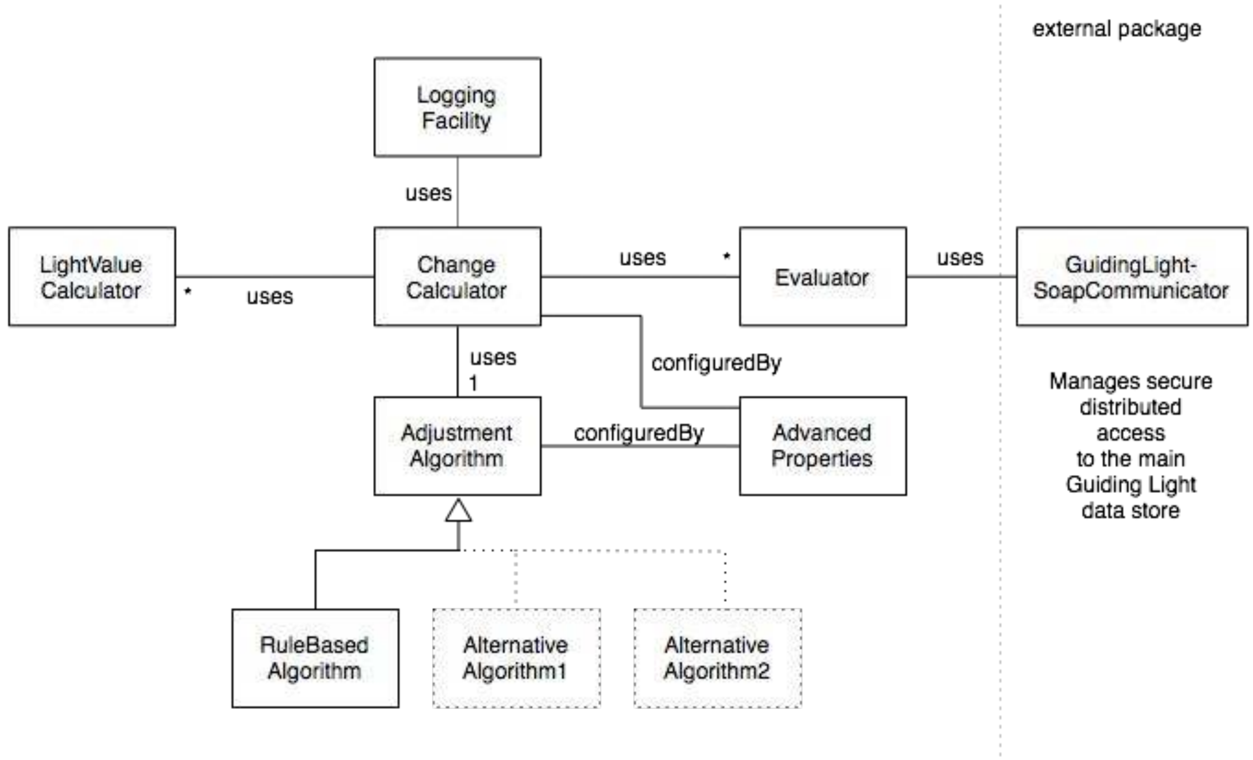
Light-Adjustments Overview

The Guiding Light system continuously gathers data about motion inside the apartment and deduces various mobility parameters from it. These mobility parameters are then evaluated by the light control system in a fixed evaluation-interval (typically two weeks), based on which new light curves for all individual lighting zones are calculated. These curves define the light variations regarding brightness and color for a whole day within a given timely structure. These new light curves are then applied for the duration of the next evaluation-interval (see next Figure).



Control loop for light adjustments in a typically two week interval.

The basic architecture of the Daily Light Curve Adjustment system allows for integration of different adjustment algorithms, but in the context of Guiding Light a rule based variant has been implemented, to make use of existing knowledge about the influence of light on circadian rhythm and mobility.



Class diagram of daily light curve adjustment system.

Guiding Light features ambient and zonal lighting. Ambient lighting provides for sufficient brightness inside the apartment. It’s mostly indirect, and very evenly distributed light. Zonal lighting illuminates certain areas inside the apartment, in which special activities are performed, therefore zonal lighting is mainly targeted, and direct light. Each light group and type can consist of multiple luminaries and both types can be adjusted in brightness as well as color.

For both types of lights three different time-frames have been defined: day, evening, and night, as all of them have unique requirements regarding brightness and color as suggested by current research on light effects on the human body. This leads to a total of six light specific targets (day, evening, night for both zonal and ambient lighting).
Mobility parameters that are calculated by the Evaluator component of the adjustment system can be grouped into three basic types: daily activity, daily structure, and sleep quality measures. These are based on raw parameters provided by the Guiding Light core system:

The daily activity measure combines the parameters

- Counts of individual stays within the apartment per day.
- Number of minutes with registered motion per day.
- Number of minutes the person has been outside the apartment per day.

The daily structure measure should reflect the matching of the defined target structure to the with the actual structure. We defined this as a combination of

- Deviation of number of target stays inside the apartment per day
- Deviation of the begin-time of a stay per day
- Deviation of the end-time of a stay per day

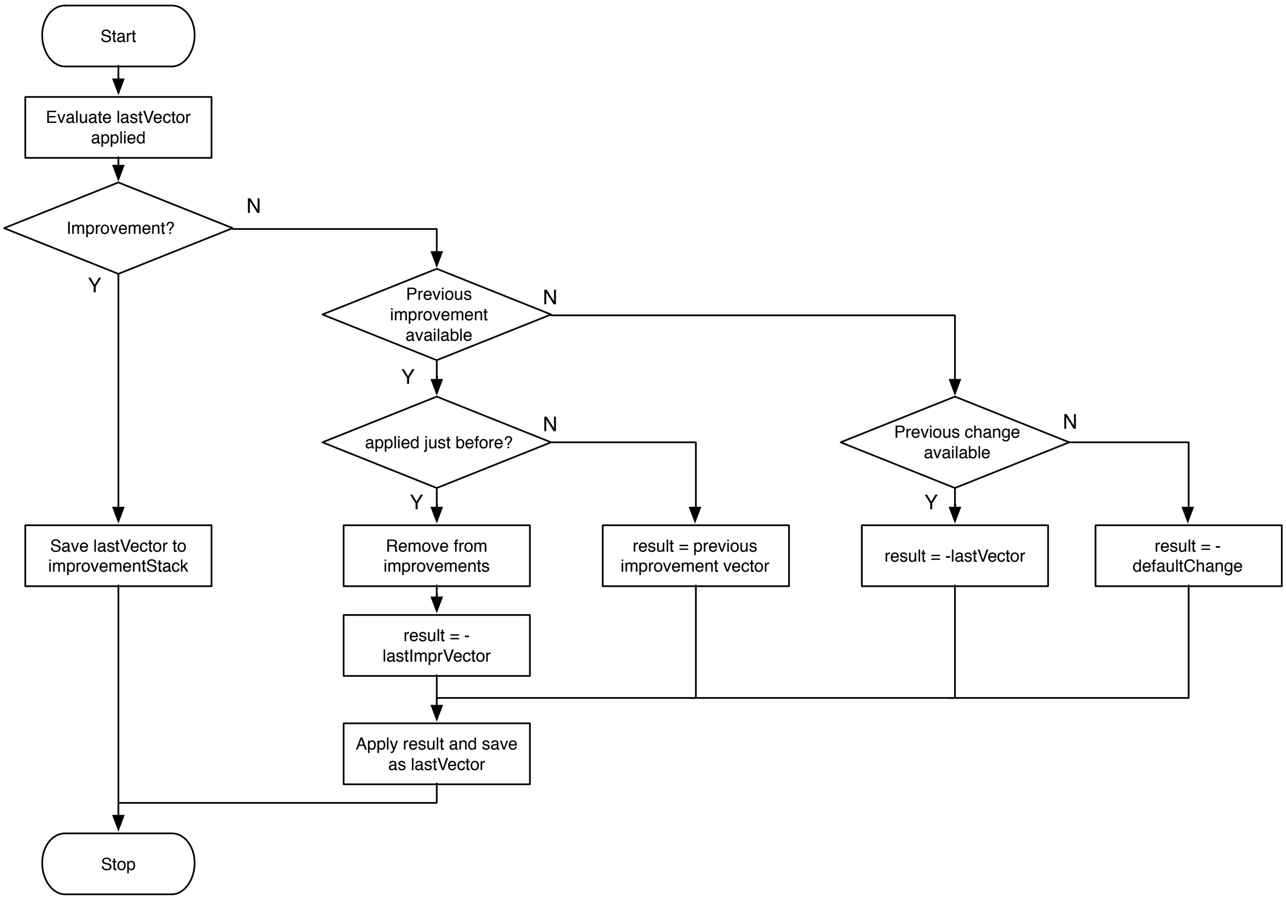
The sleep quality measure is comprised of the factors

- Motion during night time per day
- Duration of sleep during the night
- Duration of wake-times during the night

The evaluator requests these raw parameters from the Guiding Light core system for two consecutive timeframes. It then compares the states between the two timeframes and combines these measures into the group (each measure might have gotten worse, equal, or better). The result of this is a simple evaluation vector including three element, one for each group. Negative numbers represent an overall decline, 0 means no changes, and positive numbers represent an overall improvement for the group.

This evaluation vector is then passed to the adjustment algorithm as input for the calculation of a new light adjustment vector. This vector includes day-values as well as dividing factors for evening and night lighting for ambient and zonal lights and is passed to the CurveGenerator to generate a new light curve (see previous Figure). For a detailed description of light curves see the Daily Curves System documentation.

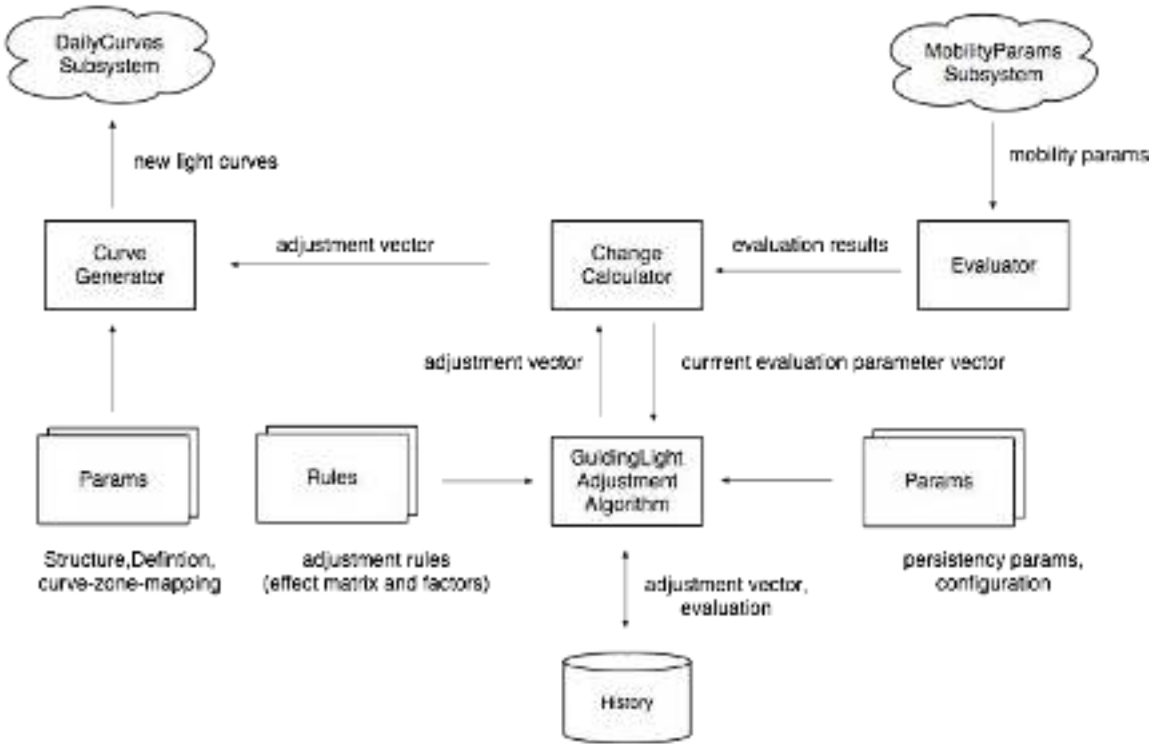
Originally the plan was to use a genetic algorithm to evolve light adjustments with desired effects, however, it soon became apparent that evaluation times of two weeks and the relatively brief duration of the field tests (half a year) would not enable sufficient iterations and generations of a population to come up with good results. Therefore we decided to take the alternative rule based approach.



Overview on rule based approach for light curve adjustment.

Light Curve Adjustment Algorithm

The main idea of the implemented adjustment algorithm is based on an effect matrix that maps ambient and zonal lights at specific times to mentioned daily activity, daily structure and sleep quality parameters, indicating which possible targets for actions exist in order to influence certain evaluation parameters (see next Table). The adjustment vector is then determined by a set of rules in combination with the input from evaluation vector.
To make this algorithm dynamic (so it can adjust to individual persons automatically), it keeps track of applied changes and their effects on these parameters. If a calculated change does not lead to an expected result, the algorithm can lookup its history and determine which changes had the desired effect, and then fall back to those with a slight variations.



Data flow between parts of the light curve adjustment system.

	Activity during day	Daily Structure	Sleep Quality
Ambient Day	x		
Ambient Evening	x		
Ambient Night			x
Zone Day		x	
Zone Evening		x	
Zone Night			x

Proposed effect matrix between light type and mobility parameters

The proposed effect matrix (table above) shows that we expect daily activity to be mainly influenced by ambient lighting during the day and evening times, as this defines the general overall lighting outside the daily structure.

