From the student's paper to the teacher's computer

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***Abstract*—**From the first parchments to the present, paper is a constant in the history. The importance of handwritten notes are similar and it is a constant during centuries. Pen and paper are still the main tools used by pupils in class for several good reasons: pen and paper are cheap, flexible, easy to use, and not distractive. But with the irruption of smartpens in the technological market, the vision of the handwriting in educational systems can change. These devices allow students to take notes or draw schemes while simultaneously recording classroom lectures or discussion. And, at the same time of the handwriting or later, all drawings, sentences, calculations, and what student has done with his smartpen can be sent to the teacher's computer and saved in a file. We present a comparison of technologies and characteristics to be used in a classroom.

***Keywords*—**Digital pen, dot paper, handwriting, paperless, smartpen.

I. Introduction

NOWADAYS interactivity is a very important factor in an educational system but, at the same time, indulging this interactivity is attained by a lot of exams, assignments, etc. and it means time consuming, stressful and involves a lot of paperwork.

From the first parchments to the present, paper is a constant in the history. Nowadays, we cannot image the future without big electronic advances, or without new gadgets based on nanotechnology, and even we speak about digital natives; but a constant during the time that will continue in that digital future is the paper and the written documents.

We use in many different ways, like take notes, do exams, extend certificates, create newspapers, even write books and papers or scientific proceedings and journals. Anyway, attempts to replace the use of paper is a continue in the last decade, with the electronic certificates (that people will print in paper), digital forms for bureaucratic matters (that people will print to save a copy) or for example some buys by internet (and we will print a copy of the transfer). Some people predicted that the paperless office would be here [1], but we see that this point is quite far from today.

There is no doubt that the use of paper has several advantages. It is in all parts of the world: in any place you can find a piece of paper to write or, in a hurry, you can use other material instead of pure paper. Writing is easy, supports any language, and it is flexible. It may include highlightings of portions of the document, textual annotations, formulae, sketches, drawings etc. as well as combinations of these. Pen and paper annotations present a great fluidity in form [2] and can both be very informal or more structured, for example if the user follows a specific annotation or notetaking method (e.g. the Cornell Notetaking Method [3]). Further, handwritten annotations on a printed document are clearly separated from the document and several people can annotate the same copy of a document [4]. While this is also true for the broader class of pen-based interfaces, including pen interaction on digital displays such as Tablet PCs, there is some evidence that the use of pen-enabled displays generates greater extraneous cognitive load than the more familiar interactions with real paper [5]. The piece of paper can be save in any place, is immediately readable, can be thrown.

And it has other non-tangible advantages. O'Hara et al. [6] show that users acquire incidental knowledge of the location of information by reference to its physical place on the page, which helps them in finding this information later on. Writing also propitiates reading: Sellen and Harper [4] point out, reading occurs with writing more often than it occurs without. In a diary study, the participants combined reading with writing in more than 75 % of the time and up to 91 % of the time. In this context, writing means both annotating the document itself and writing a separate document.

Our proposed solution to this problem is a low-cost, novel, easy-to-use electronic platform that enables teachers to provide handwritten and spoken feedback to their students on their homework assignments, as well as immediate assessment for

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the whole class. The assessment is done using an innovative system that enables all class students to answer the teacher question using their digital pen, while the system evaluate all the answers and print out the grades of all students on the spot.

The main pillar of the platform is a digital pen, which will be a new ergonomically designed input device that captures your handwriting without the need for special paper or a direct wired connection to a computer. You then can write notes anywhere and send it wirelessly to a screen or upload the files to your computer any time. It is the perfect merger of our most natural form of creative expression, pen on paper, with the modern need to digitize everything.

II. Digital Handwriting Tools

Research into pen and paper computing aims at combining the conventions of handwriting with the benefits of digital technology: such as the editing, sharing and processing of written information [7]. Successful applications of digital handwriting technology can be found in the context of design [8, 9], ideation [10], or education [11]. In classroom situations, the use of automatic handwriting recognition can translate handwritten information into typed text [12, 13, 14].

