KNX in academic education and training

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The home automation sector is a steadily growing market. Clearly, it is of importance to enhance the current education and training programs at the involved institutes. However, this is often related to a high investment into the required hardware, which provides a financial obstacle for students and institutes. The usage of simulation and training kits as proposed in this paper not only allows to reduce this financial barrier, but also enhances the quality of the education programs itself. Typical learning outcomes and teaching use cases are (1) ETS commissioning, (2) user application development on embedded devices, (3) smart phone application/visualization development or (4) providing a physical test setup for specialists and researchers.

Especially the realization of a functional prototype setup represents a big challenge, since a lot of physical devices such as lights, HVAC components or roller shutters are required. This is even harder for larger courses with around 30 participants or more (a typical size of a class at university of applied sciences), where one student or at most a group of two students should have access to smart home hardware. Besides, it is desirable that these training kits allow different teaching methods such as blended or distance learning.

To realize such a setup, one question arises: **How can training equipment be developed, which is space and cost effective on the one side and on the other side implements all necessary components, which are equipped inside a typical smart home?**

To reduce the finical investment into training devices, minimize the required dimensions of a physical training setup and enhance trainings the paper describes the following three approaches:

- *Full simulation of the hardware and software* (cf. Fig. 4): The advantage of a full simulation method is, that no smart home hardware is needed. With the aid of a software simulator (JavaFX and KNXnet/IP based, KNX group communication support), arbitrary sensors and actuators are configured the same way as real hardware and the control interfaces and the current states are displayed graphically. Additionally, a real hardware setup can be linked to the simulator via KNXnet/IP. Teaching use cases (2) and (3) are supported.
- *Physical home automation components in combination with simulated process devices* (cf. Fig. 5): Real KNX hardware such as switching and dimming actuators, KNXnet/IP devices and control panels are installed inside a mobile training case and the process devices are partly simulated. This means, that for example lights are realized as a customary LED lamps, whereas roller shutters and HVAC components are simulated by the usage of optical imitations (e.g. a visualization element consisting of 8 blue LEDs simulating the current data point value of an air condition). Teaching use cases (1) – (3) are supported.
- *Test labor with permanently installed actuators and sensors* (cf. Fig. 6): The test labor itself is realized as a room, which contains only real physical smart home components. Therefore, no physical process needs to be simulated and the whole system behavior can be observed and evaluated in real life. Teaching use cases (1) – (4) are supported.

1 Introduction and Motivation

The control tasks inside the field of smart homes technologies are getting more and more complex and it becomes increasingly difficult for students to get familiar with this domain of application. Therefore, it should be cost effective and flexible as possible for students to utilize a suitable environment to gain their experience and knowledge in this field of application.
Especially for practice orientated teaching courses the entry point represents a big challenge. On one hand caused by the need of a high financial investment into a convenient setup and on the other hand to realize a setup, which could be used for different teaching methods like in class, blended or distance learning.
An additional factor, which should not be unintended, is the division of the total number of course participants into subgroups. Ideally a subgroup consists out of one or two people and each group can work independently on their own setup. Furthermore the course itself should be designed without any constraints about the physical location.

This paper shows three different concepts to lower the entry barrier into to this field of application. The section Requirements analyses the previously named teaching use cases regarding to their applicability.
The following three sections discusses each concept in detail and shows their advantages and disadvantages. Finally the three concepts are summarized and possible further developments are shown

2 Requirements

Regarding the previous named problems some constraints need to be considered to realize these education concepts. Typically one lecture course consists of 30 students or more. So therefore a sufficient number of test setups should be available and approachable for the participants. Further the setup should be designed, that these can be used for distance learning courses, without the usage of real hardware and also for in class or blended courses.
Therefore some setups are planned to realize the different teaching concepts (see table **??** and table 2).

	ETS commissioning	user application development	visualization development	evaluation via physical test setup
Full simulation	- -	+ -	+ -	- -
Combined setup	+ +	+ +	+ +	+ -
Physical setup	+ +	+ +	+ +	+ +

$++$ applicable ; $+-$ partly applicable ; $--$ not applicable

Table 1: Analyze of practical applicability of the different concepts regarding to the teaching use cases

	group size	mobility	price
Full simulation	∞	+ +	+ +
Combined setup	1 - 2	+ -	+ -
Physical setup	1 - 2	- -	- -

∞ usable for the whole class ; ++ highly recommended ; – partly recommended; – not applicable

Table 2: Analyze of the concepts regarding to their economical factors

3 Full simulation of the hardware and software

The full simulation of the hardware and software[1] is a JAVA based program, which represents the top abstraction layer of a typical KNX installation. Additionally the user has the opportunity to link the simulation to a real installation. This delivers the advantages that each student can design the system for its own and can observe the interaction between the different devices without the need of any hardware. Later on the simulation can be proved via the connection to a physical hardware.