The daily structure should be supported by the zonal lighting, as this lighting is intended for tasks during the time and the zone defined by the structure.

The sleep quality should be influenced by the nightly zonal and ambient lighting. To bright light levels or to cold light temperatures could prevent the body from falling asleep after exposition to this light.

We formulated the following rules to be applied within the algorithm for the field test period: If a newly derived light curve caused an improvement for the corresponding mobility parameter, the same light curve should be applied for another evaluation interval without changes.

If a newly derived light curve caused a decline for the corresponding mobility parameter, the last change that caused an improvement should be repeated. But if the next evaluation still shows a decline, the most recent adjustment vector should be inverted.

If no improvement was registered in history yet and the current curve lead to a decline for the corresponding mobility parameter, the adjustment vector should be reverted. As these rules work with change factors instead of absolute values, slight variations occur when reverting an effect, which should counter against stagnation of the algorithm.

If the current light curve does not match the last one created by the algorithm, a manual adjustment must have taken place, and therefore the evaluation result must not be mapped to the current adjustment vector. If no adjustment did take place yet, the light should by adjusted by default change parameters.

In addition to these rules, change-factors as well as minimum and maximum constraints are defined for each light group. A proposed adjustment vector must be corrected to be in line with these constraints before being returned.

Default parameters for adjustments have been set to 5% for maximum (=day) brightness, 20% for change factors for zonal lighting, and 10% change for ambient lighting.

This algorithm has been used during the field tests in the test group with a detailed zonal lighting definition in a semi automatic way (resulting light curves have been investigated and manually included into the light curve system). For each test person, the initial light configuration has been set in coordination with the test persons. The change factors have also been adapted to the preferences of each test person individually.

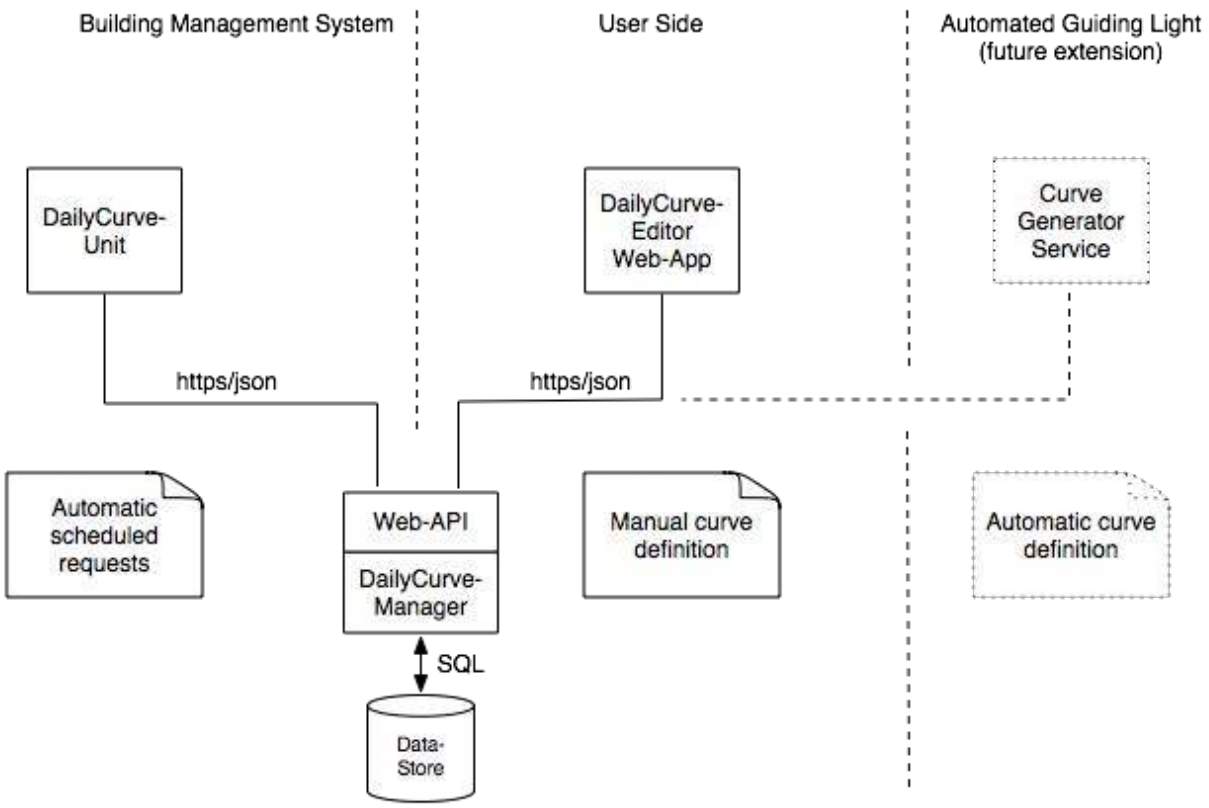
4.2 Managing daily lighting curves

Daily curves define target dim-values for luminaries for a period of 24 hours. Besides dim values (typically two per set) they also contain information about time- and motion-based switching of the luminaries.

There are currently two sides accessing the guiding light daily curve backend system. On the building management system side, each Daily Curve Unit requests their current daily curve from the guiding light backend-system. These requests are typically performed at a fixed time in the day (e.g. 00:00:00) over a secure https connection.

On the user-side these daily curves are defined using a web-based app inside a web-browser also using secure https connections. Light curves can be adjusted, and time based switch commands can be defined. Also motion based switching can be activated in accordance to a definable brightness threshold. Also an effective date can be set to be able to schedule a curve change in future.

In future a third side might be added in the form of an automated curve generator which could use the same Web API as the web-app for manual configuration.



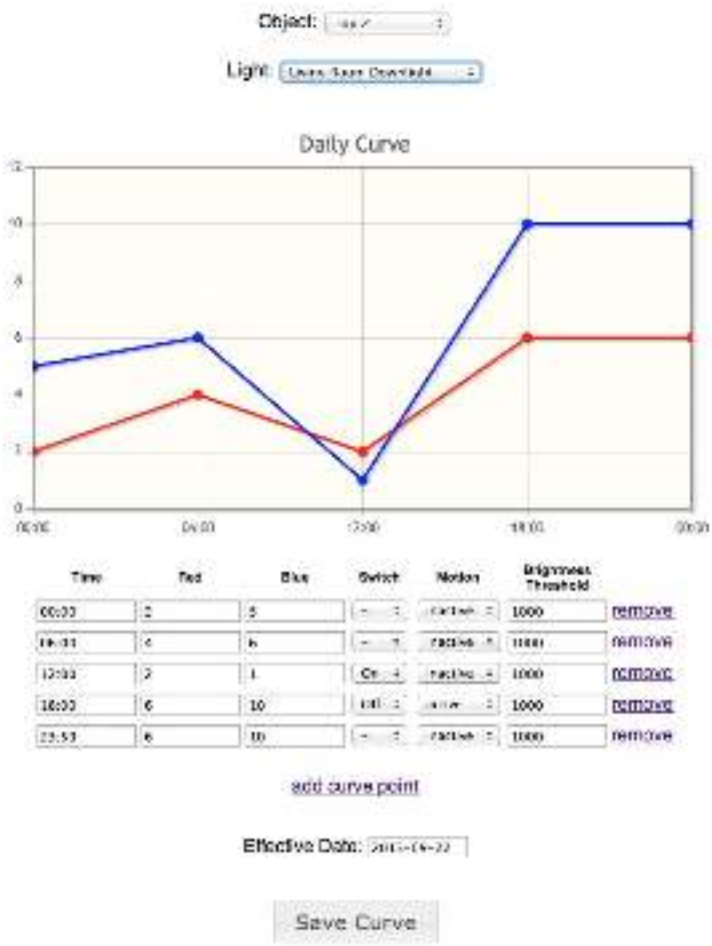
System Overview

Daily Curve Editor

The Daily Curve Editor is a web-app executed in an HTML5 compliant Web-browser for adjusting daily curves of the Guiding Light system. The reason for implementing the editor in form of a web-application was the platform independent nature of web-apps. Therefore the Daily Curve Editor can be run on Mac, Windows, iOS, Android or any other platform providing an HTML5 compliant browser.

On the technical side, the editor is built using open source based frameworks like jQuery and jqPlot (for plotting and drag&drop editing of the curves) in combination with HTML5, CSS3 and JavaScript.

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.



Screenshot of the Daily Curve Editor user interface

End User Interface

The daily curve editor provides a web-based interface to edit light target values at specific times. The daily curve editor can be accessed on:
https://uct.labs.fhv.at/glight/dailycurves/login.php

This document describes how to log into the system, and view and edit available curves for a specific apartment of Guiding Light test participants.

Login: At the login page the user name and password needs to be provided.

Login screen for the curve editor

Object and Curve selection: After a successful login the current user name is shown in the upper right corner of the interface. In the main part an object (or apartment) pulldown menu is presented, listing all objects available for the current user.

Object selection interface

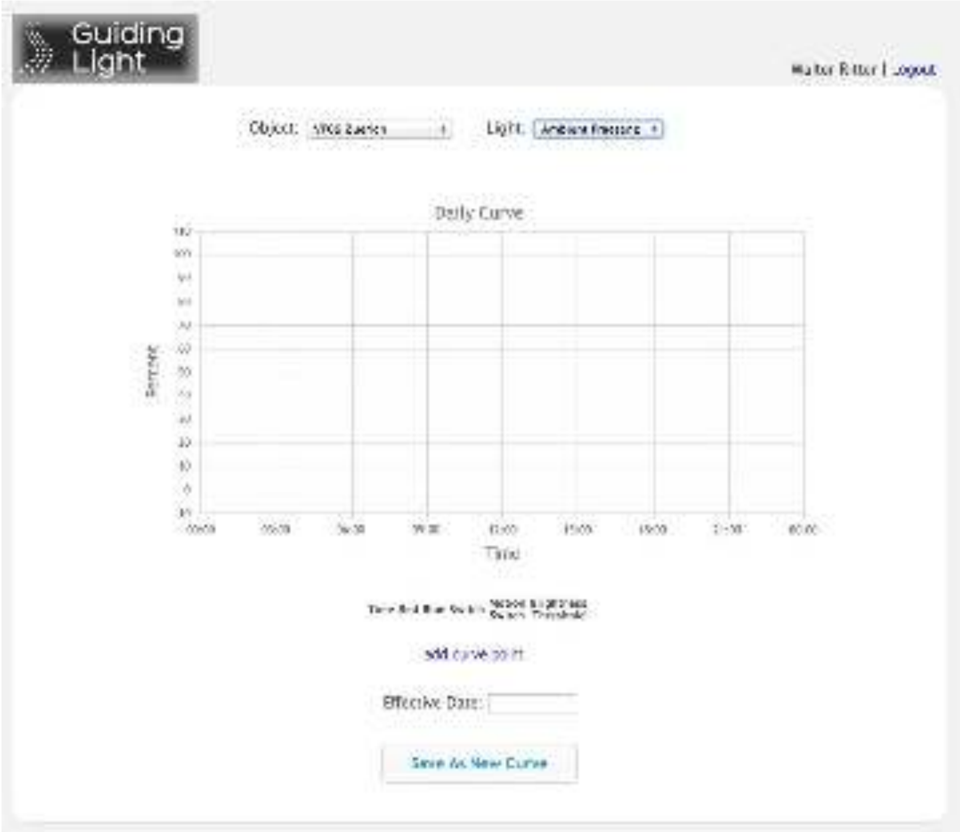
After selecting an object from the menu, another pulldown menu with all available curve-classes for the selected object will appear.