Digital pen technology can augment the handwriting process in different ways. Pens have been augmented to provide haptic feedback, resulting in improved letter recognition and phonological awareness in children [15, 16] and better handwriting fluency in adults when learning Japanese [17]. Beyond the pen itself, we see the integration of calculus functionality through digitally augmented pen and paper [18]. Other advances use pens to apply annotations on paper and also to navigate and control projected digital information [8, 9]. Similarly, digital projection on paper has been introduced to the classroom to better understand and support learning processes when teaching geometry [11].

Previous studies that have explored the differences of interacting with digital materials vs. pen and paper have shown that people still prefer paper [19, 20]. Previous studies have explored the potential of digital writing tools and handwriting recognition software as possible text entry devices in classroom scenarios [13, 21, 22].

III. Smartpens and their Technologies

A digital smartpen is an electronic pen recorder that records integrated handwritten notes and drawings.

Smartpens allow students to take notes or draw schemes while simultaneously recording classroom lectures or discussion. Simply tap anywhere in his notes and the pen will play back what was said at that moment in time. The pen also saves digital copies of the notes, which may be transferred to a computer via USB. It is not matter if student has a pretty letter, or if the written thing is an scheme or it has been written vertically. From the computer, student may review, search, and listen to the notes as he wishes.

The uses for smartpens stretch beyond simple note taking. In the early childhood classroom, teachers can create resources, such as interactive alphabets, author studies, and centers with instructions pre-recorded by the teacher, enabling students to self-direct activities. Teachers can also record themselves reading books, allowing emerging readers to engage with text on their own. Smartpens' uses continue to build as more teachers experiment with them in their classrooms and are becoming a great addition to any teachers' technology toolbox [23].

Smartpens' technology may be classified in two big groups: technology that uses a special paper, normally a dot paper; and technology that can be used in any class of paper.

A. Technology with dot paper

We can consider some parts in a digital pen. First, the pen comprises an ink cartridge with a writing tip for marking a surface; a camera system for capturing images of the surface in order to digitally record pen strokes formed on the surface, and a detachable cap to be placed at a writing end of the digital pen, is selectively operable as a non-marking pen with the cap placed at the writing end or as a marking pen without the cap placed at the writing end and configured to digitally record pen strokes both when operated as a non-marking pen and as a marking pen. Also a Bluetooth radio transceiver.

If we look part by part these components and their functions, we will observe that a smartpen is not a simple device, like a pen.

The smartpen has an ink cartridge that usually realize two different tasks:

- Standard ink cartridge, with the aim that users can buy a spare or new cartridge in any market. So that you can actually see what you have written or drawn.
- Force sensor, to make possible bold letters or use the digital pen as mouse (force sensor will act as a click of the mouse). The force sensor, which may be a contact sensor or a proximity sensor, may be operatively connected to the ink cartridge. A pen stroke may be defined by a pen down and the subsequent pen up. The pen-down and the pen-up may occur in one and the same position so that a pen stroke may consist of a single position or pair of coordinates. Based on the output of the pen-down detector, the camera system may be controlled by the processing module to capture images between a pen down and a pen up. The pen-down detector may be optical, mechanical, resistive, inductive, capacitive or based on any other appropriate physical property.

Obviously, we need a battery to supply energy to our smartpen. Preferably, Ion-Li or Li-Polymer. May be button battery. Perhaps, AAA batteries. With button or AAA batteries, USB connector will NOT be necessary; with rechargeable batteries, yes. The best option depends on the use and on the final user of the smartpen, because prices and security (by heating) of these batteries are not the same. Other difference is the size of the battery and therefore the size og the pen.

Fig. 1. Example of technology with dot paper: Echo SmartPen by Livescribe

The camera or vision device in this kind of smartpens is more than very important, it is crucial:

• Infrared camera, CMOS or CCD. The average image processing rate is normally approximately 75 Hz. It should be better 100 Hz (100 frame per second), with a minimum of 50. For example, it can be a Mitsubishi M64282FP Image Sensor with a window of 128×128 pixels.

