The digital pen and paper technology: implementation and use in an existing clinical information system

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Summary
Objective: Evaluation of the technical feasibility of tight integration of the digital pen and paper technology in an existing computerized patient record.

Technology: The digital pen is a normal pen able to record all actions of the user and to analyse a micro pattern printed on the paper. The digital paper is a normal paper printed with an almost invisible micro pattern of small dots encoding information such as position and identifiers. We reported our experience in the implementation and the use of this technology in an existing large clinical information system for acquiring clinical information.

Discussion: It is possible to print uniquely identified forms using the digital paper technology. These forms can be pre-filled with clinical readable information about the patient. When healthcare providers complete these forms using the digital pen, it is possible to acquire the data in a structured computerized patient record. The technology is easy to integrate in a component-based architecture based on Web Services.

Conclusion: The digital pen and paper is a cost-effective technology that can be integrated in an existing clinical information system and allows fast and easy bedside clinical information acquisition without the need for an expensive infrastructure based on traditional portable devices or wireless devices.

Key words: digital pen and paper; bedside clinical information acquisition; computerized patient record; human-machine interfaces

Introduction
Access to clinical reference information at the point-of-care is a goal that is difficult to achieve due to the lack of really portable devices. There are many problems that must be addressed when trying to tackle bedside data acquisition, such as global costs, wireless connections, robustness of devices, size of the screen, usability of the acquisition methods (touch pad, keyboard, sensitive screen, …) and cultural acceptance [1], amongst others. By far, the handwriting data acquisition paradigm remains the most adapted in several clinical contexts, mostly because of the mobility of care providers [2]. The transfer of handwritten data into the computerized patient record (CPR) requires digitalizing the paper. This operation can rarely be achieved in real time, and does not provide access to structured data. Currently, several mobile devices allowing bedside data acquisition are used in clinical settings [3]. They are usually based on PDAs or notebook technologies, including tablet PC’s. However, these devices suffer several defaults. The smallest devices are really portable but have very small screens [4] and the larger devices are often heavy. Most of them have short battery life, especially if connected using a wireless network. In addition, these devices are expensive, especially if used in large settings, and are often accompanied with crucial maintenance problems, both for hardware and software.

In the fall of 2003, the University Hospitals of Geneva (HUG) had the opportunity to evaluate, in real clinical situations, a beta pre-commercial release of a package, including a digital pen developed by Logitech®, digital paper using a micro pattern of dots developed by Anoto® and a form and pen management system, the Forms Automation System (FAS), developed by Hewlett Packard®. This technology was tested in two clinical settings with the objective of evaluating technical integrability, data acquisition reliability and acceptance of users according to both technical aspects and human factors. The assessment of data acquisition reliability and acceptance of users are out of the scope of this paper and are available separately [5]. The objective of this paper is to present our experience in implementing and integrating concretely this new technology in our CPR.

Background
The HUG is a consortium of primary, secondary and tertiary care facilities employing 5,000 care providers, with approximately 2,000 beds and managing over 45,000 admissions and 450,000 outpatients encounters each year. The clinical information system (CIS) is a Java based 3-tiers
architecture using event-driven processes and interoperability with Web Services. More than 20,000 patient records are open every day in the CIS.

Clinical context: Post-natal care in Obstetric Anaesthesia (PNC)

Since July 2001, the anaesthetists evaluated anaesthetic complications and maternal satisfaction after labour analgesia in the labour room using a paper form. Data collection was performed in two parts corresponding respectively to one of the two columns of the form: a) data about the labour and the delivery, that is pre-printed on the form and comes from the CPR (fig. 1, Section B); b) data relative to the "post partum", which is filled within the next 72 hours of follow up care using the form (fig. 1, Section A).

Since July 2003, a web application allowed acquisition of clinical information pertaining to labour and delivery (fig. 2, PFAnesthesio). These data were usually collected before and during the labour. Normal PC and wireless laptops were available. Within the next 72 hours, the form was printed with these data, and the second part about post-natal care was filled during visits to mothers performed by an anaesthetist, sometimes scattered in several wards. The filled forms were scanned after discharge of the patient to allow data to be transferred in the CPR. When enough forms were entirely filled, an operator collected them and processed a scanning with human-assisted optical character recognition. Only single character fields, such as check-boxes, were reliably recognized. For ambiguous situations, the operator decided which value was correct.

The DPP technology

The DPP combines mainly three components: a) a HP colour LaserJet Printer with specific drivers; b) a HP software package; c) a Digital Pen with a specific firmware. By the time of the study, all components were in alpha or beta release and not available commercially.