Inside the simulator, typical KNX devices like for example lights, switches, HVAC devices are represented by their key features. For example a lamp is abstracted as a model with the states *ON* and *OFF*, a variable which contains the information if the light is dimmable or not and a state value between 0 and 100, which represents the luminosity.
If a lamp is not dimmable the internal state value is getting automatically associated to the value 0 for *OFF* and 100 for *ON*.
Based on the model, the communication interfaces can be derived from their functionalities. For example a not dimmable lamp has only a binary communication interface, which represents the KNX data type *"DPT 1.001" DPT_Switch[2]*, whereby a dimmable lamp implements an additional communication channel to increase/decrease the luminosity step wise, regarding to the KNX data type *"DPT 3.007" DPT_Control_Dimming [2]*.

To handle the connections and the internal state of the models, the simulator is designed as a three level architecture (see figure 1). The simulation itself is handled inside the middle layer called *core* layer. Inside this layer all models are initialized and later on handled. The surrounding two layers are designed for the communication to the outer side and to enable the interaction with an user.

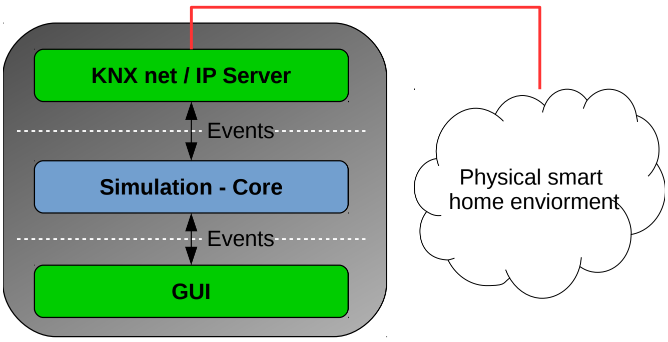


Figure 1: Architecture of the KNX Simulator

Each interaction between the different devices or user interfaces is designed as an event based operation. This means, that every state change of a device is posted into an event queue and forwarded to the depending actor/sensor models. Periodical values, like for example temperature values are posted by a separate scheduler task, which triggers all initialized device models depending on the configured post interval.

The other two layers are representing the user interaction to the simulation. These can be done via the usage of a GUI or through the connection to a physical KNX setup over Ethernet. However, both of them are subscribe and post to the internal event bus.
The KNX/IP interface contains an additional input filter, so that only messages are processed, which are already defined inside the simulator. If the telegram is known, it is parsed, transformed and handed over to the internal event bus and the corresponding modules are updated automatically.
The interface itself is realized as Server/Client architecture, whereby the simulator can be configured for both. For the message transaction the Calimero[3] library is used. Via this library it is possible to translate a message

depending to their data point format. For example a boolean value can be translated to the data point *1.001* and vice versa.

Also the GUI can trigger an update to the event bus, like for example if a user presses a switch. Consequentially all modules, which are listening to the group address, are updated. This is done inside the simulation environment and also on the physical KNX bus if it is connected.

To increase the usability for the users in view of modular expandability and stage-by-stage development during the course, it is possible to store all necessary information locally. Therefore a XML-scheme is used, which contains mainly three parameters (devices, group addresses and endpoints). Furthermore this file can be copied or moved to an arbitrary simulator instance without any lose of configuration information.
This is especially useful during teaching courses with the focus to hand over templates or examples to the participants and further to review homeworks and marking them.

4 Physical home automation components in combination with simulated process devices

A combination of physical home automation components with simulated process devices[4] opens up opportunities to integrate several typical control devices into a small space. It is especially useful for education lectures or distance learning scenarios.
The typically handled topics for KNX users during a course are the knowledge about the topology and the bus itself, the handling of the ETS and the internal functions of the devices.
Regarding that real devices like HVAC, roller shutters and lights need a lot of physical space, the devices are partly simulated.
These simulated devices are acting on the input side nearly the same as the real devices, with the only difference of the electrical load, which has to be switched. For simulating a roller shutter actor it is sufficient to observe the state of the output contacts and further to measure how long, which is switched ON or OFF. Derived from this, the simulator can calculate the current state and position of a roller shutter (see fig 2). Some constraints have to be set on the simulation side, for example the total travel time from opened to closed and vice versa and the time interval for the slat adjustment.
Through the knowledge of the idle states of the engine and the driven time, the current state can be evaluated in the simulator (see figure 2).

