Integrating Tangible and Virtual Construction Kits for Teaching Mechatronics Design

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Abstract: In this paper, an experimentation lab kit for mechatronics training and control learning is proposed, which integrates tangible and virtual building blocks using the concept of interchangeable components. Interchangeable components represent either real physical or virtual devices or software. The proposed solution opens interoperability with different construction sets allowing the construction of small mechatronics systems. Our goal is to provide a learning tool, which supports experience-based learning in mechatronics education and training.

1 Introduction

Construction kits, designed for the building or assembly of tangible models, play a significant role in engineering education, especially in learning settings where students have to solve open-ended problems through the construction of new artefacts or processes. The long tradition of construction kits illustrates that these tools have a very motivating role in engineering education and vocational training [SG07]. Existing kits like LEGO [Le09], Fischertechnik [Fi09] or FESTO MechLab [Fe09] are typical and prominent examples of such type of tools, employed not only in schools and universities, but also in industry for supporting creativity and encouraging design skills. Unlike virtual models conveyed via computer screens, constructed tangible models offer tactile, as well as auditory, olfactory and visual stimuli for their user. In their role as tangible objects, physical construction kits provide the learner with the natural behaviour of materials such as stability, friction, and dynamic stiffness. Beside these explicitly technical aspects, there are also intriguing social affordances of construction kits. They motivate for collaborative learning: students can work together on a single project or assembled models serve as stimulation for a group discussion. On the other hand, there are also limitations to traditionally physical construction kits [Ei02]. While these tools can be used to create dynamic machines, they do not offer the flexibility of virtual models or computer-based simulations. An important educational value of simulations or virtual lab kits is the opportunity to experiment and practice without being exposed to hazards. That is why computer models often acts as an antechamber (e.g. for pre-lab assignments) to real-world experiments, allowing the application of theoretical knowledge in a safe environment before trying out the same actions on real equipment

[ME07]. In other cases virtual construction kits are useful to provide complex experiments without the need to purchase real and costly equipment. By considering both, pro and cons of tangible construction kits, then, we may ask how computational media could be successfully combined or integrated with these kits. In this paper we present our suggestion for bridging tangible and virtual construction kits using the concept of *interchangeable components.*

2 Pedagogical Considerations

Mechatronics systems integrate mechanics with electronics and software. This integration involves finding a balance between the basic mechanical structure and electrical as well as information processing components [FWG04]. Accordingly, mechatronics design requires interdisciplinary thinking and multi-domain design skills. It is widely believed, that in engineering courses those competences and skills have to be practised in learning settings, where students gain open-ended problem-solving experiences [Be04]. To support an easy integration of these requirements into everyday teaching of mechatronics, we require low cost devices for students to use from home and at their own places, from lecture rooms connected to laboratories, or vocational schools connected to students industrial workplaces. Our suggestion of a construction kit, which supports open-ended problem solving and experiential learning, is intended to contribute to this aim. Last but not least, Buxtons' "less is more" design principle motivated us to reflect more about tiny and simple learning tools in relation to engineering education [Bu01].

3 System Design

The proposed construction kit is based on the concept of interchangeable components [SP07], which represent either real-physical or digital counterparts (Fig. 1). Key building blocks of a mechatronics construction set are first of all basic mechanical and electromechanical elements plus sensors and actuators. Moreover we have electronics (hardware) and information processing components (software), in which embedded computer systems (e.g. Programmable logic controller) play the "brain role". One of the most interesting aspects is how these various individual building blocks are linked to build a whole system.

