Educational scenarios for cooperative use of Personal Digital Assistants

N. Pinkwart, H.U. Hoppe, M. Milrad & J. Perez
University of Duisburg-Essen, Germany & Växjö University, Sweden

Abstract Based on experience in orchestrating collaborative learning scenarios with ubiquitous computing technology, three approaches for extending co-constructive modelling and discussion environments with Personal Digital Assistants (PDAs) connected through a wireless network are described. One application is an annotation tool, the second one replicates a modelling system on the PDA and the third one makes use of a wireless optical reader in addition to the PDA. They all provide 'lightweight' synchronisation mechanisms in PC-based environments. General design and implementation strategies for such extensions are discussed in terms of model, view and controller.

Keywords: Case study; Collaboration; Distributed; Handheld; Mobile; Primary; Synchronous; Wireless

Introduction

There is great interest in introducing Personal Digital Assistants (PDA) into educational scenarios to orchestrate classrooms by using ubiquitous computing (Weiser, 1993; Norman, 1998) in an unobtrusive way. The idea of a 'computer-integrated classroom' has been practically elaborated and put into practice in the European NIMIS project (Hoppe *et al*., 2000). The most evident and concrete result of NIMIS is a classroom installation at a primary school which features special hardware such as an interactive whiteboard and pen-based tablets embedded in the pupils desks in a networked environment with educationally designed groupware functions (see Fig. 1).

Fig. 1. The Nimis Classroom

The software includes a special application for initial reading and writing ('Today's Talking Typewriter') using pen-based input and speech synthesis, as well as a special desktop which facilitates archiving and communication functions for early learners even before they are skilled in reading and

383

writing. Scenarios using similar ubiquitous computing elements have also been installed for practical use in the authors' academic teaching (Hoppe *et al.*, 1999).

In the development of these scenarios, the following principles have been formulated and applied:

- provide uniform access to multiple representations of media and use a variety of information sources;
- avoid letting the technology 'get in the way' but facilitate existing classroom procedures;
- do not let the educational scenario be determined by the use of a computer, but let interactive digital media be a 'resource-at-hand' in the background similar to the traditional use of paper and pencil;
- exploit the added-value from being able to replicate, distribute and re-use externalised learning results easily in a networked digital environment.

More recently, attention has been focused on combining technologies for synchronous collaboration in shared workspaces with interactive-constructive environments based on computational representations resulting in what may be called 'collaborative mind tools' (Pinkwart *et al.*, 2002). Typical examples are collab-orative modelling environments, e.g. based on 'System Dynamics' or 'Petri Nets'.

As a consequence of the NIMIS and other experience, it seems that pen–based interaction with multi-representational software allows digital or computational technologies to be flexibly available without dominating the educational scenario. Yet, the NIMIS scenario used wired devices with fixed locations in the physical environment. Using wireless networking could extend the range of classroom scenarios and processes to be served, and could make the results directly 'physically portable', within the classroom but also between different locations (e.g. school, the 'field', and home). This is also supported by Gay *et al.* (2002) who claim that mobile computing can function effectively in collaborative settings by enabling students to share information and coordinate their tasks.

Currently, for certain reasons (availability, acceptance, network connectivity and price), PDAs appear to be a straightforward solution for mobile applications. The next section describes and discusses the approach and experience of incorporating PDAs into educational scenarios. One scenario also combines another mobile device, a scan pen, that is used for simplified data input.

Educational applications of PDAs

The currently available educational applications of PDAs can be categorised into two main types of use:

- the PDA serving as an interface to a 'main' desktop program to extend the use of the desktop application for specific scenarios; here, the mobile device may, in the extreme case, just serve as a front end, e.g. for outdoor data input;
- a standalone application running on the PDA, with or without connection to a central desktop application; this approach includes several mobile applications allowing collaboration via direct communication between the devices.

Examples of the first category are 'ImageMap' from SRI International or the 'museum guide' of CILT (Roschelle & Pea, 2002). In the case of 'ImageMap', the PDA is used by students who receive an image on their mobile device and have to answer a given question on it using annotation techniques. Having done so, they send their annotations back to a server where all the different comments are gathered and

displayed on a public screen, allowing teacher and students to discuss the answers.

Similar to 'ImageMap', the mobile application 'museum guide' is also essentially an interface for communication with a central server. It is used primarily for retrieving data and displaying information about a museum. The current location of a user can be detected and is used for offering location-based information to the user.

