A Unified Communication Platform for Enriching and Enhancing Presentations with Active Learning Components

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***Abstract*—There exist various audience response systems (ARS) and other standalone solutions to enrich presentations with supplementary active learning content. We propose a unified communication platform for enriching and enhancing presentations with active learning components where third-party solutions can easily be integrated via data adapters, activity plug-ins as well as a multi-directional communication channel based on a publish-subscribe pattern. We present how the MindXpres presentation platform has been extended with a communication module and discuss a number of activity plug-ins that have been realised. The presented unified communication platform in combination with the MindXpres presentation tool represents an ideal platform for the investigation and rapid prototyping of new forms of presentations that support enhanced forms of interaction between a presenter and their audience.**

***Keywords*-Presentation; audience response system; active learning**

I. Introduction

Over the last two decades we have seen the rise of *active learning* as an alternative to the classic lecture setting where often little interaction happens between the instructor and their audience. As defined by Bronwell and Eison [1], active learning is about "*involving students in doing things and thinking about the things they are doing*". As technology has been evolving, different forms of student engagement have adapted alongside and are increasingly offered in the form of so-called digital *audience response systems* (ARS). However, available hardware, applications and forms of interaction are quite diverse and frequently offered as standalone bundles. One issue that we address with the presented unified communication platform is that the functionality of current response systems is often too dependent on specific hardware manufacturers. Existing hardware is frequently bundled with software providing some fixed functionality. Unfortunately, a user is limited to the offered functionality and is typically not able to use the hardware in other settings. For similar reasons, it is often not possible to utilise hardware from different manufacturers with the same audience response system for uniform data collection. In order to address these challenges, we present a unified approach addressing the technical challenges involved in the coordination of hardware, media and the involved parties during lectures and presentations. We start by discussing some related work. We then show how the MindXpres [2], [3] presentation tool has been extended based on a number of identified requirements, in order to address the shortcomings of existing solutions. The presented architecture of our unified communication platform allows for arbitrary combinations of hardware to be used together with some plug-in-based audience interaction. The flexible integration of new devices together with the highly extensible MindXpres platform makes the presented solution a valuable asset as a research platform for prototyping novel audience-driven functionality or interaction modalities for future presentation solutions.

II. Background

Since the introduction of the term active learning by Bronwell and Eison [1], this category of instructional approaches has been thoroughly evaluated [4]–[7]. In general, the literature shows that a higher level of engagement increases attendance as well as motivation and aids in the learning process [8]. For example, a student who is forced to participate in small quizzes during the lecture will remember more content. Active learning is of course not limited to quizzes only. Students can, for instance, also be further engaged via discussions, exercises, brainstorming, simulations or games.

One of the more common forms to involve the audience in a presentation is through the use of so-called clicker systems. These are small portable handheld devices with a limited number of buttons, allowing its holder to select and submit a choice during polls or quizzes. Turning Technologies[1] and i>clicker[2] are only two of the various manufacturers of commercial clicker solutions. Due to the diversity in technical characteristics (e.g. the used wireless technology or communication protocols) the devices share a common shortcoming in the sense that they can only be used with the software supplied by the vendor and cannot be mixed. This also implies that the usefulness of the hardware is

[1]http://www.turningtechnologies.com
[2]http://www.iclicker.com

determined and sometimes restricted by the activities and features offered by the corresponding vendor's software.