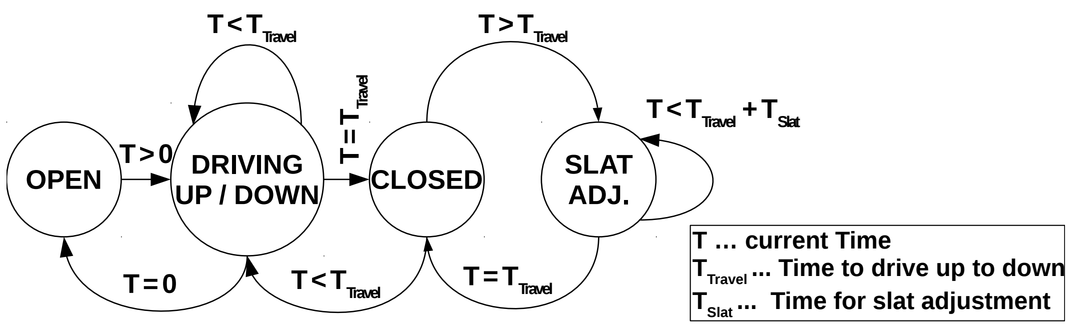


Figure 2: State machine of the roller shutter simulator

The simulation of a cooling or respectively a heating device requires a more complex hardware interface than a roller shutter. Typically heating and cooling actors switch the load through the usage of a triode for alternating current (TRIAC). Thereby it is necessary to dimension the right size of a resistive load inside the simulator. On one hand it is necessary, that a minimal holding current, which is required by the TRIAC, can flow through the load, and on the other hand the load should be not to small in view of the heat production.
To measure the duty circle of the control variable by the simulator, the signal from the actor is rectified and low

pass filtered. Through the implementation of the low pass filter, it is possible to change the sine-shaped half-wave input signal into a flat direct current signal. Afterwards the level of the signal gets compared with a reverence value to generate a square wave signal, which represents the duty circle (see figure 3).

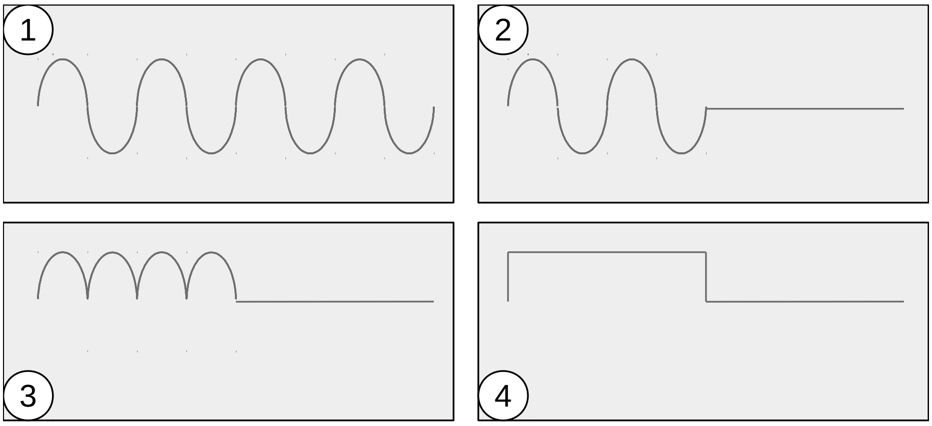


Figure 3: Signal processing of a typical HVAC outlet

Regarding to the previously named device simulators (roller shutter and HVAC), it is possible to reduce the amount of space to represent a single room as one model. Thereby real actor/sensor outputs can be linked with the simulated device and integrated into a mobile training kit (see figure 5).
Through this setup it is further possible to create a flexible setup to realize several tasks with different complexity. In detail, this means that several training kits can be connected together (for example over Ethernet or over the physical KNX bus) to represent a whole smart home with several rooms.

5 Test labor with permanently installed actuators and sensors

A permanently equipped test room delivers the advantages, that the participants can see and feel the real interaction between the different devices and the corresponding physical behavior of the installed devices.
Especially this can be seen for light luminance control scenarios. The user sees immediately the real illumination of the room as opposed to a partly or full simulation (see sections 3 and 4). Furthermore the user has the opportunity to see the physical behavior of the other installed equipment, like for example roller shutters or heating/cooling devices.

These previously named advantages implicate also some disadvantages, especially during teaching lectures. Each control scenario needs time until a tendency can be measured. This can be seen primarily during heating-up or cooling-down phases of a room, which typically needs a long time period.
If a started test setup behaves not as intended, mostly caused by an user implementation / configuration error, a huge amount of time is needed to repeat the test under the same conditions. Furthermore to recreate the initial state before the new test starts.