Curve selection interface

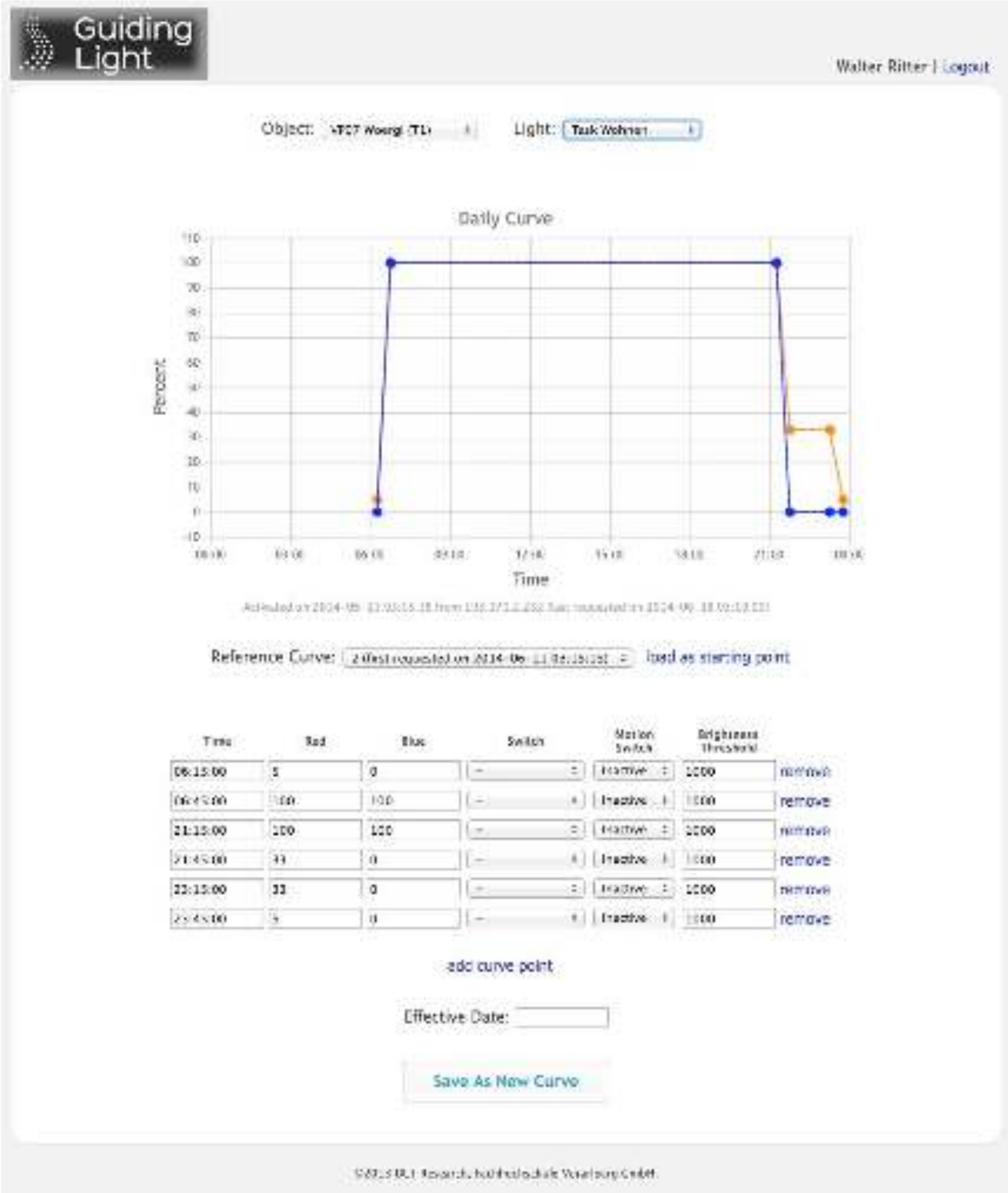
The default curve-classes for the Guiding Light project are:

Ambient Praesenz	This curve is intended for ambient lights that should be switched by presence detectors (e.g. living room).
Ambient Manuell	This curve is intended for ambient lights that will not be switched by presence detectors (e.g. sleeping room).
Task Wohnen	This curve is intended for the task lights in the living room area.
Task Kochen	This curve is intended for the task lights in the kitchen area.
Task Bad	This curve is intended for the task lights in the bath area.
Task Schlafen	This curve is intended for the task lights in the sleeping room area.

After selecting a curve-class, the latest curve for this class will be presented in the editing interface, or if non exists yet, an empty editor is shown.



Interface of the curve editor: an empty curve editor is shown.



Interface of the curve editor: the latest curve is presented on the image.

Editing a daily curve

The curve editor consists of a chart where the currently entered curve data is shown graphically. It also provides a table of data points for data entry and manipulation.
New data points can be added by clicking on the add curve point link. The data rows will automatically be sorted by their time stamp. A data row consists of the following items:

Time	The time in the format **hh:mm:ss** at which the new light condition should be active
Red	The control-value for the warm light in % (100% means full light, 0% means no light) *
Blue	The control-value for the cold light in % (100% means full light, 0% means no light) *
Switch	Time-based light switching: the pulldown offers a selection whether the lights that are assigned to this curve should be switched on or off at this point in time. The default option **-** means no action. **On** will switch to lights on, **On (if present)** will only switch the lights on if presence is detected, **Off** will turn the lights off.
Motion Switch	Presence-based light switching: the pulldown offers a selection for enabling/disabling motion based light switching starting from this specific time. **Inactive** means that the lights will not be switched using motion detectors, **Active** means, that the lights will be switched using motion detectors if the current light level is below the threshold value. **Only on** means that the light will only be switched on when motion is detected, but not off after no presence is detected anymore. **Only off** means that the lights will be switched off in case no more presence is detected, but not on, even if presence is detected.
Brightness Threshold	This level defines the max. light level that is allowed for the motion switch to turn on the light. The motion sensor will only switch on the light, if the current brightness level is below the level defined in this field. Note that this brightness value is the one that is measured by the motion detector. This might be very different from the brightness at specific locations in the room.

*) The light values for Red and Blue specified in the table are control-values, meaning this value will be used by the lighting control device. In most test installations this is proportional to the emitted light levels. In the Garnmarkt lighting systems however, the mapping between control-value and emitted light is not linear, therefore a conversion of the the desired light parameter values to the control-values entered in the curve editor and needs to be done. For this conversion a calculation form is available (the link Garnmarkt Light Conversion Utility will be shown automatically for Garnmarkt-installations), that approximately calculates the necessary control-values for a specific light setup.

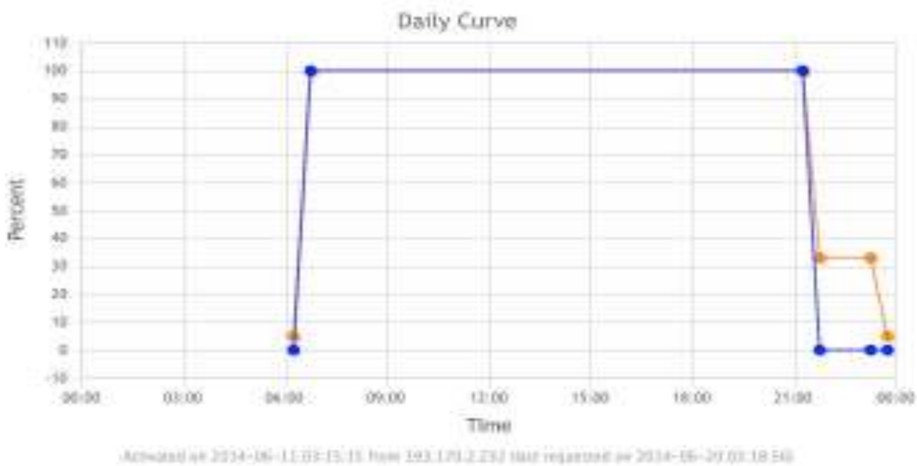
The target values for the two light channels (warm and cold) between two times are linearly interpolated. Also the values between the last value of the day and the first one will be linearly interpolated.

To hold a light level constant over a specific timespan, simply specify a row for the start time and one for the end time with the same values, like in the following picture.

11:30:00	74	74	-	Inactive	1000	remove
12:30:00	74	74	-	Inactive	1000	remove
13:30:00	99	99	-	Inactive	1000	remove

Example values: The light will be held constant between 11:30 and 12:30 and will then transition linearly to 99% levels until 13:30.

In Guiding Light we often use a transition period from one time to another. This transition period is typically half an hour, where we start the transition 15 min. before the target time, and end it 15 min. after the target time. A typical configuration would look like this:



Reference Curve: 2 (first requested on 2014-06-11 03:15:15) load as starting point

Time	Red	Blue	Switch	Motion Switch	Brightness Threshold	
06:15:00	5	0	-	Inactive	1000	remove
06:45:00	100	100	-	Inactive	1000	remove
21:15:00	100	100	-	Inactive	1000	remove
21:45:00	33	0	-	Inactive	1000	remove
23:15:00	33	0	-	Inactive	1000	remove
23:45:00	5	0	-	Inactive	1000	remove

Typical configuration showing the transition period for 6:30 starting at 6:15 and finally reaching the new state at 6:45.

Saving a curve

After setting up a curve the curve can be saved by clicking on the Save As New Curve button. If you want to ignore all the changes you have made, simply select a different curve, or leave the curve editor without clicking on the save button.
Keep in mind that changes to a curve are only saved if you actually click the Save As New Curve button.

Note also that curves cannot be deleted from the system using the curve editor. This is important to maintain a complete history of all defined curves. If you don't want a curve to take effect, simply adjust the values accordingly and save it as a new curve. The system will always fetch the latest curve that is valid.

Curve Activation

Daily curves are automatically requested every night at around 3 o'clock by the building management system. So a curve is not immediately active after saving it, but only after the building management system has requested it. The daily curve system will always hand out the most recently defined curve to the building management system, unless it's setup to take effect at a later date.
In case a curve should be defined in advance, but not activated until a specific date, an Effective Date can be provided for the curve. This means, that the curve will only by used starting from the effective date. Before that, the previously defined curve will be delivered to the building management system.

Advanced Features

The curve editor provides a simple way to compare the currently edited curve to any of the previously defined curves. For this, simply select the Reference Curve from the pulldown menu below the chart.

Curve chart showing the reference curve as dashed lines in the background.

The selected reference curve will be shown as dashed lines in the background of the current curve. If the reference curve should be used as a starting point for a new curve, simply click the “load as starting point” link to load the values of the reference curve into the table editor.

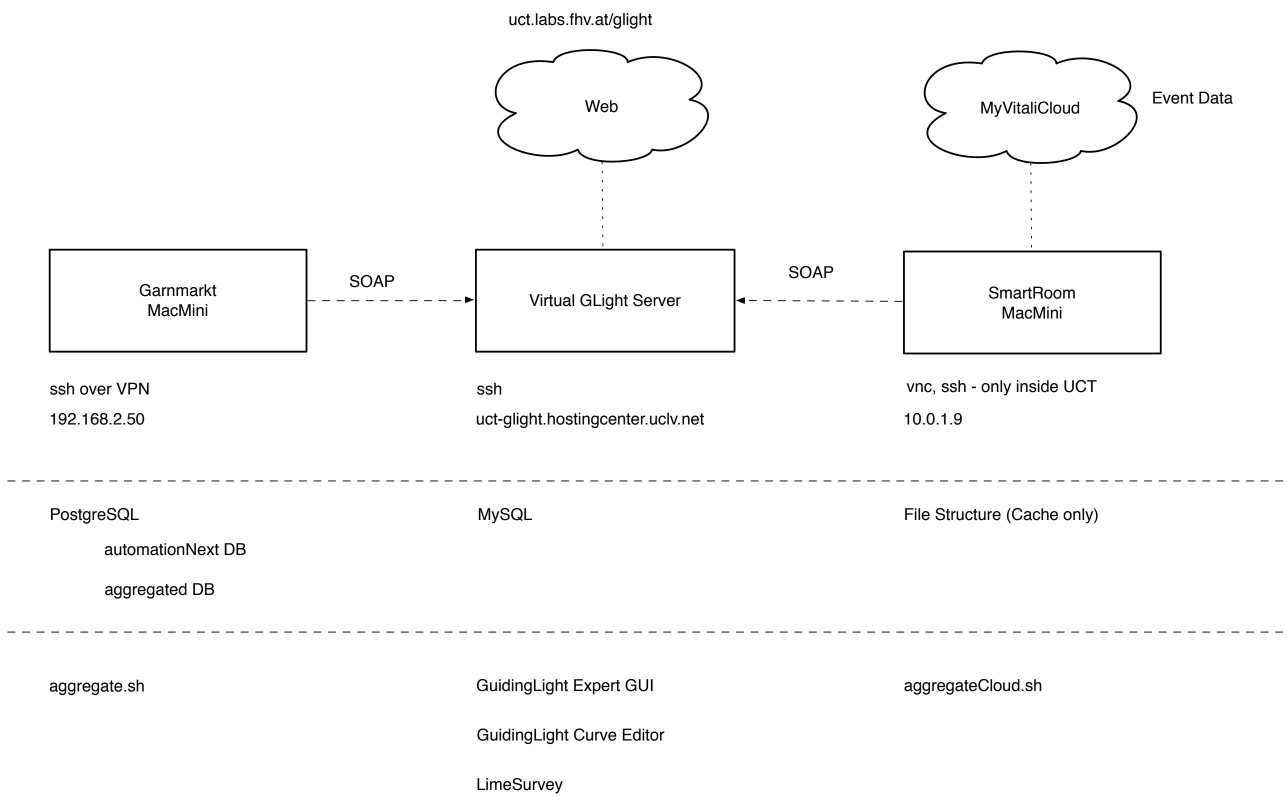
Below the chart the curve editor also shows dates when the curve has first been requested by the building management system (this is the activated date), and when the curve has been requested most recently.

Known Issues

- Opening the Guiding Light monitoring tool might invalidate the current editing session of the daily curve editor. So it’s recommended to not use both tools concurrently.
- It’s best to use modern browsers like Safari, Chrome or FireFox. The chart might not function properly in Internet Explorer.

Daily Curve Manager

The Daily Curve Manager backend system manages daily curves for Guiding Light installations and is built based on top of open source technologies like PHP and Apache for the web API and MySQL as backend storage. Using these three commonly used technologies allows for easy setup in new environments. Therefore the Daily Curve Manager could also be setup on most systems that standard web hosters provide.
The Daily Curve Manager communicates with the clients over a simple JSON based web API over the https protocol hosted by an Apache web server. The daily curves are saved in relational table structures using a MySQL database.