With technology becoming cheaper and more ubiquitous, we also see an increasing use of mobile devices, including smartphones, tablets or laptops, for audience-driven interaction. Standard Internet connectivity is commonly used to deliver activities and send back results which reduces hardware requirements, meaning that a touch screen-enabled device with a modern web browser is often sufficient. In this category of audience response-driven solutions, various commercial products such as Infuse Learning[3] or TodaysMeet[4] are available. Nevertheless, also for these solutions we can identify a number of issues. First of all, functionality is fragmented across solutions. Some systems focus on delivering activities and gathering results while others provide communication channels for discussions and brainstorming sessions. Furthermore, while the use of mobile devices is certainly beneficial, the reviewed systems do not offer the functionality to integrate third-party hardware such as digital pens[5] or the previously mentioned clicker systems. Finally, while clicker systems sometimes offer plug-ins for popular presentation tools, these web-based systems come in the form of a web application and require the instructor to constantly switch between the audience response system and a presentation tool such as PowerPoint. Note that we identified a number of other systems using different types of hardware, such as the TI-Navigator[6] or Bic Education[7], showing similar limitations.

III. Requirements

The shortcomings that we identified in the previous section can be traced back to three aspects of classroom systems that have received little attention in the past. These three aspects include hardware *interoperability*, *extensibility* of the offered functionality and the *integration* of rich media activities that go beyond simple poll results in presentation tools. We proceed by outlining some requirements to address these shortcomings which also form the basis for the implementation of our unified communication platform.

A. Multi-directional Communication Flows

Initially, audience response systems were seen as a communication channel that allows students to send information, such as the answers selected during a quiz, to the instructor. Later, the importance of communication between students has also been recognised and adopted in classroom communication systems [9], [10]. In order not to limit the potential of an extensible communication platform, we deem it necessary to support bidirectional communication between any of the involved parties. Additionally, it should also be possible to create partitions of parties (e.g. groups of students) via the underlying communication framework. Different settings require different roles such as anonymous users, identified users, instructors or content moderators. We therefore propose the adoption of a customisable role model for the distribution of authority and the corresponding linked functionality during activities.

B. Hardware Interoperability

As mentioned previously, there are many different forms of input devices for electronic response systems, including clicker systems, digital pens [11] and proprietary or general purpose mobile devices such as tablets, laptops or smartphones. Often these systems come with proprietary software that dictates the supported features. A contribution of our proposed platform is the elimination of this type of vendor lock-in. We discuss an extensible mechanism that allows different input and output devices to be integrated in the system with several important implications. First of all, institutions that have already invested in particular hardware will be able to use it with the proposed platform and can benefit from new functionality not offered by the original software. Second, since regular mobile devices can be used, we foresee to reduce the costs of full-fledged audience response systems. Last but not least, a common interface also allows arbitrary combinations of device types to be used together whenever an activity supports this form of interaction.

C. Activity Plug-ins

When using third-party hardware, one is often limited to use the software suite that comes with the product. We propose the modularisation of functionality and scenarios into so-called *activity plug-ins* in order to allow third parties to contribute. To further simplify the development process, the communication framework has to provide the necessary abstractions via an application programming interface (API). Thereby plug-ins can make use of connected hardware and the various communication flows presented earlier.

D. Integration with Presentation Tools

In order to provide a seamless learning experience, the integration of an audience response system within existing presentation tools can only be beneficial. Additionally, we recognise that a presentation's lifetime does not necessarily end after a lecture. Even though it was not the original purpose of slide decks, they sometimes form a core part of a student's available study material. As educational material is evolving, the post presentation phase might become more important and requires extra attention. Content is becoming increasingly interactive and non-linear, and a lot of information is lost when student's are offered static slide decks as study material. As a final guideline, we therefore state that

[3] http://www.infuselearning.com
[4] https://todaysmeet.com
[5] http://www.anoto.com
[6] http://education.ti.com
[7] http://www.bic-education.com

data gathered during a presentation should be replayable at a later stage. For example, the study material received by the student could contain the path that was traversed by the instructor, their annotations (as well as those by other students) or the questions and answers that were generated at a given point in time.