• LED diode emitting infrared light.

The dots of the paper pattern are illuminated by infrared light, making them visible for the digital camera. Digital snapshots, at a rate of 100 per second (for example), are taken of the pattern. (The ink from the pen is not visible to the camera. Therefore the pattern is not degraded by the user's writing.).

The camera system of the digital pen may comprise an optics module and an optical image sensor. The optics module may comprise a light source, which may include e.g. a light-emitting diode (LED) or a laser diode, for illuminating a part of the surface within the field of view of the image sensor, by means of illuminating radiation, e.g. infrared light. The optics module may furthermore include a lens arrangement for projecting an image of the viewed area onto the image sensor and possibly one or more light guiding elements for guiding light from the light source to the surface and/or from the surface to the sensor. The image sensor may for instance be a two-dimensional CCD (Charge Coupled Device) or CMOS (Complementary Metal-Oxide Semiconductor) sensor which is triggered to capture images at a fixed or variable rate, typically of about 70-100 Hz. The camera system may also include a wavelength filter adapted to remove unwanted wavelengths. One embodiment of the digital pen may include two illuminating light sources that can be selectively or alternatively activated in order to reduce problems that may occur due to specular reflections. In another embodiment the camera system may include one or more polarizers to remove specularly reflected light.

All captures will be sent to the processor and save in the memory. Memory can be a four megabyte flash memory chip, and the processor a Scenix 8 bit RISC processor chip, for example.

The image processor calculates, in real-time, the exact position in the entire paper pattern. During image processing, snapshots are compared and information about how the pen is held is also gathered and stored.

All the data from the image processor is packaged and loaded into the pen memory, which will store the fully written pages.

The processing module of the digital pen may include one or more processors, a memory block and associated software. The processing module may be responsible for different functions in the pen, such as image processing, position decoding, exposure control, user feedback and power management, and may be implemented by a commercially available microprocessor such as a CPU ("Central Processing Unit"), by a DSP ("Digital Signal Processor") or by some other programmable logical device, such as an FPGA ("Field Programmable Gate Array") or alternatively an ASIC ("Application-Specific Integrated Circuit"), discrete analog and digital components, or some combination of the above. The processing module may comprise one or more sub-modules, which may be implemented on one or more hardware components. The memory block may comprise different types of memory, such as a working memory (e.g. a RAM) and a program code and persistent storage memory (a non-volatile memory, e.g. flash memory).

In order to save battery time, the digital pen may include a power management module to control the power states of the pen. In this case, the smartpen will include a LED- Status Indicator.

The information is transmitted by the Bluetooth transceiver, either directly to the user's computer. The Bluetooth device is a small, low-powered radio on a chip that communicates with other Bluetooth-enabled products. Because it is a radio, Bluetooth eliminates the necessity for cable to connect portable computers, personal digital device, cellular phones, and printers, fax machines and the like. Bluetooth-enabled devices can connect on a one-to-one or one-to-many basis. Bluetooth technology uses the 2.4-GHz radio band, which is unlicensed and available worldwide. It supports data speeds of up to 721 Kbit per second and 3 voice channels.

B. Technology without dot paper

Similar to the previous technology, but not equal, a sensor-enabled portable device can be used with a pen and paper for capturing handwriting. The receiver, linked to paper by something similar to a clip (a mechanism configured to enable the portable electronic device to be attached to the paper), includes or is fitted with a digital sensor and a clip to grasp a piece of paper or pad. An optional lens and filter may be attached to the sensor. The pen has a tip that releases ink onto the page in the usual way as the user writes. Light sources (e.g., LEDs) are arranged on the shaft of the pen.