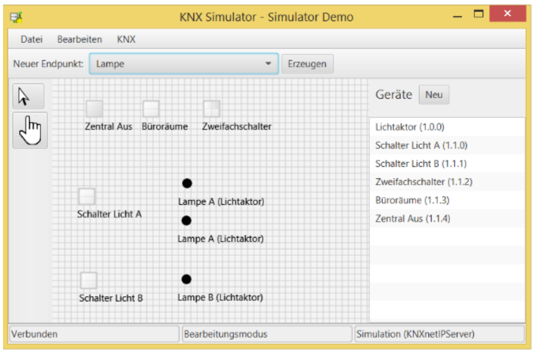
6 Resume and Outlook

Typically an education institute is equipped with a small number of physical test labors. Thus, sharing is required, the total time for one student group is limited. Therefore two alternative training devices have been shown to compensate this problematic.
The first alternative is a full simulation onto a workstation. Thereby each student can make implement his own configuration. Further some basic experiences can be gathered so that they get familiar with this field of application.
The second alternative is a partly simulated environment, like the mobile training kit (see section 4). This kit can be used to enhance the previous gathered experiences or as a standalone trainings device. Especially this kit offers the big advantage to implement typical actors and sensors inside a smart home environment into a small device and further that this partly simulated environment acts nearly as a real environment. Both of them are very useful for students to test different configurations and to improve them. During the development inside a simulated environment most of the typically made errors or failures can be precluded.

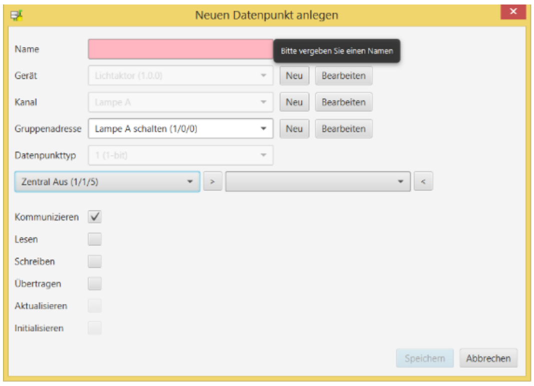
Under the usage of a tested configuration, the total time inside the test labor can be reduced to a minimum. This would further automatically increase the number of possible groups, which could use the labor in a given time period.
For distance learning lectures, the combination of simulator and real test labor can be especially useful. They can implement their setup locally at home and only for a final test, they have to visit the test labor.
For blended learning scenarios the mobile training kits could be used. Each group can prepare their implementation for their own, by reference to a given system layout diagram. During the next lectures the participants can implement their designed configuration onto real hardware.

Regarding the aspects to improve the factor demonstration and modularization inside a lecture course and for completely beginners additional test devices are currently under development. In detail, this means that a mock-up model is planned, which is equipped similar as a physical test labor only with the constraint, that the size of the devices and the room are downscaled. Additionally sensor and actor interfaces are planned, so that it is possible to exchange the control device with a little amount of time.

A further development, which is currently planned, is the expansion of the full simulator. Currently their is no interface to the ETS and linked to that no ETS commissioning is possible. With the fact, that more and more courses are designed for eLearning, this area of application can be an interesting research area.



Simulation view



Configuration

Figure 4: KNX Simulator[1]

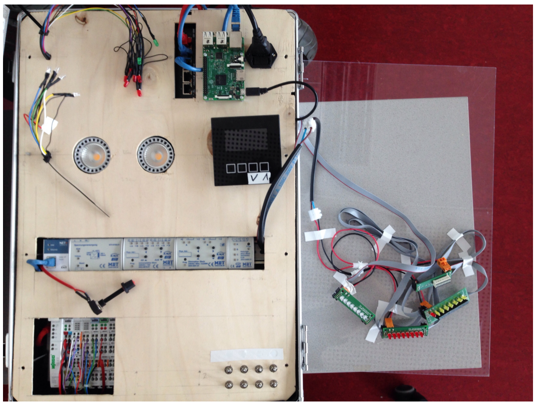


Figure 5: Prototype of a mobile KNX training kit (final kit will be available after the conference time)

Figure 6: Test labor with permanently installed smart home components

References

[1] J. Klug, “Virtueller knx simulator,” Tech. Rep., Mai 2015.

[2] KNX Association, *System Specificaation - Datapoint Types*, KNX Association Std., 2010.

[3] TU Wien, “Calimero - EIBnet/IP Tunnelling (and more) for Java.”

[4] C. Hammer, “Smart home mobile trainingskit,” FH Technikum Wien, Tech. Rep., 2016.