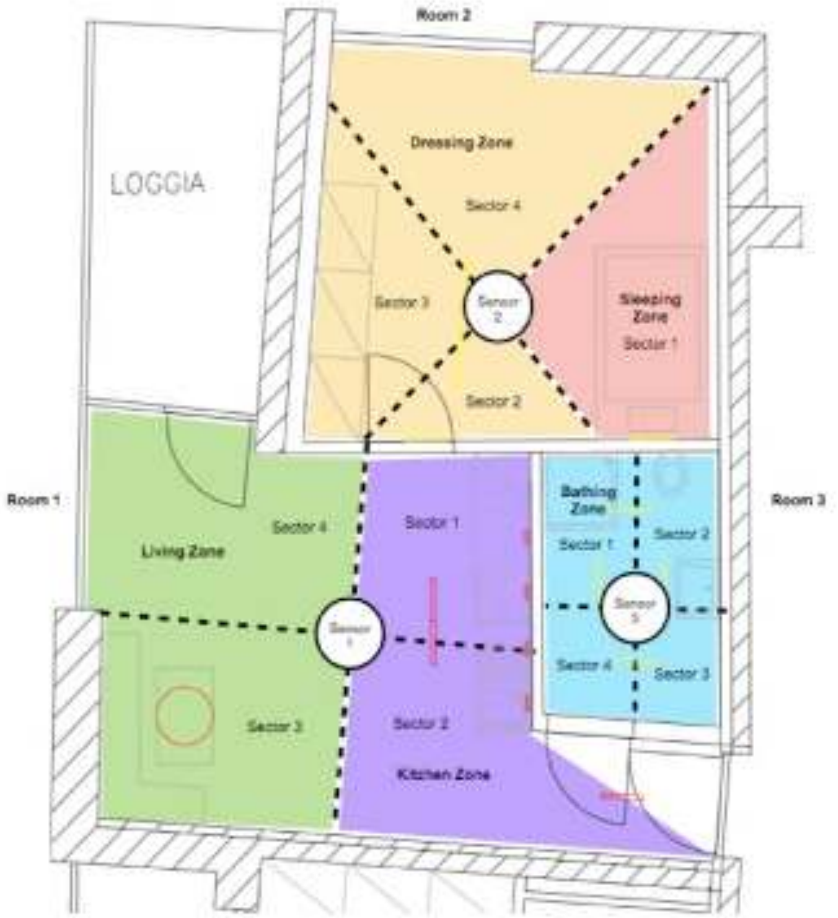
Involved servers for Guiding Light implementation.

4.3 Managing mobility monitoring

For Guiding Light we developed a mobility monitoring tool for single person households that relies on standard passive infrared motion detectors, usually used in home automation. By using multiple sensors in an apartment - each indicating motion in a specific sector (see next figure) - a motion profile inside the apartment can be extracted, which in turn can be used as an indicator for daily activity.

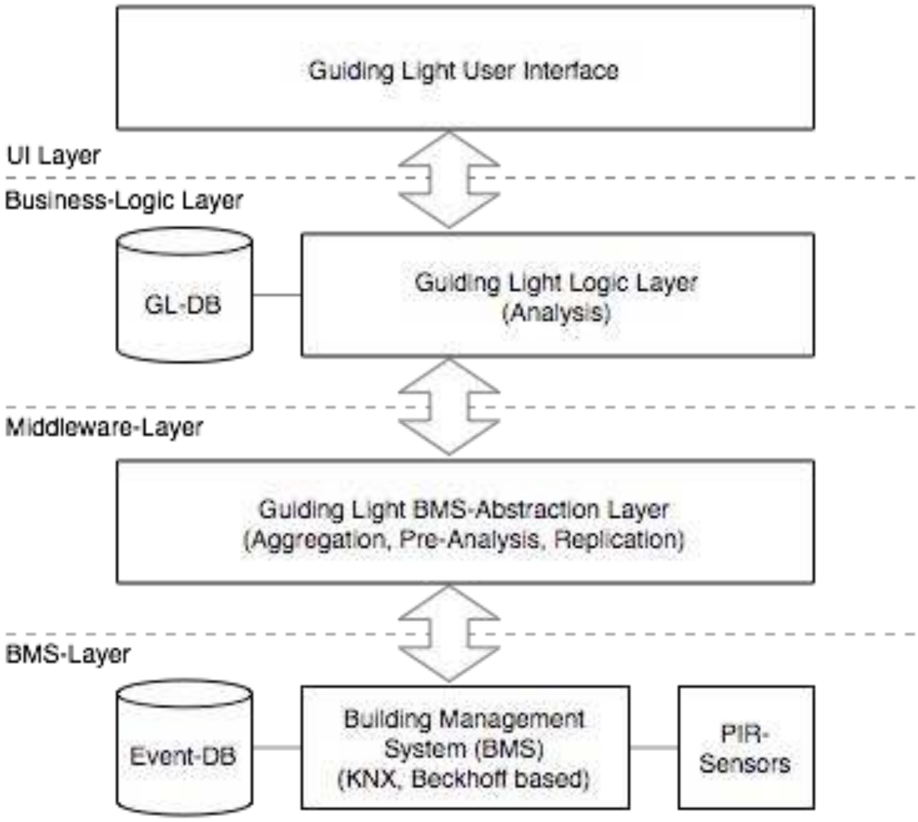
PIR data monitoring

In contrast to body-worn accelerometers motion detectors only deliver a very basic signal (being ‘0’ for no motion, ‘1’ for motion) in much lower time resolution (0.1-1Hz) compared to accelerometer based systems. However, by collecting this sensor data and combining data of different sectors, a surprisingly concise picture of activity inside an apartment can be drawn (see D2.2), without the need of any active contribution on the user’s part. As smart room technology is already used in many homes and will be present even more in future, this approach could prove to be an unobtrusive and simple way to gather information about daily structures and changes thereof.



Floor plan of an apartment with several motion detector sectors allowing for attribution of motion to specific areas inside the apartment.

The Guiding Light mobility monitoring tool is based on a KNX or EnOcean field bus system that logs occurring motion events into an event database (see next figure for a system overview). The system accesses relevant data in this database over an abstraction layer to allow for integration of data from different sources. Besides keeping a time stamped event log, we aggregate data into minute long slots, where we keep the min-, max-, and average-values as well as the number of motion-events occurring during that minute for each sensor sector. The system then analyses these time slots and deduces a set of activity parameters as indicators for a daily structure.



Basic system overview

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 poin

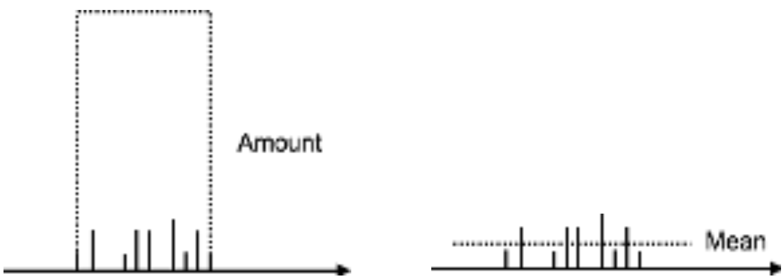
Variant A	t1	t2	t3	t4	Amount	Mean
Sector 1	x	x				
Sector 2	x	x	x			
Sector 3		x				
Result	**2**	**3**	**1**	**0**	**6**	**1,5**

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**

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.



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).

Guiding Light mobility monitoring tool

End User Interface

The processed in-formation is accessible via a web-based user interface, so for example previous figure). The interface provides a simple way to compare activity zones for different date ranges. Therefore changes in a daily routine can be easily detected visually. In addition to the visual comparison, we developed and are currently evaluating a range of different parameters to quantitatively judge daily activity.

Parameters for deducing daily structure

For a numerical representation of daily structure we established stay-blocks among room zones. A stay-block signifies a time period for which a person stayed within a specific room zone, ignoring brief interruptions. For this we calculate motion activity per room zone as basis. This motion activity reflects the number of minutes in which motion was detected by one or more motion sensing sectors attributed to the room zone within the time period of the block. The room zone with the highest motion activity is then marked as the place where the person stayed within the evaluated time frame. The user interface currently allows for stay-blocks in time periods of 15 minutes, half an hour, or alternatively hourly periods.

When the daily structure is calculated over multiple days, the arithmetic average of motion activity per room zone is calculated and the zone with the highest value is then determined as stay-block for that period.

Based on this stay-based structure the number of independent stays is deduced. It reflects how many times a person changed their place inside the apartment during a day. If this number is getting smaller and smaller it could be a hint for reduced mobility (e.g. a person staying in the bed room all day, or just lying on the couch in the living room), especially when considered in combination with the corresponding motion activity for that zone or the whole apartment.

Motion activity across the whole apartment is also calculated as a sum for day- and night-times (currently daytime is defined as 8am to 8pm).

Besides these activity measures, also sleep parameters are deduced from motion sensor da-ta by the system. Currently the total sleep duration, the number of sleep interruptions (for example when a person needs to visit the bathroom during the night), the approximate deep-sleep time (calculated as amount of time where no motion was detected during sleep), and the number of motion detections during sleep (a measure for restless sleep) are calculated using a state-machine as depicted in figure 4. When a person enters the bedroom, and no motion is detected in the whole apartment for a specific time, the system assumes sleep start. Motions occurring after sleep start inside the bedroom are counted as movements during sleeps. If motion is detected outside the bedroom, a sleep interruption has occurred (for example a nightly visit of the bathroom). If the person gets back to the bedroom within a specific time, and then doesn't move anymore for a specific time, the system again assumes sleep. If the person doesn't come back to the bedroom within the specified time, the system assumes that the sleep has ended at the time the person left the room.

PIR based motion detectors in general only detect motion of persons and cannot directly report a person's presence. If a person is sitting still for a long enough time, it will become invisible to the standard PIR sensor. However, distinguishing if a person left the room and/or the apartment is an important information for interpreting the other parameters correctly. A typical approach to detect that no person is left in the range of a detector is to just use a long enough timeout value after the last motion was detected and then assume the person left. However, this approach would not work well in times of no motions (like while watching TV or sleeping in the bedroom). Therefore we currently use a state-machine like depicted in figure 5 to estimate if a person left the apartment. The idea is to use the information that a person can only leave the apartment through the main entrance. So if the motion detector next to the door was the last one to trigger a signal (and maybe an optional door contact reported an opening door), chances are high that, if there is no motion afterwards for a relatively short amount of time, the person left the apartment.

Limitations

There are several limitations to our approach, however. One obvious shortcoming of this approach is that at the moment it can only work properly if there is just a single person present in the apartment. If there are multiple persons present, motion activity will be overstated in the best case (if all people are in the same room zones) or wrong interpretations might be made in the worst case (e.g. if people are in different room zones doing different things). Currently we evaluate different strategies on how to detect the presence of multiple persons. One approach is to detect motion in different sectors at the same time and then deduce there must be ore than one person present, another one is to use counting-light-barriers at the entrance. Both however bear their own challenges (overlapping sensor sec-tors, unreliable counting).

Another limitation of the stationary PIR sensors based approach is the lack of mobility-information for the times when the person is outside the apartment. Currently we can only detect the time of absence and interpret this as a good sign for mobility. This limitation could be worked around, if persons would wear fitness trackers while they are outside.

This is planned as an optional addition to our system, but we are confident that the information about activity inside the apartment will offer enough data points for detecting trends in daily structure changes. PIR sensors have a certain range where they can detect motion. This range and the number of sensors define the maximum possible resolution for location tracking. Camera based systems would offer much better location tracking abilities (and therefore the opportunity to get a better idea of what a person is doing at the moment), however, they would also intrude the privacy of inhabitants massively and therefore would hardly be accepted by possible users, especially considering the current debate about privacy. RFID based location tracking solutions might be an alternative, however, they require users to carry a tag. With the progress of integrating these tags into clothing, this might not be a reason for objection in future.

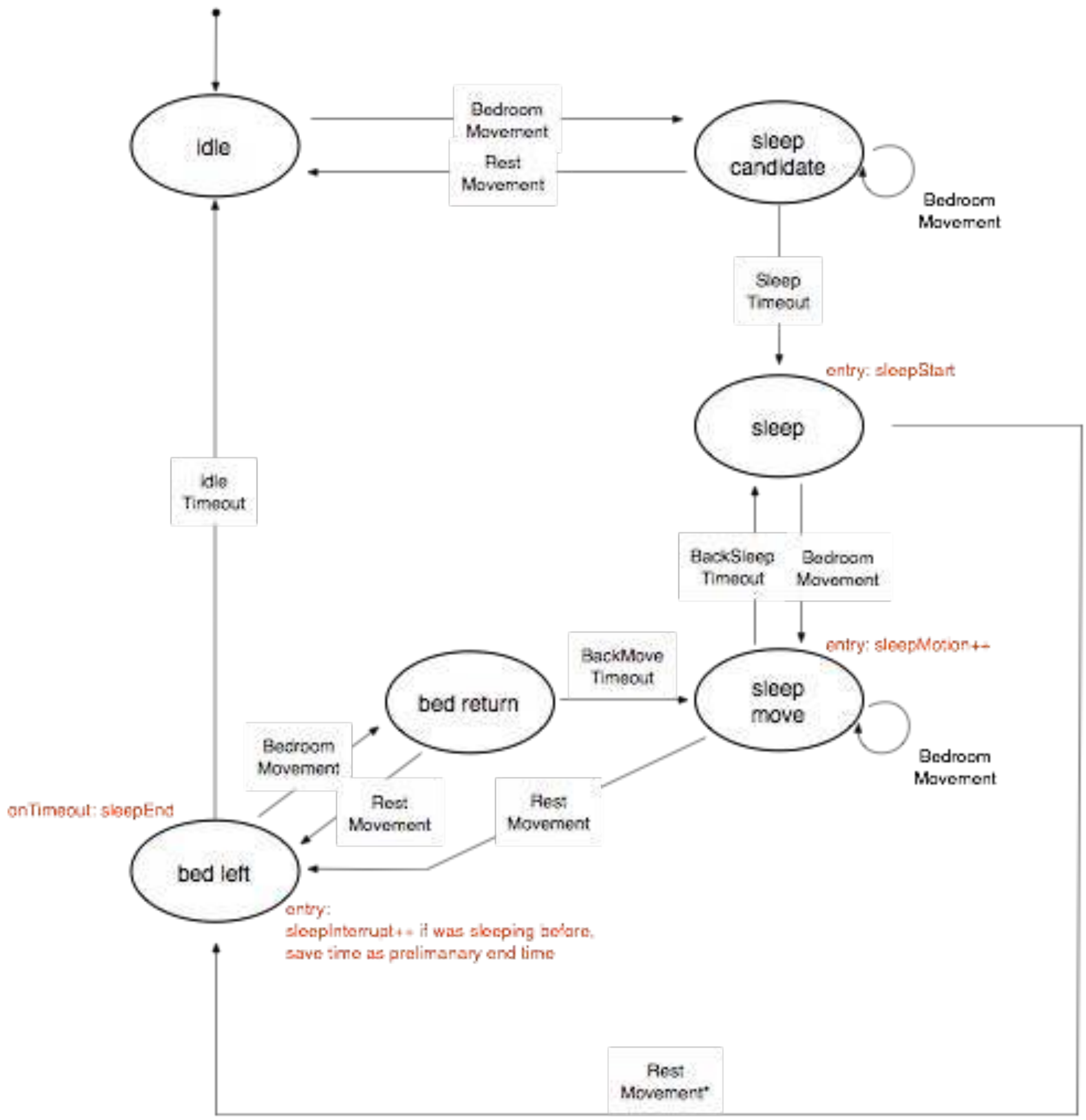
4.4 Preprocessing Algorithms

Within the GuidingLight system several preprocessing algorithms are executed on raw- or aggregated data of motion detectors. Raw data refers to the original event stream of the motion detectors (basically a time stamp an a value of zero or one). Aggregated data refers to a motion data aggregated into 1 minute bins. Depending on the task one or the other can be better fitted for the purpose.