IV. Unified Communication Platform

Based on the principles presented in the previous section, we have developed a functional prototype of the proposed communication platform by extending the existing MindXpres presentation tool [2], [3]. One of the characteristics of MindXpres is the extensible data-driven approach for visualising content. Presentations are defined in a LaTeX-like language and similar to LaTeX, the layout of content is handled automatically based on themes and plug-ins after compilation to a portable HTML5-based presentation bundle. Plug-ins are implemented in JavaScript and may add content or attach event handlers to the DOM tree in order to visualise the data that they are responsible for. Unlike existing declarative languages for presentations, MindXpres is geared towards modern presentations where navigation becomes increasingly non-linear and content is richer and more interactive. As most of the visualisation and navigation is realised via plug-ins, the MindXpres program code consists of little hardcoded functionality. Rather, it offers powerful abstractions such as a graphics engine, where plug-ins can be used to integrate novel presentation media types with as little effort or restrictions as possible. Similar to the existing graphical abstractions, we have now extended the core of MindXpres with a communication module. The goal is to provide the necessary abstractions that MindXpres plug-ins do not need to worry about the technical challenges related to the connectivity in audience response systems. The provided interface allows plug-ins to interact with audience hardware in a uniform way and make use of the multi-directional communication flows described earlier. Therefore, the plug-ins can focus on implementing specific audience-driven activities.

A. Network Infrastructure and Central Access Point

On the network infrastructure level, our solution is based on a small but powerful computer that acts as a central hub for audience devices and instances of a MindXpres presentation. For our prototype we used an Intel Next Unit of Computing Kit (NUC) equipped with high end WiFi and Bluetooth modules for wireless connectivity. Although we mainly focussed on wireless devices, the access point also provides USB, HDMI and Ethernet interfaces which are equally valid means of adding new devices to the platform. Our setup consists of off-the-shelf components but is by no means defining the platform. Since the implementation of previously presented principles mainly contributes on the software level, one could easily switch the access point for a similar device with other hardware or adapt it for different scenarios. Mobile devices, which can act as input as well as output device, simply connect to the WiFi network that is broadcasted by the access point. After connecting to the access point, a user is presented with a MindXpres presentation instance and forms part of the network of devices. In addition to WiFi, Bluetooth can be used as a way to add devices such as digital pens or headsets to the network.

B. Unified Hardware Interface

In order to provide a solution for hardware interoperability, we need to support a variety of communication protocols and channels. As a first part of the communication module, we introduce the concept of *data adapters* which translate device-specific communication formats to a uniform representation before the core and its plug-ins can handle the data as illustrated in Figure 1. If an input device already conforms to the proposed interface (e.g. a web application developed for our platform) it can directly use the interface to pass input data to the communication module via the WebSocket protocol. For third-party devices that do not directly interface with the MindXpres core, a data adapter that performs the translation between a device-specific protocol and the access point's WebSocket-based protocol has to be developed. The access point can thereby act as a container for JavaScript-based adapters but they can also be implemented as separate processes and in different programming languages on the access point or even on other machines. For instance, a dedicated computer could be used to perform processor-intensive gesture recognition on a video feed and pass the detected higher-level gestures to the central hub via the WebSocket interface. Data adapters are often bi-directional but in some cases, for instance for output-only devices such as large LCD displays or projectors for the delivery of assessments, they might also be limited to one-way translation.

