An Augmented Stripboard for Air Traffic Control

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ABSTRACT
This paper describes an augmented reality prototype that precisely tracks the position of paper flight strips used by air traffic controllers. By embedding resistors with different values into slightly modified plastic stripholders and inserting contacts along the sides of a stripboard frame, we can detect the exact position of individual stripholders (and their corresponding paper flight strips). When placed over a graphics tablet or touch sensitive screen, and properly calibrated, we have a simple, inexpensive solution for identifying paper flight strips and linking them to capture and display technologies.

KEYWORDS: Augmented Reality, paper flight strips

INTRODUCTION

Air traffic controllers still use pre-printed strips of paper, called *flight strips*, to track their planes. Writing on them, manipulating them, and organizing them on a *stripboard* helps controllers memorize information on the strips and build a mental representation of the air traffic. Paper flight strips are easy to use, robust against failures and adapt to an individual controller's way of working.

The main drawback with paper flight strips is that they are not connected directly to other computerized tools. Many countries are working to computerize aspects of air traffic control, and most have decided to replace paper flight strips with electronic versions displayed on a computer screen. Yet electronic strips lack important characteristics that controllers rely upon, e.g., holding a strip in one hand to remember to do something with it. We decided to try another approach, *augmented reality*, which, instead of replacing the strips, keeps the physical strips and links them to the computer system. The goal is to capture relevant information from and add functionality to the paper strips, without losing the current familiarity, ease of use and flexibility.

We used a participatory design approach to explore these 'augmented flight strips', working with controllers to identify the most useful functionality (Mackay et al., 1998). We developed a series of progressively more realistic prototypes, designed to simulate the existing use of paper strips while adding new communication and computational support. Each prototype had to *track* the position of each paper strip in a stripboard, *capture* information from it, and *display* information onto it. The earliest versions were very informal, using video and overhead projection to let controllers experiment with and imagine different ways of augmenting the strips. Later versions replaced "Wizard of Oz" simulations with working hardware and software. Final versions linked printed paper strips to a training simulator with a real RADAR screen and simulated air traffic. This paper explains the general technical approach and describes a new device, an electronic stripboard, that tracks the location of each strip in relation to other capture and display technologies.

CENA technical report, 1998.

THE PROBLEM: INTERACTING WITH STRIPS

At the Paris en route control center, controllers insert paper flight strips into stripholders which are then snapped horizontally into a "stripboard" of two metal rails (Fig. 1). Controllers slide stripholders up and down to indicate the status and relationships among planes.

The problems of capturing and displaying information from paper strips can be resolved with a variety of off-the-shelf solutions, including video cameras, graphics tablets and touch-sensitive screens. Accurately tracking the position of paper strips with respect to these technologies is more difficult. We needed a simple, inexpensive solution that preserves the existing user interaction. Instead of tracking the paper strips directly, we decided to track the position of the stripholders. Paper strips themselves can be coded and read as they are placed into a particular stripholder (e.g. with a barcode reader).

Fig. 1: Stripholders in a stripboard. at the Paris (Athis Mons) en route air traffic control center.

REALIZATION: CREATING A NEW DEVICE

We built a wooden stripboard frame with a row of spring-loaded metal contacts along each side (Fig.2). We embedded a resistor with a unique value into each plastic stripholder. When the stripholder is inserted into the stripboard, it completes a circuit and produces a measurable level of resistance. The resistance level is sampled repeatedly at each position. Whenever the resistance equals one of a predefined set of values, the presence (and exact location) of that particular strip is reported. Whenever the system measures an infinite resistance, the position is reported as being empty. To avoid measuring the resistance of several strips in parallel with the selected position, we added a diode to each circuit. By locating the diode on the stripboard, rather than in the stripholder, we avoided forcing the user to place the strip in only one direction.

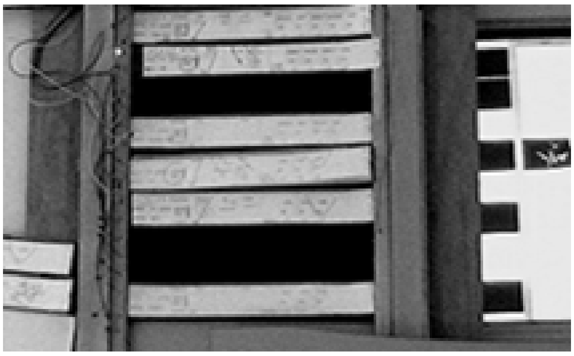

Fig. 2: Stripholders are detected by the electronic stripboard. Writing is captured by the graphics tablet underneath . Information is displayed on the touch screen to the left.