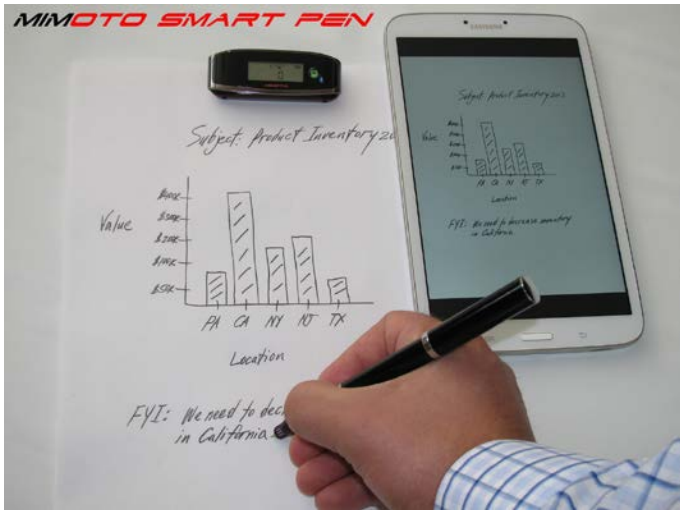

Fig. 2. Example of technology without dot paper: Mimoto SmatPen by Mimoto Tech

In this case, the sensor "reads" the movement of the pen and stores in its memory. That is, in the pen there is not sensor and memory. These devices are placed in the receiver.

The infra-red LED is oriented, in this case, to one side of the pen, in the opposite to the previous technology where the light is oriented to the bottom (to the writing surface).

IV. Some Characteristics of the Smartpens to be Checked

Some characteristics to be checked when a digital pen will be selected may be the following:

- Handwriting Capture Quality

The percentage rating determined through a comparison of physical copy of handwriting to the digital image.

- Sketch Capture Quality

The percentage rating determined through a comparison of physical copy of a sketch to the digital image.

- Audio Recording and Playback

A microphone and speaker within the pen that records audio as you write and plays it back, either through a speaker or an 3.5mm audio jack.

- Audio Sync with Notes

Syncs recorded audio in time with the notes that you write so that you can access exact moments of a lecture by simply touching the pen to a specific part of the written notes.

- Wireless Connectivity

The ability to connect and interact with compatible devices, like a computer or mobile device, via Wi-Fi or Bluetooth signal.

- Battery Life (Hours)

The expected amount of time that the pen can be used before requiring battery recharge. Use of Wi-Fi, Bluetooth and other options decreases the time between charges.

- Diameter at Grip Point (Inches)

The measurement of the shaft at the point of the grip. A thick grip can cause hand fatigue because it requires more muscles to grasp firmly.

- Weight (Ounces)

Weight is important to hand fatigue. The heavier the pen, the quicker your hand will get tired.

- Length (Inches)

Length affects the balance of a pen in your hand. You want to choose a pen that's close to the size pen you normally write with.

- Write on Any Surface

Doesn't require special paper that you have to purchase or print from a color laser printer rated at 600dpi or higher. Some digital pens require paper with an Anoto pattern of microdots.

- Desktop Software

Primary desktop software for archiving, editing and sharing notes uploaded from the digital pen.

V. Conclusion

The importance of handwritten notes is similar and it is a constant. Pen and paper are still the main tools used by pupils in class for several good reasons: pen and paper are cheap, flexible, easy to use, and not distractive.

But digital pen technology is now a real alternative to the couple pen and paper. Among all the different cases, classes, and types of uses and technology that can be used, we have focus on the smartpen.

Our aim is a low-cost, novel, easy-to-use electronic platform that enables teachers to provide handwritten and spoken feedback to their students on their homework assignments, as well as immediate assessment for the whole class. The assessment is done using an innovative system that enables all class students to answer the teacher question using their digital pen, while the system evaluate all the answers and print out the grades of all students on the spot.

The main pillar of the platform is a digital pen, which captures the student's handwriting without the need for special paper or a direct wired connection to a computer. This point is very important because the user do not depend on the paper, a common and problematic matter in the majority of the commercial smartpens.

Main characteristics and main technologies of these devices have been checked in order to guide in the selection of the best option.

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