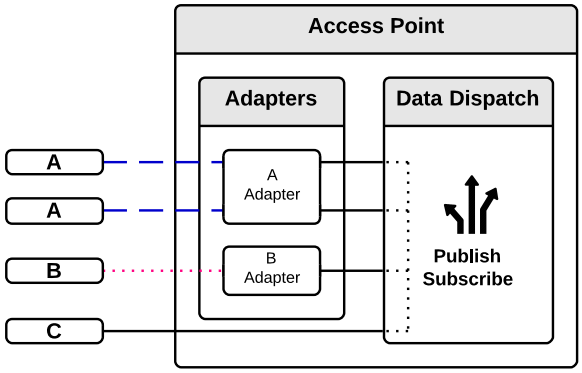


Figure 1: Access point as a bridge between hardware

C. Inter-Presentation Information Flow

While the access point acts as a bridge between different hardware components, we also have to provide a mechanism to orchestrate the flow of data between connected devices in order to provide more than simple broadcast-based communication. We decided to base our solution on the publish-subscribe software pattern and offer a publish-subscribe mechanism on the access point. Devices that are running an instance of the presentation and its associated plug-ins can make use of a number of abstractions to send events to specific parties (*publish*) or they can ask the access point to receive specific events generated by plug-ins running on other devices (*subscribe*). Our abstractions further enable the targeting of specific roles and partitions as suggested earlier when discussing the requirements. Any unidentified device is given the role of an anonymous student by default but a user can then identify themselves to obtain a role with more authority. All users are served the same instance of the MindXpres presentation with the same set of plug-ins but the currently acquired role can be used by plug-ins to change their behaviour and the offered functionality accordingly. An instructor might, for example, be able or disable a quiz while this feature will not be offered to a student.

D. Unified Communication Platform in Use

As an illustration of how the presented components work together, we would like to provide a detailed description of a feature that we call *navigation mirroring* and which will also be used by the use cases in the next section. The general idea is that a presenter's navigational state represented by the currently projected content is also shown on the screens of devices forming part of the network. If the presenter navigates to another piece of content, the content should also be updated on other devices forming part of the network. We have realised this functionality via a single MindXpres plug-in.

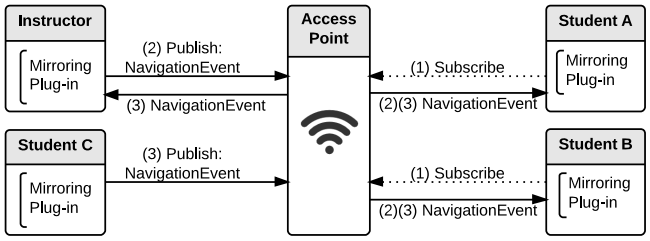


Figure 2: View mirroring via publish-subscribe mechanism

In Figure 2 we illustrate how the plug-in makes use of the publish-subscribe system to synchronise the views. Step (1) shows how devices that are interested in receiving a mirrored view (i.e. student A and student B) may subscribe to events related to navigation. When executing with the anonymous or student role, the plug-in simply acts as a listener. Step (2) highlights how the mirroring plug-in executed under the instructor role publishes navigational changes made by the instructor. The provided abstraction automatically delivers the event that is generated on the instructor's device to the access point which then forwards it to any other devices that have subscribed for this type of event. Once the subscribing plug-ins receive an event, they only need to update their view based on the information attached to the event. Note that this basic idea has been extended to allow audience members to take over navigation if they are given the permission. In step (3) we illustrate how a mirroring plug-in running under the student role (i.e. student C) can also trigger view updates on subscribed devices if given permission.

V. Use Cases

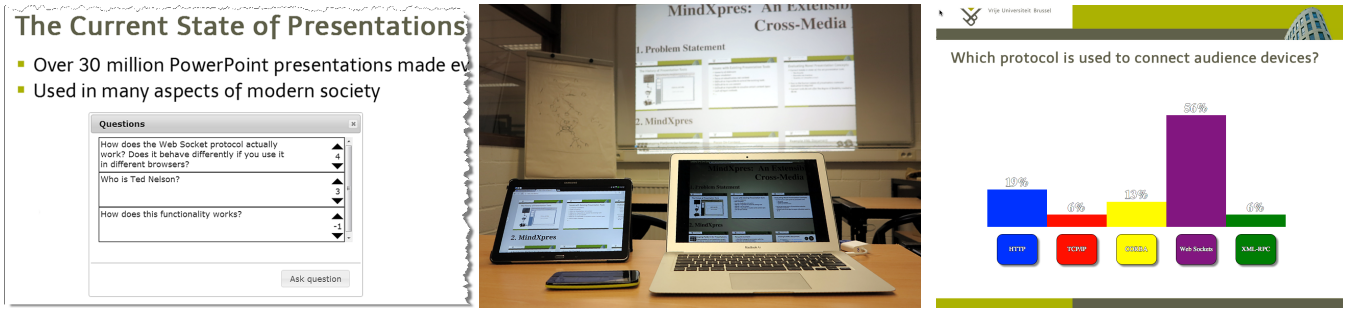
After having discussed the technical details, we would like to illustrate the potential of our unified communication platform by describing some of the realised activity plug-ins.