Examples of applications falling within the second category include 'Geney' by EDGE Laboratory/CS Division and 'PiCoMap' from the hi-ce group (Luchini *et al*., 2002). The goal of 'Geney' is to collaboratively 'engineer' a fish with a particular set of characteristics under restrictions arising from genetic rules. The students take different roles: one of them acts as a 'manager' whose fish will be paired with a fish constructed collaboratively by the other students. During a so-called 'what-if' mode, the view on the mobile applications differs according to the student's role: the manager sees a condensed overview whereas the other participants have a more detailed but restricted view of resulting characteristics. So, the students have to combine perspectives and collaborate to achieve optimal results.

With the 'PiCoMap' application, students can illustrate a specific given problem using a graphical representation consisting of nodes with text input and directed links. Having done so, they can exchange their developed models in pairs. Afterwards, they annotate the ideas of the co-learner. The aim of this system is to lead students to a discussion about their different views and, finally, to a revision of their original ideas taking into account the result of co-learners.

Most of the tools mentioned use infrared connection as the channel to exchange information between mobile devices. The disadvantages of this approach are:

- it does, at least using the currently available interfaces, not directly support continuous co-construction in shared workspaces. Instead, only repeated 'one-time' data upload or download is facilitated;
- it is quite restricted in terms of usage (just up to one metre distance and directional).

Both disadvantages restrict the spectrum of potential collaborative processes. The use of wireless network connections can solve the problems and could offer completely synchronised mobile applications that are enabled for a variety of collaborative scenarios.

The next section presents different approaches to extending existing co-operative modelling and discussion environments with mobile devices, especially with PDAs. Completely replicated and fully synchronised applications do not make much sense due to the limitations of the PDA and the available bandwidth. Therefore, *lightweight* integration strategies are favoured which can be formulated following the model-view-controller concept:

- a partial view of the general application state, especially considering the screen size;
- a reduced processing functionality (control), adapted to the device and its I/O capabilities;
- a partial data (model), taking into account memory and processing restrictions of the mobile device.

The 'partial view' principle originates because of the physical size restrictions of PDAs and other new devices like programmable mobile phones or 'intelligent' watches. It could potentially be relaxed or overcome by using bigger handheld devices such as e-book readers or tablet PCs. However these devices have a number

of disadvantages. One disadvantage of these devices is the higher cost and unclear future in the market. A second disadvantage, shared by PDAs and e-book readers, is that they usually do not run the same system platforms as PCs or workstations. This might require costly re-programming.

A platform for collaborative modelling

As a background for the three applications that incorporate the use of mobile devices as presented in the next section, it is first useful to outline the common desktop application that is connected to them (depending on the scenario, in different ways), and the communication mechanism used to communicate between the applications.

The desktop application, Cool Modes (*CO*llaborative *O*pen *L*earning and *MODE*lling *S*ystem) as reported by Pinkwart *et al*. (2002), is a collaborative tool framework designed to support structured discussions and co-operative modelling processes in various domains. As in some other environments such as Belvedere (Suthers *et al*., 1995), this is achieved through a shared workspace environment with synchronised visual representations. A special feature of Cool Modes is that it does not use a predefined built-in representation, but different 'visual languages' can be easily specified and made accessible on the collaborative Cool Modes platform as plug-ins. A plug-in specifies the basic lexical and syntactic elements of the language in terms of node and link types. Operational semantics can be added through specific interpreters. Such interpreters are currently available for Petri Nets and different mathematical models (including stochastic and System Dynamics). A Belvedere-like language for argumentation graphs is only defined at the syntactic level. The different languages can be mixed in the same workspace and, additionally, they can be annotated using pen-based input. This flexibility of mixing different visual languages and annotations allows for the use of Cool Modes as a tool 'at hand' in the same way as paper and pencil.

As a standard feature, Cool Modes allows the use of multiple workspaces represented in different windows which can be arranged freely. Each workspace consists of a number of transparent layers that can contain 'solid' objects such as, hand-written strokes, images and other media types. Four predefined layers with different functionality exist by default — one for a background image, one for annotations and two for other objects.

The built-in cooperation support in Cool Modes relies on the provision of synchronously shareable representations based on the MatchMaker server (Jansen *et al*. 2001). It is built upon Java Remote Method Invocation (RMI) and basically
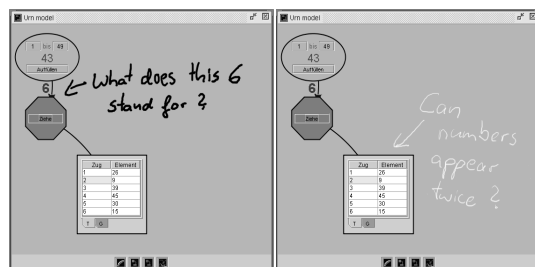

consists of one central server and one client per application. The client had been designed for a 'standard' Java environment but also runs nicely on the currently available 'small' Java environments for mobile devices (e.g. PersonalJava for Windows CE). Different

Fig. 2. Partially synchronised workspaces in Cool Modes

from NetMeeting or other centralised approaches, MatchMaker works with replicated applications. It arranges the synchronised data in a tree, allowing clients

to listen to changes on arbitrary sub-trees. In Cool Modes, the synchronisation tree reflects the logical structure of the application (workspace, layer and objects contained in the layer). Accordingly, flexible partial coupling is possible by workspace or by layer (as shown in Fig. 2 with an example from 'stochastic experiments') or even between single objects.