Preprocessing is done automatically during the night to increase the speed of the visualization process. All preprocessing could be repeated on demand with a different parameter set. Currently there are algorithms for sleep detection (creates a sleep log), for absence-detection (rather the inverse of actual overall presence) and a zone - presence detection.

Sleep-Detection

The sleep detection algorithm tries to deduce sleep-times from the stream of raw event data. For this it considers motion in the sleeping room and the rest of the apartment. If the last motion event happened in the sleeping room and for a certain time no more motion is detected, sleep start is assumed. Moves during the sleep phase are counted. Short interrupts of sleep, like when having to get up to visit the bathroom are also counted. Sleep is considered as ended, when the person leaves the sleeping room for a certain minimum time. The following state chart describes the detection algorithm in more details:



State machine for the sleep detection algorithm

Parameters

Parameter	Description
sleepBedMotionNodes	Comma-separated list of ID's of sensors located in the sleeping area
sleepOtherMotionNodes	Comma-separated list of ID's of sensors **not** belonging to the sleeping area
sleepTimeout	Time that needs to pass by with no further events, after the last motion event in the sleep area happened, before sleep-start is assumed.

Parameter	Description
sleepSaveEventList	Saves all considered events for the sleep detection in a text file (mainly only interesting for debugging purposes)
sleepBackSleepTimeout	Time that needs to pass by with no further events, after a motion event during sleep has been detected, to get back into the standard sleep state.
sleepBackMoveTimeout	Time that needs to pass by with no further events, after the person got back to the bedroom again during a sleep phase in order to get back into the sleep move state (and finally the sleep state).
sleepIdleTimeout	Time that needs to pass by with no further events inside the sleeping area, before sleep end is assumed and the sleep period is ended.

Output

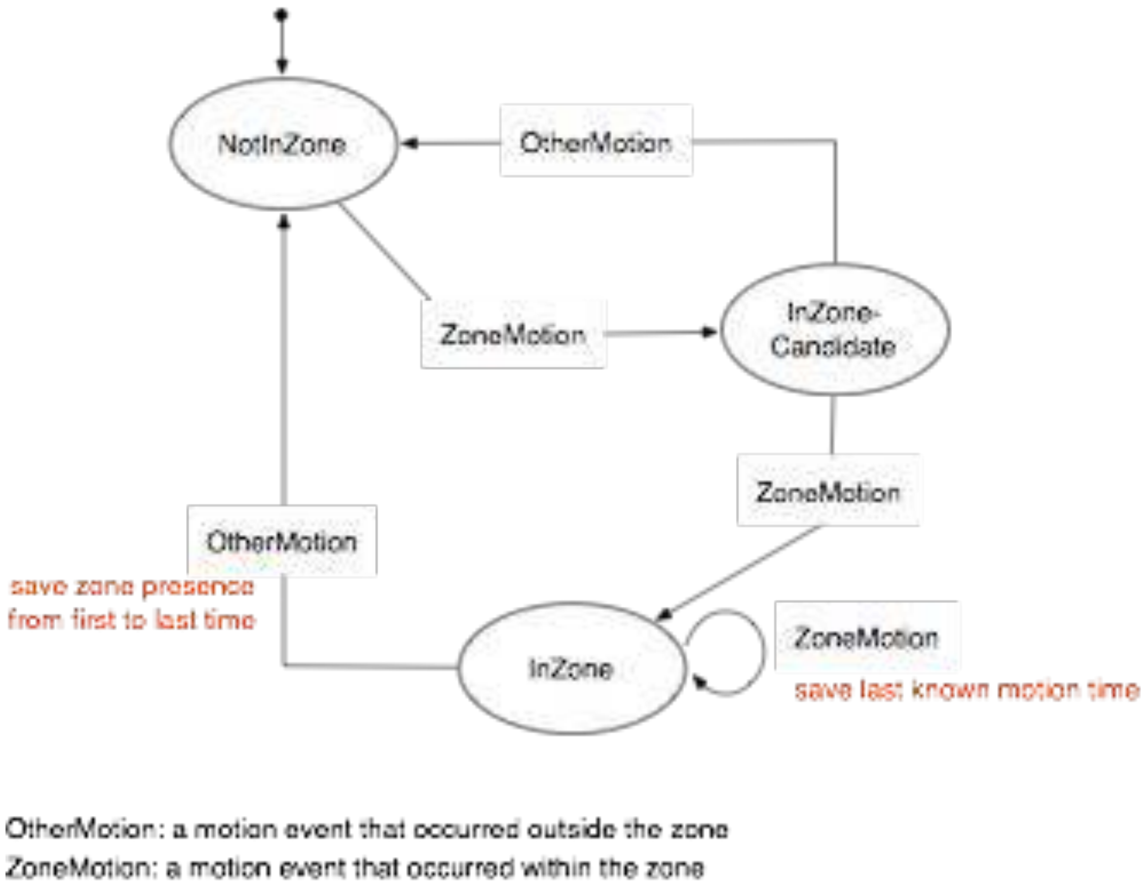
The output of the sleep detection algorithm is a list of detected sleeps for the given time frame consisting of the following information:

Column	Description
Sleep-Start	Start-Time of the sleep.
Sleep-End	End-Time of the sleep.
Moves	Number of moves during sleep.
Interrupts	Number of times the sleeping area has been left during the total sleep time.
Duration	Complete duration of the sleep (from start-time to end-time).
Deep-Sleep Duration	Duration of sleep within the plain sleep state (i.e. no motion occurred).

Note: What the sleep algorithm cannot deliver is an exact sleeping protocol as it's only measures are motion detections. If a person stays in the sleeping room after waking up without movement, the time will still be considered as sleep. Still, the measures extracted from the sleep detection algorithm should give valuable insight into the sleeping habits of persons.

Zone Presence Detection

This algorithm tries to determine presence blocks for certain zones from the stream of raw motion events. The idea is that if there are consecutive events in one zone without events in other zones, a presence block in that zone has happened. The basic algorithm is based on a simple state machine illustrated in the figure below.



State-diagram for zone-presence detection

This algorithm is run for each zone separately.

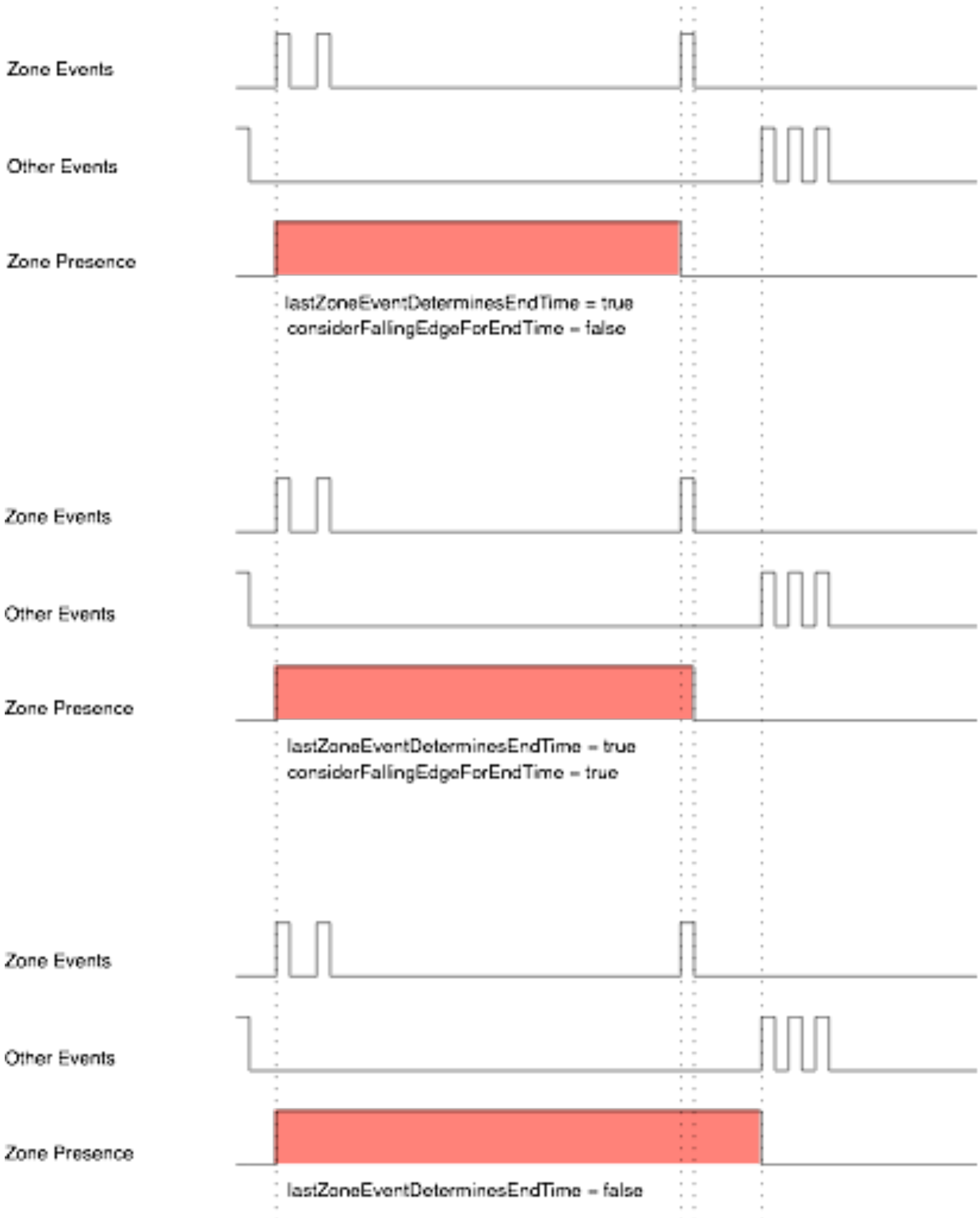
To further fine tune the detection of such zone presences, two parameters are introduced that determine the handling of the end-time of such zone presences (lastZoneEventDeterminesEndTime and considerFallingEdgeForEndTime).

