The Digital Pen and Paper Technology: Implementation and Use in an Existing Clinical Information System

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Abstract

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 analyze 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 report 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 care 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.*

Keywords
Digital pen and paper, bedside clinical information acquisition, computerized patient record, human-machine interfaces

1. Introduction

Access to clinical reference information at the point-of-care is a goal that is difficult to achieve by 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, weight, size, duration of batteries, size of the screen, usability of the acquisition methods (touch pad, keyboard, sensitive screen, …) and cultural acceptance [1], amongst others. By far, the pen and the paper remain the most cost-effective, efficient and easy to use means for acquiring data. 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. In addition, it does not allow direct feedback to care

providers. Currently, several mobile devices allowing bedside data acquisition are used in clinical settings [3]. They are usually based on PDA's 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 Fall 2003, the University Hospitals of Geneva (HUG) had the opportunity to evaluate, in real clinical situation, 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 forms and pen management system, the Forms Automation System (FAS), developed by Hewlett Packard®. This technology was tested in two clinical settings with the objectives 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.

2. 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 Service of Medical Informatics, in addition to its teaching and research activities, is responsible of the clinical information system (CIS), including the design, development and support of tools and processes for the institutional management of medical knowledge, the computerized patient record and a general medical order entry system. The 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.

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

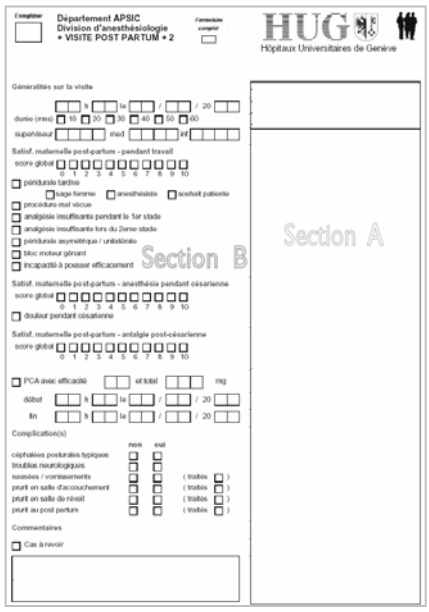

Figure 1: The PNC form

Since July 2001, the anaesthetists evaluated the anaesthetic complications and maternal

satisfaction after labour analgesia in the labour room using a paper form. The data collection is 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 (Figure 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 (Figure 1, Section A).

Since July 2003, a web application allowed acquisition of clinical information pertaining to labour and delivery (Figure 2, PFAnesthesio). This data is usually collected before and during the labour. Normal PC and wireless laptops are available. Within the next 72 hours, the form is printed with this data, and the second part about post-natal care is filled during visits to mothers performed by an anaesthetist, sometimes scattered in several wards. The filled forms are scanned after discharge of the patient to allow data to be transferred in the CPR. When enough forms are entirely filled, an operator collects them and processes a scanning with human-assisted optical character recognition. Only single character fields, such as check-boxes, are reliably recognized. For ambiguous situations, the operator decides which value is correct. This process respects the standards imposed to all CIS in HUG: a secure user authentication and a traceability of the requests and actions performed.

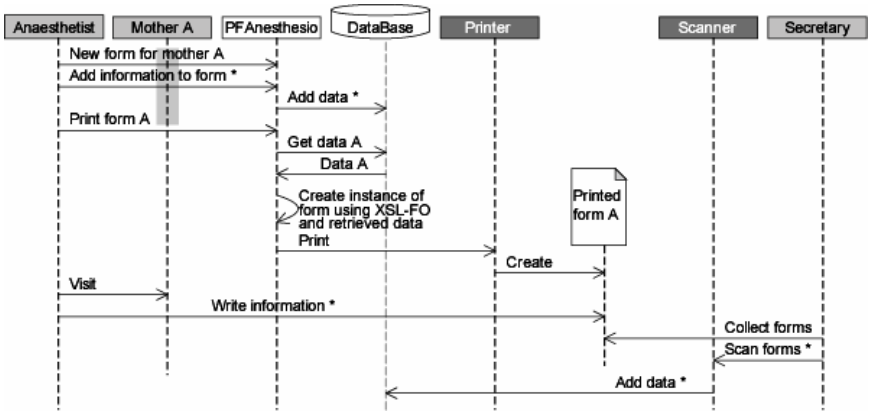

Figure 2: workflow of data acquisition before the DPP trial
"" means that the request or action can be performed several times*

2.2 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.

2.2.1 The form: printer drivers, document and the "digital" pattern

When the form is printed, using the dedicated driver, a layer of a slight pattern of black dots is also printed. This layer, using a technology developed by Anoto®, identifies the function of the paper and encodes much information, such as unique ID and 2D position. It allows the pen to record the cursive information, including speed; direction acceleration etc. For the CPR, it is important to ensure an unambiguous association between the pattern, that is the document identification, and the patient whose information has been printed on the document. The pattern allows such kind of unique identification of printed sheets. Only a subset of HP colour LaserJet printers are certified for printing these patterns, which requires extreme precision. In addition to the standard driver of the printer, a digital driver allows to establish a link with a Paper Lookup Server (PLS). This server, which has to be installed first, allows storing the clinical context and the distributed patterns, and ensures the link between clinical contexts and patterns. This is important to be able to reliable link a paper form to a computer clinical session. When a user requests a print of a digital form, the driver sends 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 is printed with the document and will be recognized by the digital pen. The pattern is made out of very small black dots resulting in a slightly off-white colour. It is almost not visible and gives a slight grey appearance to the paper and can identify categories of paper, such as post-it or notes, or unique documents. The technology developed by Anoto can manage several billion of unique patterns. To increase discrimination of the pen's camera between the pattern and the layout of the form, the black colour is reserved to the pattern. Therefore, layout or any information devoted to human reading on the form has to be printed in another colour, generally blue, but a complete colour palette is provided by HP. The paper used in our study was a standard recycled paper in accordance to HUG requirements, judged as a bad quality paper by experts of HP. However, it is not proved that the paper quality was implied in problems encountered during data acquisition.