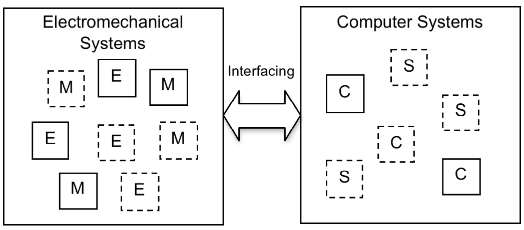

Fig. 1: Key building blocks of a mechatronics construction set (M=mechanical, E=electrical, C=control hardware, S= software. Dashed blocks characterize digital/virtual components)

The consideration of the means by which components are connected is certainly accompanied by considering the materials of those components: Fischertechnik bricks, for instance, use a mechanical ‘channel-and-groove’ connection system, other construction sets use screws and bolds. While tangible building blocks are connected via material, software components are linked using communication lines, where information (data, software) is transferred. There are various possibilities to connect physical with digital or virtual systems. In mechatronics a wide spectrum from real-time communication technologies to distributed control systems (DCS) exists. For didactical purposes low budget interfaces with minor technical requirements are sufficient. Physical computing [OI04] provides interesting concepts, frameworks and easy to handle prototyping tools, which can be applied to develop a middleware for interfacing physical with virtual objects. Such a middleware plus embedded microcontrollers are something like ‘glue’ for assembling mechatronics modules. A key goal of our approach is to integrate also external engineering tools, like LabView [La09], MathLab/Simulink [Ma09] or PLC (Programmable logic controller) software in combination with LEGO, Fischertechnik or FESTO material or other physical construction sets, because these learning tools are very common and popular in mechatronics classes. Moreover external simulators (e.g. for digital circuits or pneumatics) should be adaptable. In the final stage, the proposed construction kit should support hardware-in-the-loop (HIL) functionality. Some of these ideas are not easy to put into practice, but they are a starting point for designing engineering learning tools for the future.

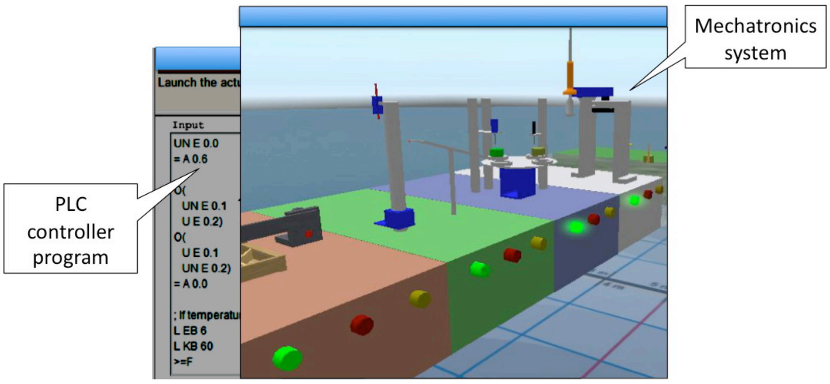

Fig 2: Virtual mechatronics device (OpenSim 3D client).

4 Implementation of a First Prototype

The current work is at early stages of development. Most of the results are in the research field. So that selected standards and technologies were studied. In the first prototype we have implemented a middleware, which allows interfacing a PLC controller – either virtual or real – to physical or virtual sensors or actuators. The developed prototype is based on the PROCESSING programming tools [Pr09]. For the hardware we choose the ARDUINO open-source prototyping platform, which is widely available and inexpensive [Ar09]. The prototype includes a basic Web Service providing a compiler for PLC languages and an interface driver to connect the PLC controller board with the lab server. The compiler itself is also written in PROCESSING and capable to translate a PLC instruction list in an intermediate runtime code, which could be executed on the microcontroller hardware. The concept is open for further enhancements. Clients' access is realized through TCP/IP network connections. We used the PROCESSING network library to implement the appropriate services. In a second case study a solution to link a PLC controller to a virtual mechatronics device, which is modelled in OpenSim [OP09], is under development (Fig. 2).

5 Conclusion

The design of mechatronics systems requires multi-disciplinary studies in modelling systems and processes to meet specific needs. This is a creative, iterative and often open-ended process. There are several papers discussing this issue from different perspectives. The goal and subject matter of our work is to provide a learning tool, which supports experience-based learning in mechatronics and opens interoperability with available tangible and virtual construction kits.

6 References

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