Polls and Quizzes: The poll or quiz plug-in allows audience members to use their hardware to select one of multiple possible answers for a given question. The results can either be collected anonymously or traced back to specific users. The plug-in also provides the instructor with a real-time overview of the incoming answers as highlighted in Figure 3 (c). Questions and answers can be hidden by either blurring them out or by keeping them completely invisible until the instructor opens the quiz for input.

Navigation Mirroring: The mirroring plug-in allows other devices to see a copy of the currently presented content on their own devices as shown in Figure 3 (b). If the presenter navigates to different content, this is immediately propagated to all connected devices. Note that audience members can enable or disable this functionality at any time.

Navigation Takeover: As it is often inappropriate to interrupt a presenter during a presentation to ask a question, most people keep their questions until the end of a presentation. However, since the relevant content is likely not displayed anymore, the presenter might be asked to navigate back to the corresponding slide. This can lead to problems if the audience member does not know the slide number or the presenter does not immediately understand what the audience member wants to see. To deal with this issue, we developed a plug-in that lets audience members control the presentation. In order to avoid any abuse, audience members need to digitally request permission or the presenter has to select them manually.

Content Discussions: In order to allow audience members to debate about the content during or after the presentation, we have developed a plug-in that allows them to provide comments or ask questions about individual slides. In the spirit of social media, users can mark a question or comment as interesting which ranks this question higher than other questions. The presenter is offered an overview of the audience feedback as illustrated in Figure 3 (a) which allows them to identify the most popular unanswered questions or



(a) Questions (b) Navigation mirroring (c) Polls and quizzes

Figure 3: Some of the activities implemented as MindXpres plug-in

to spot parts of the presentation with a lot of activity. The plug-in can not only be used to collect questions during the presentation for answering them afterwards, but it can also serve as a discussion platform in the post-presentation phase.

Annotations: The ability to use different types of hardware as input media has interesting consequences for annotating the content. Annotations can be made with the mouse, keyboard, touch-enabled devices or digital pens. Annotations by the presenter are relayed to other instances of the presentation in real time or they can be kept hidden if desired. Future work includes the ability to allow audience members to share annotations with other audience members.

VI. Discussion and Future Work

There is no shortage of audience response or classroom connectivity systems and we do not claim that the presented use cases are unique to the MindXpres presentation platform. However, our contribution is a unifying communication platform making this category of systems more open and extensible on the software as well as on the hardware level. The presented architecture allows a broad range of hardware to be unified for usage within the extensible MindXpres presentation solution. Immediate benefits include the possibility to give existing proprietary hardware a new purpose during lectures and classes and use them for a wide selection of pluggable audience-driven activities. However, in the long term, MindXpres shows potential as a rapid prototyping platform for investigating innovative presentation features.

The contribution of this paper is mainly on the architectural level but future work includes the evaluation of the implemented use cases in terms of their usability. Also on the technical side there is still room for improvement. The single access point results in a star-shaped network topology with a single point of failure and limited scalability. We are therefore currently investigating WebRTC-based P2P connectivity as an alternative. Furthermore, we are looking into supporting virtual classrooms which involves the extension of our system's reach beyond the local network in order to connect remote users and devices. Given that we achieved a uniform representation of the data flow between users and devices, we also see potential for integrating functionality related to learning analytics. A core MindXpres module for gathering and processing analytics would provide immediate access to all the standardised information shared between users and devices, resulting in a more detailed analysis.

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