Parameters

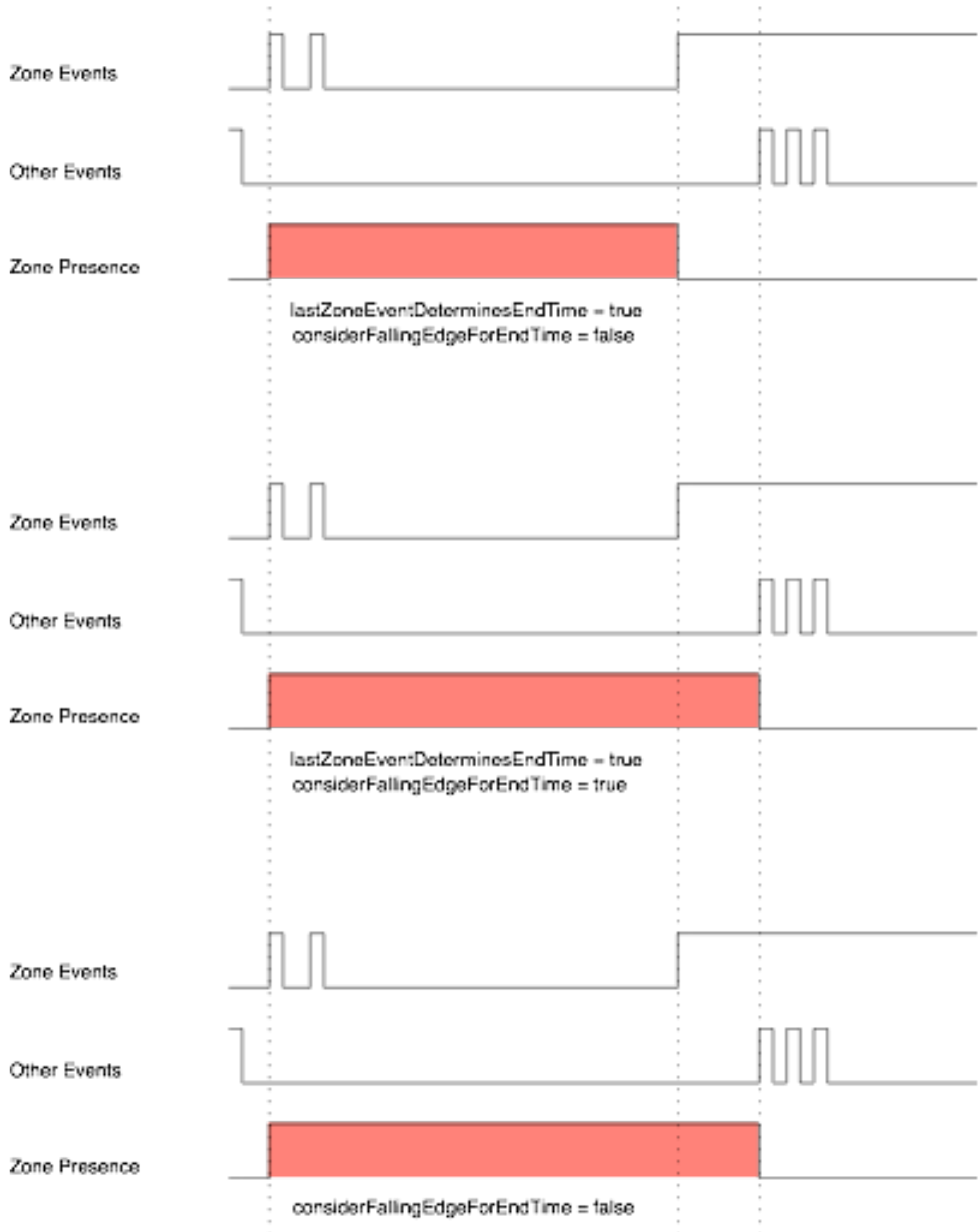
Parameter	Description
lastZoneEventDeter mines-EndTime	True: the last event within the zone marks the end time of the zone presence (think of it like the last confirmed presence in that zone) False: the first event outside the zone marks the end of the zone presence.
considerFallingEdge For-EndTime	Only applicable if lastZoneEventDeterminesEndTime is true. Determines wether the end time should be taken from the falling edge of the signal (1 to 0) (true), or from the last 1 value (false).
zonePresenceMinim um-Time	Minimum time for a zone presence (presences shorter than this time will be filtered out).
zonePresenceMaxi mum-Time	If a presence is taking too long, it might be an absence (fallback strategy). Presences longer than this time are filtered out.
zonePresenceMaxi mum-NightTime	Like zonePresenceMaximumTime but during the typical night time (during the night presences will be longer)
zonePresenceSleep Time-Start	Start time of the night time fallback duration
zonePresenceSleep Time-End	End time of the night time fallback duration
zonePresenceMotio n-Nodes	Comma separated list of ID’s of all relevant motion nodes
zonePresenceZone-Defintions	Semi-Colon separated list of key-value pairs in the form of <zoneName>=<Comma separated list of motionIDs of the zone>

The output is an event list in the form <Timestamp><zonePresenceID><value (1…presence, 0…no presence)>.
The signal examples on the following pages should illustrate the different scenarios that might appear, and how the algorithm will react on them with different parameter settings.

Standard Cases (showing the effect of different end detection parameters)

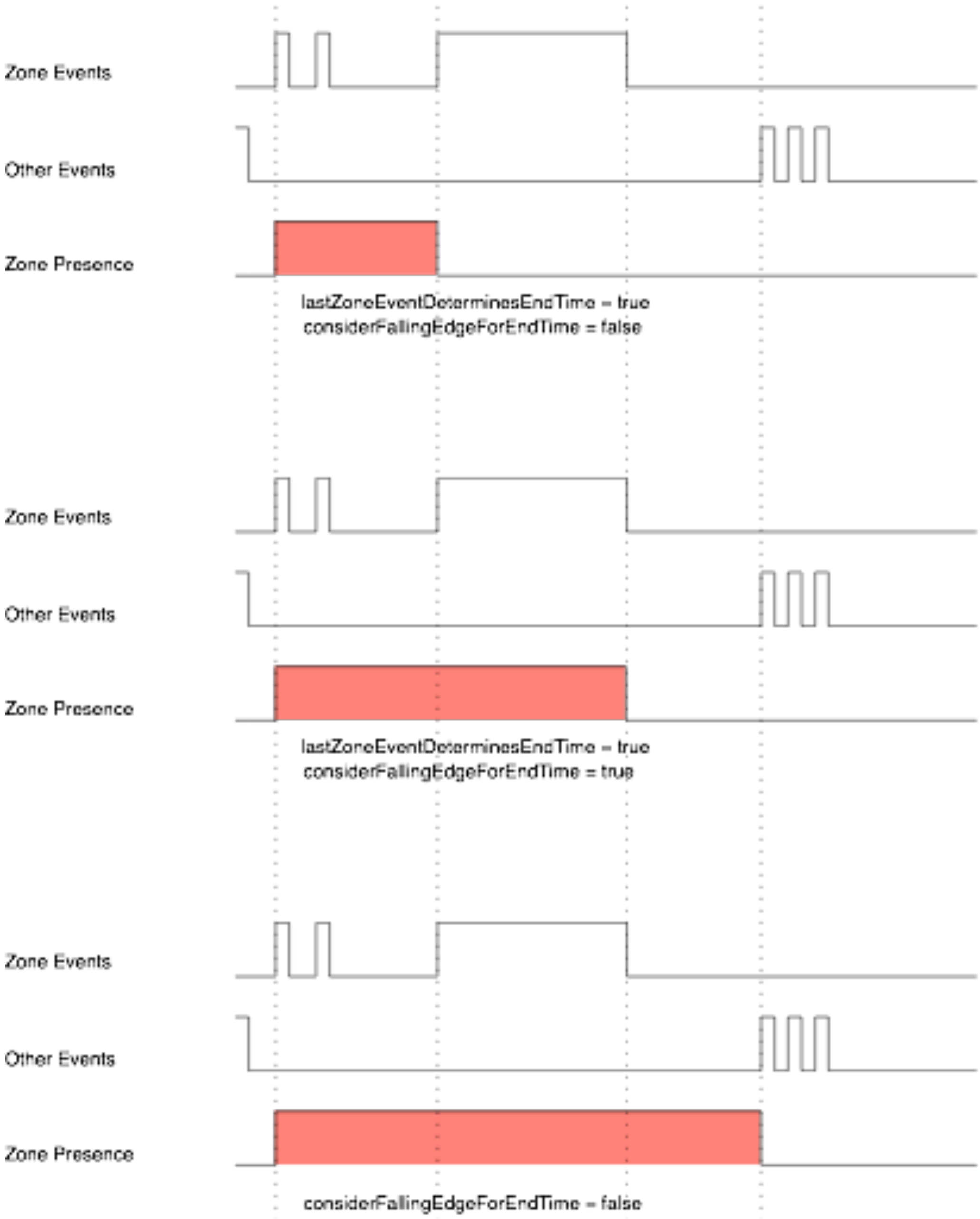


Alternative Case: stuck motion sensor* A



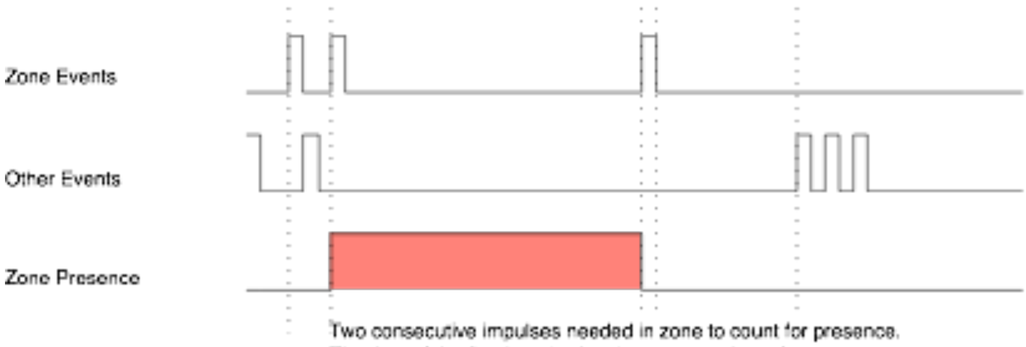
*) A stuck motion sensor can have two causes: real continuous motion (working properly) or a delayed/lost 0 transition (device issue?). Note that this is different from multiple consecutive 1 events, which indicates actual continuous motion and is fine.

Alternative Case: stuck motion sensor* B



*) A stuck motion sensor can have two causes: real continuous motion (working properly) or a delayed/lost 0 transition (device issue?). Note that this is different from multiple consecutive 1 events, which indicates actual continuous motion and is fine.

Start Cases: (for simplicity only for first parameter set, as end is not relevant here)



Two consecutive impulses needed in zone to count for presence.
The time of the first impulse is taken as start time of presence.

Two consecutive impulses needed in zone to count for presence.
No presence is assumed for the zone as it's always interrupted by motion in other areas.

Two consecutive impulses needed in zone to count for presence.
No presence is assumed for the zone as only one change from 0 to 1 is encountered for the zone.

Presence Detection (based on aggregated data).

The Presence Detection algorithm tries to deduce overall presence in an apartment by looking at aggregated motion- and door-contact events. The basic idea of the algorithm:

Put all relevant motion information of the considered time frame into an ordered motion-event list. For this take the COUNT column of the aggregated data points as value.

Put all relevant door-contact information of the considered time frame into an ordered door-contact-event list (also using the COUNT column).

In the resulting motion-event list search for periods where the event count remains below a specified minimum for a specified minimum time and save these periods (from-to) into an absence-candidate list.

For each entry in the absence-candidate list check if there are door-events near the start and end of the period.
If this is the case, add this period to the absence list.
If this is not the case, check if the absence-candidate period is longer than a specified minimum time (can be different during day- and sleep-times). If this is the case, add the period to the absence list anyway (fallback strategy in case no door contacts were received).

The inverse of the absence list is the presence list.

Parameters

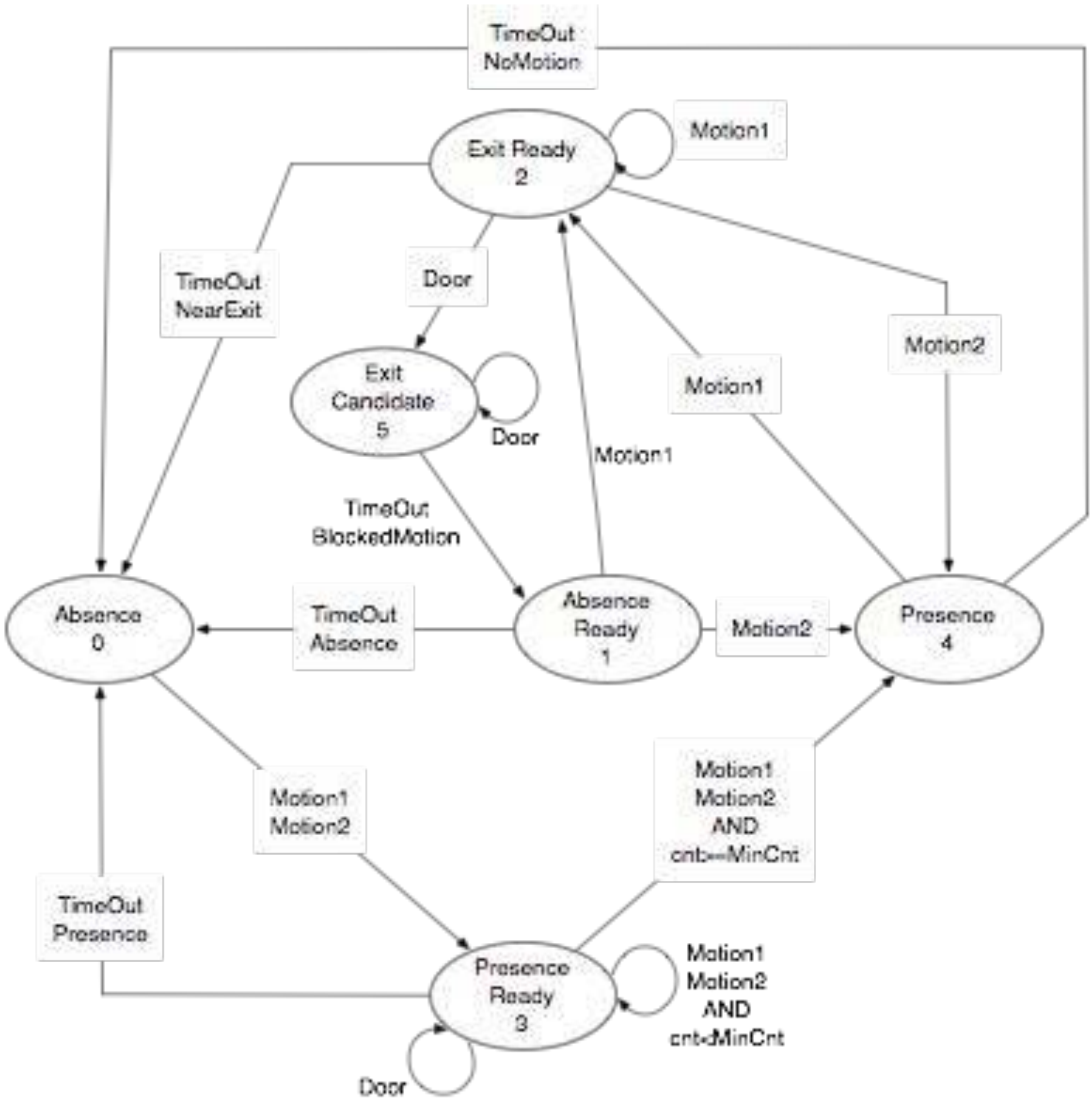
Parameter	Description
presenceMotionNodes	Comma-separated list of ID's of motion sensors
presenceDoorNodes	Comma-separated list of ID's of door-contact sensors
presenceMinBlockTime	Minimum time for an absence block. Absence blocks smaller than this time are filtered out.
presenceActivityFloor	The event-count must be below this number to be counted as absence candidate.
presenceToleranceCount	During a detected absence, how many cases of minutes with an event count > 0 should be

Parameter	Description
	ignored (e.g. to counter sporadic actuations)
presenceDoorEvent -Deviation	Amount of minutes plus/minus the start and end of an absence candidate period within a door-event needs to be present to be counted as absence period.
presenceFallbackDuration	If no door-events are within the presenceDoorEventDeviation, if the absence candidate period length is above this value, count as absence anyway.
presenceSleepTime -FallbackDuration	Like prsenceFallbackDuration, but relevant if absence-candidate lies within typical sleep time.
presenceSleepTime Start	Start time of the sleep time period (relevant for fallback handling)
presenceSleepTime End	End time of the typical sleep time period (relevant for fallback handling)

The output is a presence event list containing time and value (presence or not).