In order to communicate with the on-line systems, we used a hardware bus card created by Ruiz (1997). The card is plugged into the serial port of a workstation and is based on the Access.BUS standard, using an I2C-RS232 translator. Although the card handles up to 48 (8x6) multiple, simultaneous input and output events, we used only 18 (3x6) for the prototype. The ADC of the Access.BUS card codes voltage from 0 to 4V, using 7 binary digits, with a precision of 31.25 mV. Our software, written in Tcl/Tk, calculates a two-digit hexadecimal number, NN, based on the measured voltage U=4*NN/128. For example, to calculate NN for a resistance value of 13 Ohms:

R=13 => U=4.3*100/113=3.8V =>
NN=128*U/4=122 (decimal) = 7A (hexadecimal)

The voltage measured by the ADC card is converted into a resistance. We established a bridge between the input side of each position and ground, with one hundred 1% precision resistances. Since the internal resistance of the board is theoretically infinite, the voltage in the card's inputs can be computed as: V=4.3*100/(100+R)

where R is the resistance of the strip in ohms. If there is no strip, R is infinite and the voltage is measured at 0.

Our software successively selects each of the six outputs of the Access.BUS card in an infinite loop, reading the NN value ten times and calculating an average based on the eight values closest to each other. Since several strips can be connected simultaneously to the same output, which loses current, a relay-controlled power supply was added, with six positions corresponding to the six outputs. We stabilized this power supply to limit oscillation measurement errors and to reduce the minimal distance between the resistances of the strips.

Our goal was to change the stripholders as little as possible. We created a mould from ordinary stripholders using RTV-2 flexible polyurethane resin. We experimented with different colors and embedded a computer-controllable LED. We created transparent stripholders (Fig. 3), with transparent strips, that can be placed directly over a touch screen, displaying computer information directly onto the strip from below.

Figure 2 shows the stripboard prototype placed over a graphics tablet that can detect writing through the thickness (5mm) of the plastic stripholders. Knowing the precise position of the strip lets us interpret hand-written annotations, based on the type of mark and location within the strip. Feedback is displayed on the touch screen to the left. For example, a controller suggests a new exit flight level by writing it on the strip. This level appears on the adjacent touch screen and is sent to the next sector. As that controller underlines it, it appears on the first controller's touch screen.

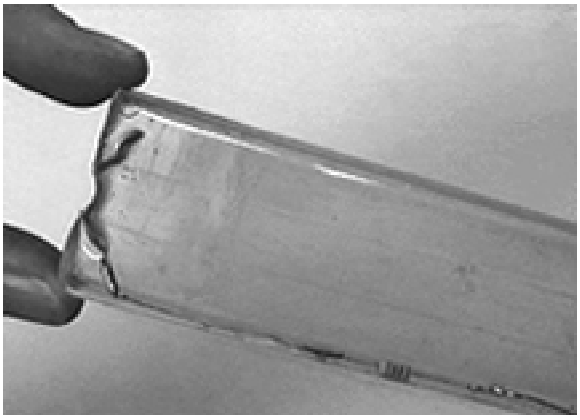

Fig. 3: Transparent version of a stripholder with an embedded resistor and metal contacts.

CONCLUSION

The creation of the stripboard was a multidisciplinary effort, with contributions from people with backgrounds in physics, engineering, computer science and graphic design. The result is an inexpensive, flexible device that can be linked to various other capture and display devices. Although the stripboard is only a prototype, it has effectively communicated to controllers how a future augmented reality system would work. As one controller said, "This system is practically invisible!". Our research illustrates a new direction for designing systems that improve air traffic control.

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REFERENCES

Mackay, W.E., Fayard, A.L., Frobert, L. & Médini, L. (1998) Reinventing the familiar: Exploring an augmented reality design space for air traffic control. In Proc. of CHI'98, Los Angeles, CA: ACM Press.

Ruiz, D. (1997) Étude et réalisation d'un bus d'entrées/sorties. Qualification Technique Supérieure IESSA, CENA. (Technical Report.)