2.2.2 The HP software package

In addition to the PLS, several components are required to allow a fine-tuned integration between the existing CPR and the DPP technology. The most important components are a) a plug-in added to Adobe Acrobat® to design forms; b) a toolbox that allows 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 care providers, the package includes a tool for validating data transferred and for the identification of users. The tools for administrators allow linking a service with a form, registering and managing users and pens as well as linking specific pens with users. A complete trace is available. The plug-in added to Acrobat allows to design forms. For the form designer, the operation consists to draw an area above each structured field of the form and defines its type, such as Boolean, free text, etc. A unique ID must be assigned to each area, which will be associated with the information recognized by the pens. In addition the pattern area is drawn encompassing all the fields that have to be digitalized. When the form is ready, it must be linked with the corresponding service. The toolbox provided by HP allows to access all information transmitted by pens, but does not process the data nor establishes 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 allows the 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 is also possible to access to consolidated data, where all single points are grouped into strokes, defined as a cursive path performed without pressure interruption. Strokes have a start time (pen down), an end time (pen up), and belong to a field of the form. If a unique form has been filled with several pens, it is possible to reconstitute the consolidated result. The system can be linked to an Intelligent Character Recognition (ICR) system to recognize handwriting.

2.2.3 The Digital Pen

The digital pen contains a standard ink cartridge, a camera, a communication unit, a pressure captor, an image processing unit, a storage unit and a battery. All these components result in a bigger and somewhat bulkier pen than usual. The camera, placed under the ink cartridge, is able to record 50 frames per second. When the pressure captor detects that the ink cartridge is in contact with the paper, the camera samples 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. For each sample, the pen stores at least the pattern, the coordinates, the timing. The pen stores up to 40 handwritten pages between transfers and one full power charge allows writing up to 25 full

pages. A led located on its side indicates the battery charge and the status. The activation of the pen is ensuring by the cap which acts as power switch. The pen is able to emit vibrations to provide feedback to users, for example when the pen is unable to recognize the pattern. A digital pen can only interact with patterns groups that are part of its "writing domain", which might be only one form. When docked, the pen will only transmit data if a validation box on the form has been checked. A form will be saved every time that box is checked, allowing multiple save operations. Once docked in its USB cradle, the PLS is called with information of every patterns for which data has to be transmitted. The server retrieves the context and a pointer to the ASH allowing data to be correctly processed. Validated data is automatically transmitted to server. Each pen validates its own data and several pens and users can contribute to a unique given form simultaneously or with time intervals. Data is merged when it is transferred, and at each transfer forms will be consolidated if needed.

2.3 Details of the implementation of the DPP in the CIS

There are 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. We used the following environments:

For development:

- Windows 2000 Server SP3 or Windows 2000 Advanced Server SP3
- Microsoft SQL Server 2000 SP3, Standard or Enterprise Edition
- Sun Java 2 SDK, Standard Edition 1.4.1_01 or later
- Apache Tomcat 4.1.18 or later

For production:

- Solaris 9
- Oracle 8
- BES or WebObjects application servers

For clients:

- Windows 2000 Professional SP3 or Windows XP Professional SP1
- Microsoft Internet Explorer 5.01 SP2 or 6.0 SP1

As already mentioned, the ASH was developed in JAVA, to meet the production requirements. It has been developed using a Servlet called when a pen requests a transfer. For all simple types, such as lists and checkboxes, the toolbox gives a direct access to the value of the field. For text fields, using the SDK, pen data can easily be transform in two picture formats: BMP and SVG (vector). We used both and stored them.

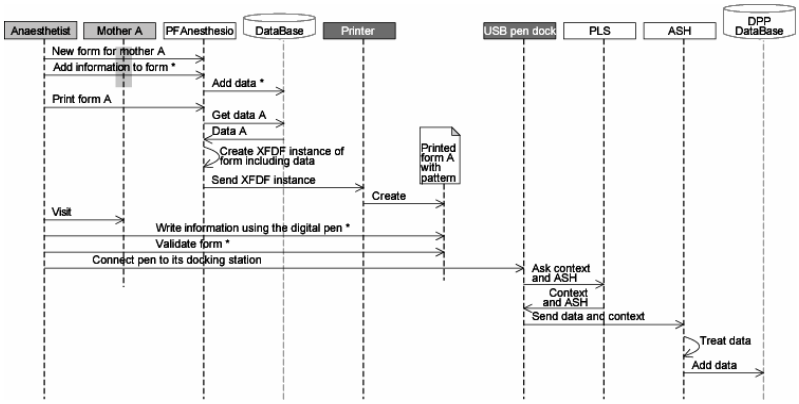

Figure 3: workflow of data acquisition during the DPP study
"" means that the request or action can be performed several times*

Before the DPP study, PDF forms including existing data were generated using XSL-FO

(Figure 2). During the DPP study, the technology requires the registration of the PDF file generated with the plug-in to the PLS. This file is stored on the server and linked with the corresponding ASH. Patient data must then be merged with this file, using XFDF. The printer driver manages directly XFDF files and includes data in the corresponding PDF descriptor file when printing.

2.4 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 Figure 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.

3. Conclusions

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 databases. 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. Care providers have been enthusiastic at using this technology, with criticisms towards the ergonomy of the pen that are addressed with new versions of the system.

4. Acknowledgments

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5. References

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