Depending on the specific scenario, each of these options can be useful, e.g. private handwriting layers in synchronised workspaces or the sharing of model parts without 'publishing' the whole model.

The option of partial application coupling is of special relevance for PDA's or other non-standard computing devices as it can be used to achieve the desired lightweight integration without a loss of information for the other applications.

Extensions for handheld devices

The principal approach for integrating mobile devices into the Cool Modes framework was based on the desire to support synchronous hand-written input from the PDAs on a dynamically added user-specific annotation layer and to have the rest of the lightweight synchronisation dependent on the specific scenario. In the first case presented, only an image of the Cool Modes workspace is transmitted to the PDA; in the second case, a specially adapted 'small' modelling tool runs on the mobile device, completely synchronised with the other environments (desktop or mobile). Finally, the third case shows a scenario with the PDA serving as middleware to annotate scanned texts and to provide them as input for a discussion environment.

Hand-written annotations
The first scenario and tool was motivated by practical experience with presentation and group scenarios in academic teaching (Hoppe *et al.*, 1999). Several lecture halls are equipped with an electronic whiteboard that can be used by the teacher instead of the traditional chalkboard. Thus it allows for the free-hand exposition of ideas, both written and in the form of sketches, but also for using computerised modelling tools, which is an ideal combination in many areas of science and economics.

The (digital) interaction with the students is a crucial point. It is thought that the possibility of making private annotations to public slides developed by the teacher *at the time that these are created* would often be beneficial, e.g. in order to support students in highlighting difficult parts or writing their questions directly next to the

Fig. 3. CoolCom annotating Cool Modes

section these refer to. The teacher might also want to allow the presentation of some student's annotations on the whiteboard or to initiate certain collaborative tasks among the student group following the presentations.

This is realised by 'CoolCom', an annotation tool implemented under Windows CE with PersonalJava 1.1. The CoolCom window is synchronised with a section of a Cool Modes workspace (see Fig. 3) and shows the

current content as a background image which can be annotated in different colours. CoolCom has the following characteristics:

- the local view consists of 320 x 240 pixels (scrollable) so that only parts of the workspace can be annotated;
- in contrast to the main application, CoolCom only allows free-hand input (as strokes with colour);
- in CoolCom, the Cool Modes graph of linked objects (JGraph) is reduced to a background image.

In detail, the synchronisation between Cool Modes and CoolCom is realised as follows: the CoolCom application on a Compaq iPAQ joins a MatchMaker session and selects a specific Cool Modes workspace to annotate. In Cool Modes, when this is detected, a new layer for the hand-written annotations is dynamically created and completely synchronised with the corresponding CoolCom instance. Taking into account the intended use of the mobile application (hand-written annotations) and the transmission times in a wireless network, all the other layers of the workspace in the 'main' application are *not* directly coupled but instead captured as images at regular intervals. These images are sent to CoolCom and displayed as background images so that they constantly mirror the state of main application. The images can be annotated by users of the mobile devices, even by several users at a time. Due to the layer structure, these local annotations done on the PDA can be made visible or invisible in Cool Modes according to the requirements.

Model transfer between PDA and desktop computer

In the second scenario support in provided for normal school lessons in mathematics, especially an introduction to probabilities using the 'stochastic' plug-in of Cool Modes (cf. Fig. 2). An integral part of the activities in this area are simulated and real stochastic experiments can be undertaken as well as the comparison and aggregation of the results from different learning groups. Here, PDAs make it possible to provide computational support in the classroom with minimal changes in the physical scenario. For the classroom, the only assumption is that there is one workstation or PC connected to a big interactive screen and a wireless network to support the information exchange.

This scenario required the development of the mobile application, 'Cool Modes Mobile Edition (ME)' in SavaJe, a pure Java-based operating system for the iPAQ that supports Swing and most other classes of Java version 1.3. It is a 'lightweight' version of Cool Modes that uses MatchMaker to replicate the data (i.e. the model of stochastic phenomena) between applications. Thus, in terms of model, Cool Modes ME is not restricted — but still in terms of view (only parts of the model/data is visible) and controller, as the available calculation functions are adapted to the PDA.