The form: printer drivers, document and the "digital" pattern. – When the form was printed, using the dedicated driver, a layer of a slight pattern of black dots was also printed. This layer, using a technology developed by Anoto®, identified the function of the paper and encoded much information, such as unique ID and 2D position. It allowed the pen to record the cursive information and an unambiguous association between...
the pattern, that is the document identification and the patient whose information had been printed on the document. In addition to the standard driver of the printer, a digital driver allowed to establish a link with a Paper Lookup Server (PLS). This server, which has to be installed first, allowed the storage of the clinical context and the distributed patterns, and ensured the link between clinical contexts and patterns. When a user requested a print of a digital form, the driver sent a request to get an instance of pattern associated to the corresponding clinical form. The PLS stores a) the context received from the CIS, in our case a unique ID identifying the encounter; b) a unique form identifier, and c) the unique ID created for the new pattern to be printed with the form. This pattern was printed with the document and was recognized by the digital pen. The pattern was made out of very small black dots resulting in a slightly off-white colour. To increase discrimination of the pen’s camera between the pattern and the layout of the form, the black colour was reserved to the pattern. Therefore, layout or any information devoted to human reading on the form had to be printed in another colour, generally blue, but a complete colour palette is provided by HP.

*The HP software package.* – In addition to the PLS, several components were required to allow a fine-tuned integration between the existing CPR and the DPP technology. The most important components were a) a plug-in added to Adobe Acrobat® to design forms; b) a toolbox that allowed the development of services and the transfer of structured data on the form to web services, and c) several management tools for users and administrators. For healthcare providers, the package included a tool for validating data transferred and for the identification of users. The tools for administrators allowed linking a service with a form, registering and managing users and pens as well as linking specific pens with users. The plug-in added to Acrobat allows to design forms. For the form designer, the operation consists in drawing an area above each structured field of the form and defining its type, such as Boolean, free text, etc. A unique ID must be assigned to each area, which will be associated with the information recorded by the pens. The toolbox provided by HP allowed access to all information transmitted by pens, but did not process the data nor established the link with the existing CPR. In order to get the correct data in its corresponding field in our CPR’s database, we had to develop an application service handler (ASH). This has been done using JAVA, but it is not mandatory. The granularity of data recorded by pens allowed access to every single elements corresponding to one sample (see next section), including unique ID of the form, coordinates of the pattern area defined before, timing in millisecond, information from the pressure captor and the ID of the pen used to fill the area. It was also possible to access consolidated data, where all single points are grouped into strokes, defined as a cursive path performed without pressure interruption. Strokes had a start time (pen down), an end time (pen up), and belonged to a field of the form. For all simple types, such as lists and checkboxes, the toolbox gave direct access to the value of the field. For text fields, using the SDK, pen data could easily be transform in two picture formats: BMP and SVG (vector). We used both and stored them. The system could be linked to an Intelligent Character Recognition (ICR) system to recognize handwriting.

*The Digital Pen.* – The digital pen contained a standard ink cartridge, a camera, a communication unit, a pressure captor, an image processing unit, a storage unit and a battery. The camera, placed under the ink cartridge, was able to record 50 frames per second. When the pressure captor detected that the ink cartridge was in contact with the paper, the camera sampled the position of the pen on the paper using the pattern. Less than 2 square millimetres are needed for the pen to localize its position, whatever the entry place, direction or angle. The pen stored up to 40 handwritten pages between transfers and one full power charge allowed the writing of up to 25 full pages. A led located on its side indicated battery charge and its status. The activation of the pen was ensured by the cap which acts as a power switch. The pen was able to emit vibrations to provide feedback to users, for example when the pen was unable to recognize the pattern. Once docked to its USB cradle, the PLS was called with information of every patterns for which data had to be transmitted. The server retrieved the context and a pointer to the ASH allowed data to be correctly processed. Several pens and users can contribute to a unique given form simultaneously or with time intervals. Data was merged when transferred, and at each transfer forms could be consolidated if needed.
Details of the implementation of the DPP in the CIS

There were two important steps to implement the system: a) installation of all components, required only once and b) development of the ASH for each form to be linked with existing databases.

Before the DPP study, PDF forms including existing data were generated using XSL-FO (fig. 2). During the DPP study, the technology required the registration of the PDF file generated with the plug-in to the PLS. This file was stored on the server and linked with the corresponding ASH. Patient data then had to be merged with this file, using XFDF. The printer driver directly managed XFDF files and included data in the corresponding PDF descriptor file when printing.

Acquisition quality and satisfaction of users

The scan system has been maintained during the study to compare the reliability of data acquisition (path not represented in fig. 3). The DPP technology proved to be as reliable as OCR using a professional scanner without human intervention. Acquisition errors only occurred for specific fields when the design of the form was badly adapted to the technology. Quality surveys as well as a complete user satisfaction study have been conducted [5]. The DPP appears to be a well accepted technology.

Conclusion

The DPP is a promising technology that proved to be easy to integrate with an existing CIS, using new technologies such as JAVA and Web Services. One major inconvenience of the technology is the need to print using colour printers, in order to increase discrimination of the camera of the pen between human-readable information and the pattern devoted to the DPP technology. Structured data originating from single state fields, such as checkboxes and radio buttons, or scales, are immediately addressable to store in a relational database. Handwriting, for letters and numbers, must be processed with a third-part OCR or ICR.

The data acquisition reliability proved to be similar to a professional scanning system, with the great advantage of mobility and direct acquisition at the bedside. Healthcare providers have been enthusiastic about using this technology. Criticisms towards the ergonomy of the pen are addressed with new versions of the system.

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References