Presence Detection (raw based, deprecated)

The Presence Detection algorithm determines whether a person is present in an apartment or not. To achieve this, 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 algorithm should help 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 figure 1).



Door: a door contact event occurred

Motion1: a motion event of the detector closest to the main entrance occurred

Motion2: a motion event of other detectors occurred

TimeOut: after a specific amount of time of no events this route is taken

State-diagram for presence/absence detection

Input

Input	Description
Door Input	Light barrier or door-contact on the main entrance door.
Motion Entrance	Motion detector near the entrance area inside the apartment.

Input	Description
Motion Rest	All other motion detectors inside the apartment
Reset	Resets the internal state to no presence.

Output

Output	Description
Presence	Shows presence or absence (true/false)
State	Shows the internal state of the state machine.

Parameter

Parameter	Description
Absence Delay	Required time (in seconds) with no motion, before the node switches from the internal absence ready state to the actual absence state.
Presence Delay	Required time (in seconds) with no motion, before the node switches from the internal presence ready state to the actual absence state again (this might happen for example if the door is opened but then closed again without entrance).
No Motion Delay	Required time (in seconds) with no motion before the node switches directly from presence state to absence state. A value of 0 disables a direct transition from the presence state to the absence state (this is the default behavior).
Near Exit Delay	Required time (in seconds) with no motion, before the node switches from the internal exit ready state to the actual absence state. This option might be a workaround solution, if no door contact is present. A value of 0 disables a direct transition from the exit ready state to the absence state.

Parameter	Description
Lock Time	The time in seconds for which motion events are ignored after a door-event appeared.

Since this algorithm only performs well with reliable order of events, it didn't work well with the EnOcean based installations, where some delay in event-delivery could occur that would scramble the order. This algorithm therefore is no longer used, but remains here for documentation purposes.

4.5 Field bus programming

Our field bus system (automationNext) features an OSGi based plugin architecture allowing for flexible extension of functionality of the base system. These plugins (also referred to as nodes) can be written in Java. The functionality provided by these plugins can be connected to standard system-functions by system administrators using the next-manager software. In the following sections plugins developed for the Guiding Light project are described.

Daily Curve Node

The Daily Curve Node allows for a day-time dependent light control with predefined values for specific times. The node supports the control of multiple lighting-devices that are grouped together (like warm/cold or RGB controls inside a luminaire). The curve can be disabled temporarily (e.g. when manual dimming has been performed) via the Pause input, all values of the curve can be scaled by the Scale input (e.g. to increase/decrease overall brightness without changing the actual curve), or a new curve can be requested from the pre-configured URL via the Request Curve input. The node supports requests to http- or secured https-URLs. The requested curve is expected in JSON data format.
Status inputs that signal the current dim-value of a luminance allow for a seamless transition from the manual setting to the predefined daily curve after a manual pause timeout expires. Motion and brightness inputs can be used to implement daylight- and motion-dependent on/off switches of the connected lights. The node also allows for time-based on/off switches of the connected lights. Time- and motion-based switching can be enabled/disabled via the daily curve.

Inputs

Input	Description
Request Curve	A “true” signal on this input causes a new daily curve to be requested from the URL defined in the parameter “Curve URL”. See below for a description of the required format.
Brightness	Current brightness level that is used to determine if a detected motion should switch on the lights. If this value is below the corresponding brightness threshold and motion is detected and motion based switching is enabled, the light(s) will be switched on. The corresponding brightness-threshold and motion based switching are defined in the light curve.
Motion	Input for motion. If motion-based light switching is enabled in the curve-definition, this signal will be sent to the switch output if the brightness requirements are met.
Pause	Any incoming value on this input will pause the daily curve for the time defined in the Pause-Timeout parameter.
Scaling	Any curve value defined in the daily curve will be scaled by this factor before it’s sent to the output. This allows for scaling an entire curve without the need to change all individual values explicitly. One particular usage example could be a daylight

Input	Description
	dependent scaling of the output values.
In*	These inputs report the current control-value of the connected lights and allow for a seamless transition between manual and automatic states. These inputs should therefore be connected to the status outputs of the light control nodes.
On/Off/Switch	These inputs allow for enabling/disabling the entire node function (e.g. switching daily curve control on/off).

Outputs

Output	Description
Switch	Switches the output on/off based on either time and/or motion events.
Debug	For debugging purposes only - it indicates the internal state of the node. This output will be removed in the final version.
Out*	Target output value (should be connected to the corresponding dim-input of the light nodes).
Curve Paused	Signals if the daily curve is currently paused.
Manual Transition	Signals an ongoing transition between manual and automatic mode.
Status	Signals the state of the node (if the daily curve control node is on or off).

Parameter

Parameter	Description
Curve-Config	The curve definition (see below for a detailed description of the format). Typically this

Parameter	Description
	setting is requested from a URL.
Curve Count	Defines how many target value outputs will be controlled. By using this parameter, parts of the outputs defined in a curve could be ignored (only the first n will be used). This value must not be greater than the number of target values defined in the daily curve definition.
Curve URL	The URL from where a curve should be requested. Supported URLs start with http or https for secured connections. If this field is empty, no action will be performed after a “Request Curve” input.
Time-Shift	The daily curve will be shifted by this value along the time-axis (value in seconds). This allows for easy time-shifting of an entire curve (e.g. shift the entire curve by 15 minutes).
Min-Change	Defines a minimum change of the calculated output before the new value is actually sent to the output. This setting helps to reduce traffic on the system.
Pause Timeout	Defines the time (in seconds) that the curve will be paused after a Pause input is received.
Ticker Interval	Defines the update cycle time (in seconds). E.g. an entry of 1 will cause the outputs to be calculated every second. Small values might lead to high system load (depending on the count of total daily curve nodes), big values might cause recognizable brightness changes after each cycle.
Transition Time	Defines the transition time (in seconds) between the manual light level and the daily curve level, after a manual pause timeout.

Curve Definition Format

The daily curve is defined in the following format
<Time in HH:MM:SS form> <SwitchMode> <MotionActive> <BrightnessThreshold> <TargetValue 1> ...<TargetValue n>

SwitchMode:
0...no action, 1...switch lights on, 2...switch lights off
MotionActive: 0...no action on motion, 1...switch on/off on motion input if it's too dark in the room (defined by brightness threshold).

BrightnessThreshold:
The value (typically in lux) that defines the upper bound of available brightness for which a motion event should trigger a light on/off switch.

TargetValue*:
The desired output control value for this time in percent (0-100) for this light channel.
Columns are separated by a space character, individual entries can be separated either by a newline character or a semicolon.

The following example shows a simple curve-definition for two outputs in plain text format, where time- and motion based switching are disabled. During the night the illumination level is kept at a 20% level. Between 6 and 12 the lights will be increased from a 20% to a 100% level. Between 12 and 18 the first output will be dimmed from a 100% to a 80% level, and the second output from a 100% to a 40% level. Until 22 both outputs are dimmed to the 20% level again. Levels in between two defined times will be linearly interpolated. Note that the curve-values automatically wrap around in time.

```
06:00:00 0 0 1000 20 20
12:00:00 0 0 1000 100 100
18:00:00 0 0 1000 80 40
22:00:00 0 0 1000 20 20
```

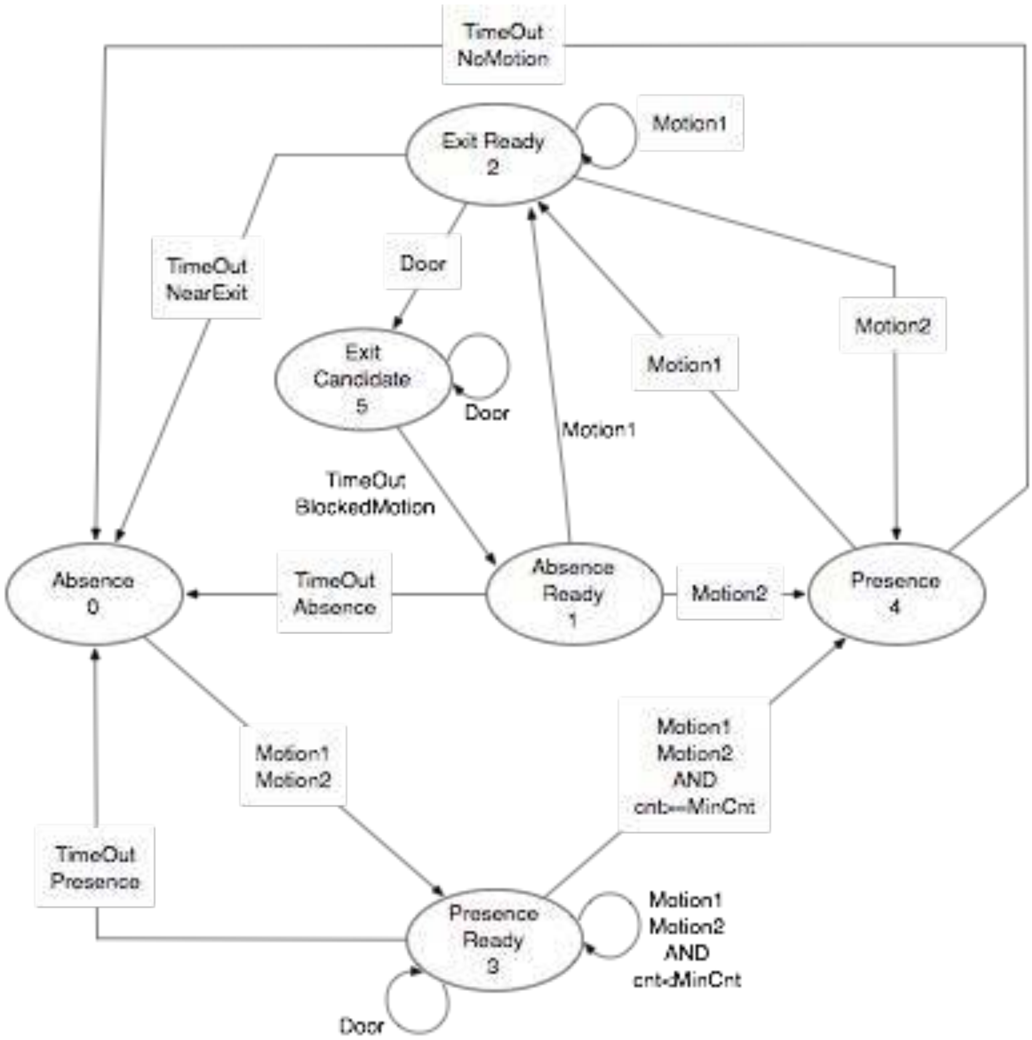
The following example shows the same curve in JSON data format:

```
[
	["06:00:00",0,0,1000,20,20],
	["12:00:00",0,0,1000,100,100],
	["18:00:00",0,0,1000,80,40],
	["22:00:00",0,0,1000,20,20]
]
```

Presence Detection Node

The Presence Detection Node indicates whether a person is present in an apartment or not. To achieve this, 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 node should help 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).



Door: a door contact event occurred

Motion1: a motion event of the detector closest to the main entrance occurred

Motion2: a motion event of other detectors occurred

TimeOut: after a specific amount of time of no events this route is taken

State-diagram for presence/absence detection

Inputs

Input	Description
Door Input	Light barrier or door-contact on the main entrance door.
Motion Entrance	Motion detector near the entrance area inside the apartment.
Motion Rest	All other motion detectors inside the

Input	Description
	apartment
Reset	Resets the internal state to no presence.

Outputs

Output	Description
Presence	Shows presence or absence (true/false)
State	Shows the internal state of the state machine.

Parameter

Parameter	Description
Absence Delay	Required time (in seconds) with no motion, before the node switches from the internal absence ready state to the actual absence state.
Presence Delay	Required time (in seconds) with no motion, before the node switches from the internal presence ready state to the actual absence state again (this might happen for example if the door is opened but then closed again without entrance).
No Motion Delay	Required time (in seconds) with no motion before the node switches directly from presence state to absence state. A value of 0 disables a direct transition from the presence state to the absence state (this is the default behavior).
Near Exit Delay	Required time (in seconds) with no motion, before the node switches from the internal exit ready state to the actual absence state. This option might be a workaround solution, if no door contact is present. A value of 0 disables a direct transition from the exit ready state to the absence state.
Lock Time	The time in seconds for which motion events are ignored after a door-event

Parameter	Description
	appeared.