It is foreseen to use Cool Modes ME in the classroom to ease the step from direct, physical experiments to virtual ones that facilitate the simulation of repeated processes which are important for the analysis of stochastic problems (e.g. throwing two dice 1000 times). The intention is to support students in abstracting from the concrete experiment to the underlying generic stochastic model. Another use of the application might be outdoors where 'real' data from traffic or the environment may feed into the experiments more authentically than numbers simply taken from literature. In course situations that use the experiments in order to confirm results that have been elaborated before at a theoretical level, this authenticity is important.

The collaboration support will, in both cases (classroom and outdoor), be an integral part, allowing the students to exchange their ideas and hypotheses peer-to-peer between the mobile applications and to project them onto the electronic whiteboard in order to initiate a classroom discussion about specific solutions.

Combined use of PDAs and optical readers

The third scenario presents ongoing work on C-Notes, a tool that aims at enhancing collaborative knowledge building (Scardamalia & Bereiter, 1994) using mobile computing. The envisaged educational context is of a seminar in which seminar groups collect information (references, citations) to be presented in discussion sessions. By providing learners with new mobile devices and tools to mark key ideas that they find particularly useful, the C-Notes tool is designed to facilitate collective management of knowledge and text-based inquiry. The data produced by marking key ideas can be used to give learners new opportunities to exchange, merge and visualise these concepts. C-Notes is a research software prototype for note taking, text highlighting and collaborative knowledge exchange. Its hardware components
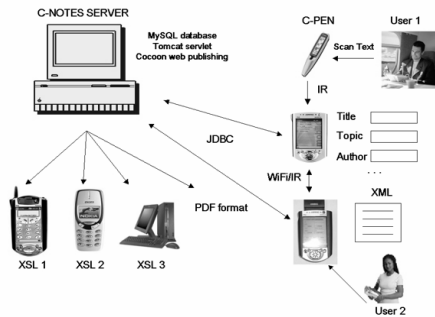

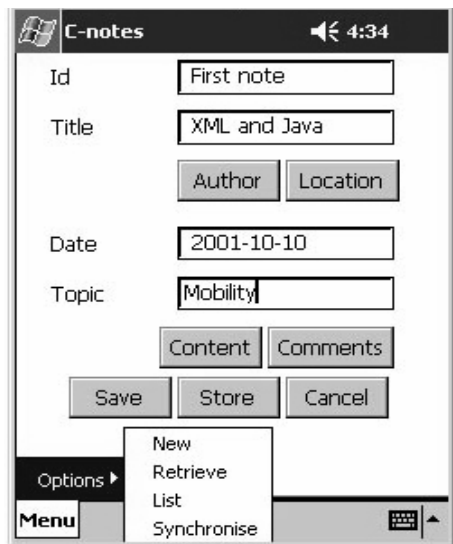**Fig. 4.** The C-Notes architecture

are handheld devices with wireless communication, optical readers of the C-Pen type and a C-Notes server containing a MySQL database. A C-Pen device consists of a digital camera, a processor and memory components making it possible to read and interpret printed text. The digital camera captures the text and saves it in C-Pen's memory as documents that can be transferred to the student's PDA using infrared communication.

The C-Notes application on the PDA (Compaq iPAQ) has been developed using the PersonalJava Runtime Environment.

Fig. 5. The graphical user interface of C-notes

As illustrated in Fig. 4, all data stored on the C-Notes database can be smoothly distributed to other clients like desktop computers, PDAs and cellular phones. Figure 5 shows the user interface of C-Notes on the PDA.

In the seminar scenario, students would generate input directly into the library working individually or in small groups. Here, the use of the C-Pen (in a library, at home or anywhere else) allows the digital highlighting of relevant parts of the resources. Using the infrared port, the students can then transfer these notes to the PDA, classify them according to author, topic or article features and exchange them to share their resources. Using a

wireless network available, e.g. in the classroom, it is also possible to upload the notes to a database. This allows the teacher or other members of the work group to access the collected results and use them for collaborative work phases in class, relating the notes created by the different students and (potentially) discussing the different approaches and results within the learning group. Current work will integrate C-Note entries extracted from the database with a collaborative discussion and argumentation environment called 'FreeStyler' (Hoppe & Gaßner, 2002), essentially a variant of Cool Modes. This environment can be used for presentation and discussion in the seminar, e.g. around a big interactive display. In this context, the C-Notes extension facilitates a seamless information flow between individual information collection and group discussion. The annotation metadata (thematic and user perspectives) in combination with FreeStyler's elaborate retrieval mechanisms allow for a flexible filtering of the information items retrieved from the database.

Table 1. Integration strategy with desktop applications

	CoolCom	**Cool Modes ME**	**C-Notes**
Model	Model not available on the PDA	Model completely replicated	Parts of the model are available on PDA and CPEN
View	Limited view (scrolling)	Limited view (scrolling)	Full view of each note (but not all notes visible)
Controller	Handwritten input only	Functionality adapted to computing power of PDA	Functionality adapted to I/O options of devices

The C-Notes application is lightweight in terms of model and controller: on both the C-Pen and on the PDA, only selected parts of all the notes within the system are available, and the manipulation/annotation options for the notes are adapted to the device that currently handles them (C-Pen, PDA or desktop application). The communication channel through the database is an example of loose, asynchronous coupling. Table 1 summarises the design principles of the three tools in terms of model, view and controller.

Conclusions and futures

This paper has outlined three different strategies for supporting synchronous cooperation with visual modelling environments, with and without 'deep' sharing of data models and with different input/output functionalities. The applications are restricted in terms of view and processing aspects. Processing limitations may be overcome, but not every possible function makes sense on a small device that is frequently switched on and off (e.g. group archival functions). It is appreciated that PDAs are really 'at hand' without binding the attention of the learner too much. Yet, the view limitation is inherent in the definition of PDA as a compact 'pocket device'. It certainly seems worthwhile to look for alternative wireless and pen-based devices with bigger displays and similar portability.

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References

Gay, R., Rieger, R. & Bennington, T. (2002) Using mobile computing to enhance field study. In *CSCL 2: Carrying Forward the Conversation* (eds. T. Koschman, R. Hall & N. Myake), pp. 507–528. Lawrence Erlbaum, Mahwah, NJ.

Hoppe, H.U. & Gaßner, K. (2002) Integrating collaborative concept mapping tools with group memory and retrieval functions. In *Proceedings of CSCL 2002* (ed. G. Stahl), pp. 716–725. Lawrence Erlbaum, Hilsdale, NJ.

Hoppe, H.U., Lingnau, A., Machado, I., Paiva, A., Prada, R. & Tewissen, F. (2000) Supporting collaborative activities in computer-integrated classrooms – the NIMIS approach. In *Proceedings of CRIWG 2000* (eds. A.C. Salgado, P. Antunes & C. Costa), pp. 94–101. IEEE Press, Los Alamitos, CA.

Hoppe, H.U., Luther, W., Mühlenbrock, M., Otten, W. & Tewissen, F. (1999) Interactive presentation support for an electronic lecture hall – a practice report. In *Proceedings of ICCE'99* (eds. G. Cumming, L. Gomez & T. Okamoto) pp. 923–930. IOS Press, Amsterdam.

Jansen, M., Pinkwart, N. & Tewissen, F. (2001) MatchMaker – Flexible Synchronisation von Java-Anwendungen. In *LLWA 01 – Proceedings of GI-Workshop 'Lernen-Lehren-Wissen-Adaptivität'* (eds. R. Klinkenberg, S. Rüping & A. Fick), pp. 180–186. Forschungsberichte der Universität Dortmund, Dortmund.

Luchini, K., Quintana, Ch, Curtis, M., Murphy, R., Krajcik, J., Soloway, E. & Suthers, D. (2002) Using handhelds to support collaborative learning. In *Proceedings of CSCL 2002* (ed. G. Stahl), pp. 704–705. Lawrence Erlbaum, Hilsdale, NJ.

Norman, D.A. (1998) *The Invisible Computer*. MIT Press, Cambridge (USA).

Pinkwart, N., Hoppe, H.U., Bollen, L. & Fuhlrott, E. (2002) Group-oriented modeling tools with heterogeneous semantics. In *Proceedings of ITS 2002* (eds. S.A. Cerri, G. Gouardères & F. Paraguacu) pp. 21–30. Springer, Berlin.

Roschelle, J.M. & Pea, R.D. (2002) A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology*, **1**, 1, 145–168.

Scardamalia, M. & Bereiter, C. (1994) Computer Support for Knowledge-Building Communities. *The Journal of the Learning Sciences*, **3**, 3, 265–283.

Suthers, D., Weiner, A., Connelly, J. & Paolucci, M. (1995) Belvedere: Engaging students in critical discussion of science and public policy issues. In *Proceedings of AIED 1995* (ed. J. Greer), pp. 266–273. AACE, Washington.

Weiser, M. (1993) Some Computer Science Issues in Ubiquitous Computing. *CACM*, **36**, 7, 75–84.

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