Multi Presence Node

The MultiPresenceNode tries to discriminate if there are more then one persons in an apartment. The node 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 node will be. Therefore it's recommended to only use clearly separated sectors for this node.
Note that this node 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 node 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.

Inputs

Input	Description
In ...	Inputs for the motion detectors. The individual motion detectors should be clearly separated from each other (meaning that a single person can not activate both at the same time).

Outputs

Output	Description
Multi-Presence	Indicates that multiple motion detectors are active at the same time, therefore suggesting multiple persons being present in the apartment.

Parameter

Parameter	Description
Input-Count	Defines how many independent motion detection sectors should be available
Delay	Delay (in seconds) of activity states during which an input will be counted as active even though it already switched back to inactive.

Light Control Converter Node

The Light Control Converter Node adapts between the automationNext dimlight node and the Beckhoff ADS backend. Lights in the Beckhoff system at Garnmarkt only feature toggle commands and have a dim-value range of 0-254 while the automationNext dimlight node has dedicated on/off commands and a dim-value range of 0-100%. This node allows for the use of the standard automationNext dimlight nodes by abstracting away from the Beckhoff backend system.

Inputs

Input	Description
Dim	The Dim-input for standard Dim-outputs of automationNext dimlight nodes (values 0...100%).
Switch	Switch-input for standard Switch-outputs of automationNext dimlight nodes (values on/off).
Target-Level	Setting a target level for the output without switching the device on/off (values

Input	Description
	0...100%). In Guiding Light this will mostly be connected to a daily curve output.
Current-Level	The current level of a light from the target device (values 0...254). In Guiding Light this will be the actual dim value of the Beckhoff light device.
Power	The power state of the target device (values on/off). In Guiding Light this will be the actual on/off state of the Beckhoff light device.

Outputs

Output	Description
Switch	This output can be connected to the toggle input of the Beckhoff light device.
Target Level	This output can be connected to the target value of the Beckhoff light device (values 0...254)
Current Level	Shows the current dim level of the Beckhoff device in the value range of the automationNext dimlight node (values 0...100%) and is usually connected to the Status input of the automationNext dimlight node.

Parameter

Parameter	Description
Scale	Defines the scaling factor between the value ranges of the automationNext dimlight node and the Beckhoff light devices. By default this is set to 2.54 and usually should not be changed.

Direction Detection Node

The Direction Detection Node recognizes the direction in which two inputs are crossed (e.g. two light barriers that are close to each other) and activates the according output for a specified impulse length. This node can then for example be connected to a counter node to count the number of persons in a room. Timing parameters allow for fine-tuning of the direction detection.

Inputs

Input	Description
Input 1	First input (e.g. from a light barrier).
Input 2	Second input (e.g. from a light barrier).

Outputs

Output	Description
Forward	Indicates a crossing in the direction of Input 1 to Input 2. The duration for which the output is set to true can be specified in the parameter impulseLength.
Backward	Indicates a crossing in the direction of Input 2 to Input 1. The duration for which the output is set to true can be specified in the parameter impulseLength.

Parameter

Parameter	Description
Impulse-Length	The duration in ms for which the outputs should be set to true if a direction is detected.

Parameter	Description
Inverted	If true, the inputs are logically inverted (e.g. of use, if light barriers are on true if not blocked, and false if blocked).
Lock-Time	Time in ms for which processing is paused from the last output change on.
Max-Time	The maximum time in ms between the state-changes of input 1 and input 2 in order to be recognized as movement event.

Counter Node

The Counter Node features increment and decrement input and increases or decrements a counter variable accordingly. The increment/decrement amount can be configured. It also features a reset input, to reset the counter to a defined starting value. An application example would be as a person counter in combination with the direction detection node with its outputs backward/forward connected to decrement/increment inputs of this node.

Inputs

Input	Description
Decrement	Decrements the current count by the amount specified in the increment parameter.
Increment	Increments the current count by the amount specified in the increment parameter.
Reset	Resets the counter to a starting value.

Outputs

Output	Description
Status	The current count value.
Warning High	A warning output that is switched to true if the count value is above the specified high warning value. This output is only available if warnings are enabled in the parameters.
Warning Low	A warning output that is switched to true if the count value is below the specified low warning value. This output is only available if warnings are enabled in the parameters.

Parameter

Parameter	Description
Increment	The amount by which the count value should be incremented/decrement upon a count input.
Start-Value	The value to which the counter should be set to upon a reset input.
Warnings Enabled	Activates/deactivates warning outputs for high and low limits.
Warnings Upper Limit	The upper limit for the warning high output. If the count value rises above this value, the warning high output will be switched to true.
Warnings Lower Limit	The lower limit for the warning low output. If the count value falls below this value, the warning low output will be switched to true.

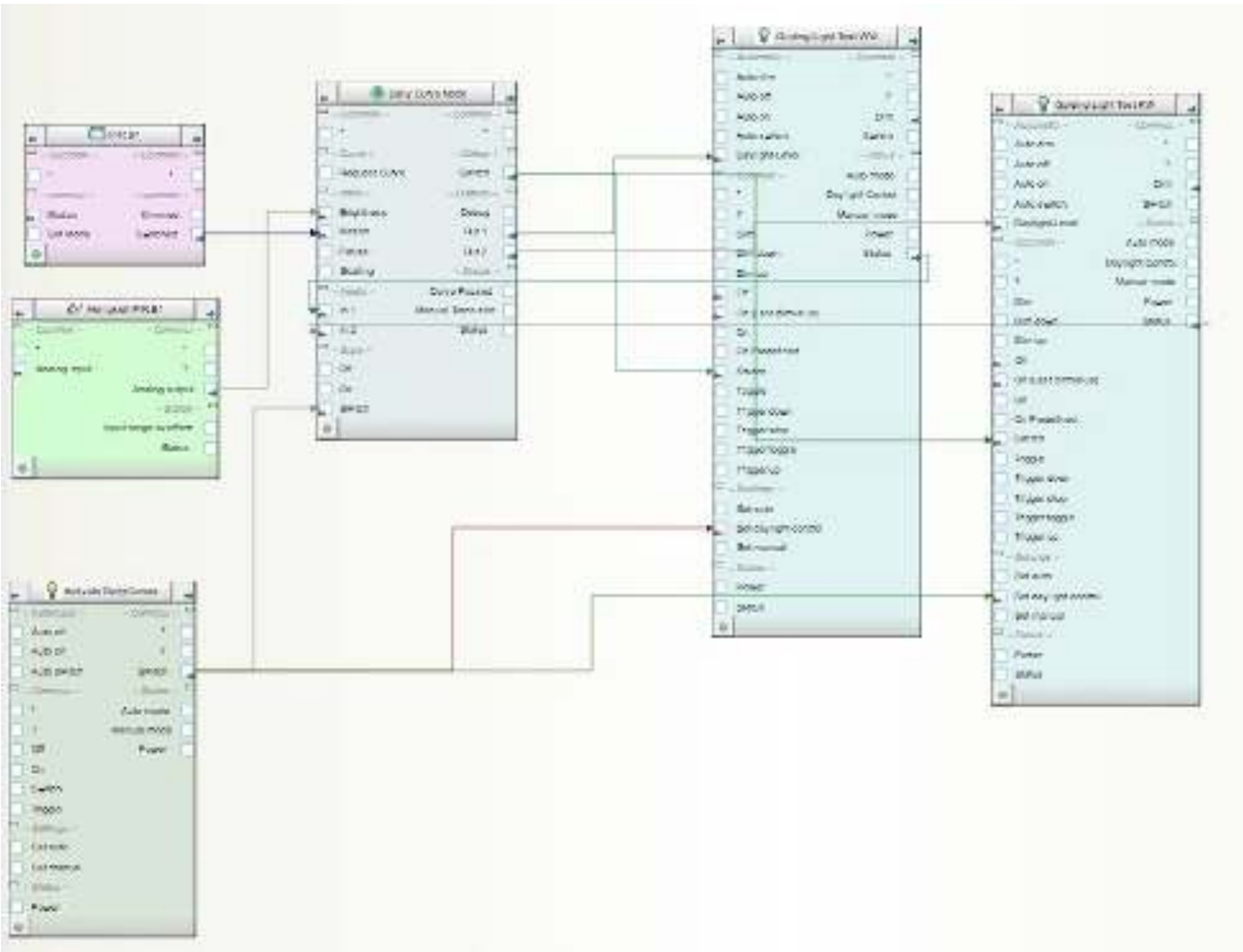
Application-Notes

DailyCurveNode in Guiding Light

The DailyCurveNode works in collaboration with the Dimlight node of the automationNext system. The DailyCurveNode outputs are connected to the Daylight-Level inputs of the dimlights. It’s important to connect the first output to the warmwhite dimlight, and the second output to the coldwhite dimlight. The Status outputs of the dimlights are then reconnected to the inputs of the daily curve node in the same order.

For the DailyCurveNode to work correctly, the daylight control needs to be enabled on the dimlights. The easiest way to achieve this, is to create a new virtual switch using a light-node and then connect the switched output to the Switch inputs of all daily curve nodes as well as to the Set daylight control inputs of the connected dimlight nodes. This way the daily curve functionality can be enabled by switching on this virtual light even from an iPhone control.

The following picture shows a typical use of the DailyCurveNode in the context of Guiding Light.



The following connections need to be made:

Source		**Target**	
DailyCurveNode		Dimlight	
	Out 1	warmwhite	Daylight-Level
	Out 2	coldwhite	Daylight-Level
	Switch	warmwhite+coldwhite	Switch
Dimlight		DailyCurveNode	
warmwhite	Status		In 1
coldwhite	Status		In 2
Activate Daily Curve (Light node used as Switch to turn on the DailyCurve)			
	Switch	DailyCurveNode	Switch
		Dimlight warmwhite	Set daylight control
		Dimlight coldwhite	Set daylight control
Brightness		DailyCurveNode	
	Analog Output		Brightness
Motion		DailyCurveNode	
	Switched		Motion
A schedule trigger to request the current daily curve connected to the *Request Curve* input of all daily curves is needed to automatically update the daily curve at regular intervals.			

To update the daily curve definition it is recommended to use a schedule trigger connected to the Request Curve input. It’s best to trigger this event during the night so no abrupt light changes occur (a typical time would be every night at 3 am). It is also a good idea to have separate triggers for the individual Guiding Light apartments, each for example 5 minutes later then the one before.

The default parameters of the DailyCurveNode should be fine for the GuidingLight context, only the appropriate CurveURL needs to be filled in for the light groups.

5. Summary

5.1 Onsite experiences

Summing up the initial lighting situation within the private homes of elderly people shows typical low values. Low means values below 200lx of horizontal illuminance. Bartenbach can approve out of its long lasting experience that this are typical values within private homes. As depicted in [1] these values are far too low in order to get good visual performances or to establish physiological effects with lighting parameters.
Punctual single and zonally limited situations within the test apartments showed adequate illuminance values. These areas were mainly near the cooker in the kitchen zone, near the bathroom mirror, or near individual adjusted floor lamps. The reason for enhanced illumination in these areas is self-explanatory or rather can be found in the fact of lamps integrated in furniture.
The initial situation was highly characterized by the utilization of diffuse shining and room centred (simple) luminaires. These luminous elements establish a balanced ratio of vertical and horizontal illuminance and were generating a low shadiness (advantages) but these luminaires were also marked with areas with high luminance (> 10.000cd/m²) which are direct visible and therefore glary.

The mounted Guiding Light luminaires guarantee ambient illuminance values up to 300lx, zonally illuminance values up to 2000lx, low glare and a balanced ratio of luminaire luminance and wall luminance.

5.2 Lighting design and sensor positioning guidelines

For refurbishment issues the wireless solution is strongly outcasting the wired solution. The wired solution is only suitable for buildings under construction or rather if the building is already equipped with an electrical bus installation. The wireless solution is preferred by the consortium and for the final business plan.
Based on the experiences of the installation of these field test households the lighting design guidelines are adequate. An installation handbook with detailed description of luminaire orientation is needed. If approved by the test person (e.g. due to aesthetical issues) within separate sleeping rooms the modified suspended luminaire was mounted and showed a good performance by having at the same time a lower installation effort. Therefore this version of lighting design for sleeping rooms is recommended.
It turned out that for the PIR-Sensor positioning it is the best to do an optimization of positioning directly on site during installation. This can be done by the person who is installing and at the same time testing detection range, detection sensitivity, etc. in real

time with the software visualization (e.g. on a tablet PC) and with a proposal for a preliminary positioning.

5.3 Optimization potential

Technical optimization potential can be found in the utilization of directly wireless controllable electrical ballast. Prototypes were already shown by industry (e.g. at the fair "Light and Building" in April 2014 in Frankfurt). Readiness for market is predicted for 2015. Such electrical ballast will tighten the amount of components and decrease the technical complexity (e.g. wiring amount on site is decreased to possible minimum, which is only the power supply).

Appendix

References

[1] D1.1 Medical, psychological, and technological framework
[2] D2.1 Applicable hardware components
[3] D2.2 Applicable software components
[4] D3.1 Solution package description
[5] Datasheet of new EnOcean-actuator "SRC-AO MULTI V / VV" from Thermokon http://www.thermokon.de/produkte/easysens-empfaenger/actuatoren/src-ao-multi.html

Used scales for photometrical measurements

Illuminance simulation (all situations)	Luminance pictures (all test persons except VP5 and VP6)	Luminance pictures (initial VP5 and VP6)	Luminance pictures (with Guiding Light VP5 and VP6)