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Tangible Encoding of Temporal Data in Air Traffic Control

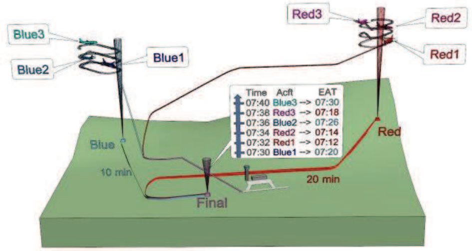

Figure 1: A stack and calculation of the Estimated Approach Time (EAT)

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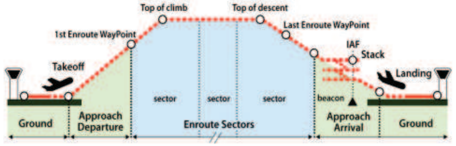

Figure 2: phases of flight and associated control areas. Final approach control manages aircraft from the stack and the IAF (Indicated Approach Fix) point before landing.

Abstract

In this position paper, we describe a tangible design to support temporal processes in Air Traffic Control. We discuss how we balanced between physical and digital allocation of time-related features, relying on cognitive studies that show how physical space and physical objects manipulation support the encoding of real-time and planification concerns.

Author Keywords

Tangible interaction; Augmented paper; ; Distributed cognition; Representations of time; Security.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

For air traffic controllers, safety means managing real-time events: planes arrive at their destination or take-off at given times. A critical part of the controller's task is to manage these events in real-time by talking to the pilots to give clearances. Another critical task is full preparation in order to ensure that these real-time actions will unfold properly and effectively. Cognitive approaches have explained how these tasks may be supported through an intelligent use of space and physical objects [8]. In this paper, we briefly describes the ATC activity involving critical time management, and a tangible system, Strip'TIC [6], that supports ATC work by keeping the advantages of physical features. We then describe how we designed features to support temporal processes management, relying on these cognitive studies

Related Work

Our work relates to interface approaches that employ physical means of interaction: tangible user interfaces (TUIs) [13] and augmented-reality [11]. Tangible interface research aims to explain properties and

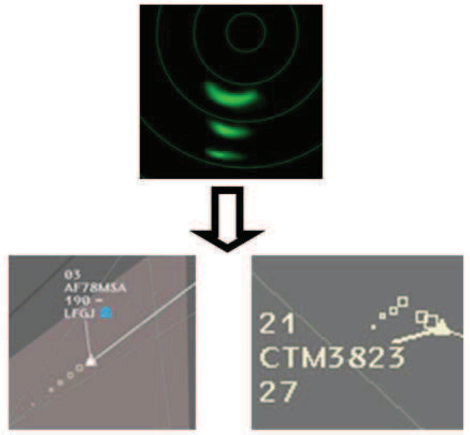

Figure 3: The shape decreases in intensity over time on a scope (top picture). ODS comet metaphor (bottom picture).

Figure 4: tangible computation of an arrival sequence: allocation within projected time slots (blue), computed stack exit times (red), strips linked to their projected stack level (white - crossing links show a misordering). This was inspired by a kind of paper ruler that is used by Orly approach controllers as rough paper that helps visualize free time slots and calculate mentally (Fig 6).

affordances of the physical world these interfaces rely on (e.g [5]). For designers, a general issue thus becomes the allocation problem to either virtual vs physical objects according to performance or interaction needs. Interestingly, few TUI approaches have addressed time-related data, except for logging or controlling data streams, maybe due to the fact that these data are relatively abstract [9]. For instance, ChronoTape [2] is a temporal tangible interface, which enables the tangible representation and control of time for supporting family history research. This approach differs from ours: air traffic controllers do not control time (i.e they cannot pause or rewind!), instead, as explained in the paper, they need to *manage* it.

ATC Activity and its instrumentation

Air traffic controllers (ATCo) maintain a safe distance between aircraft and optimize traffic fluidity, usually working by pair. The planner controller predicts potential conflicts between aircraft. The tactical controller devises solutions to the conflicts, implements them by giving instructions to the pilots by radio, and monitors the traffic. Air traffic controllers currently use a combination of computer-based visualization (e.g. radar image) and tangible artifacts (paper strips) to manage traffic. In approach mode (Fig. 2) aircraft are most likely ascending or descending, with 2 minutes between two consecutive planes. Therefore the time of analysis and action decreases rapidly as the aircraft get closer to the field. When the runway capacity is exceeded, controllers can delay the arrival of aircraft by piling them up into a ‘stack’ and making them perform horizontal loops (Fig. 1). Since controllers do not feed the system with the instructions they give to the pilot and write onto paper, authorities have decided to replace paper with digital devices. However, there is still reluctance to the adoption of Electronic stripping, either prospective [12], or operational (Frequentis SmartStrips or NAVCANStrips). This is partly due to the fact that screens do not offer the same level of interactivity as paper. Mixed interaction may be an appropriate approach to the improvement of the ATC environment.

Visualization of the past present and future aircraft positions

Air traffic controllers currently use a comet to display the current past and future aircraft position. The comet indicates a heading and its shape indicates its turn and degree of veering (Fig. 3). The design of the comet is built with squares, whose size varies with the proximity in time of the aircraft’s position. This provides an efficient visualization of temporal data, with the possibility to interpret naturally emergent information such as speed, tendency and acceleration [4].

Prototype description

We have designed Strip’TIC, a novel system for ATC that mixes augmented paper and digital pens, vision-based tracking and augmented rear and front projection [6]. The paper strips, the strip board and the radar screen are all covered with Anoto Digital Pen patterns (DP-patterns). Users’ actions with the digital pen are sent in real-time to IT systems wherever they write or point. Bottom and top projection on the stripboard and strips display dynamic information. Controllers can manipulate paper strips as they are used to with the regular system.

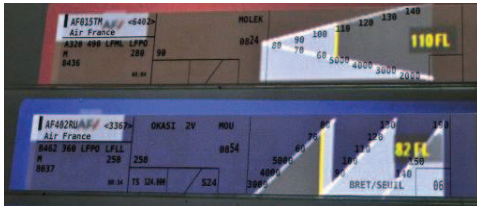

Figure 5: colors (light grey, yellow, dark grey) indicate past, present and future flight levels.

Figure 6: a) a rough paper ruler on the back of a strip to allocate an arrival sequence; b) the paper ruler contains stack exit times as mentally computed by the approch controller.

Tangible encoding of ATC temporal processes

We explored whether augmentation could provide useful support to time-related features.

Structure of temporal processes in ATC

In [10] Loft et al describes ATC activity as a subtle combination of two modes of control: a proactive mode that consists – often for the planner – in building an efficient encoding of the problems so that they can be resolved very quickly and without errors, and a reactive mode which is often performed by the tactical through reactions to events (pilot calls, clearances, potential conflicts). The two parallel modes occur at different timescales, as explained by a controller: «*the tactical […] is dealing with a problem at 15 nautical miles and we speak here about a conflict that will happen in 15 minutes*». ATC activity thus involves constant phasing between two timescales: that of the controllers, during which they organize their work, and real time, where real traffic occurs.

Temporal processes physical encoding

In [8], Kirsh describes how spatial arrangements support expert activities involving a preparation phase, and a high tempo execution phase. For instance, experts ensure that information needed to act quickly is available locally, and that actions can be performed almost automatically. To achieve this, they pre-structure their workspace physically to simplify choices, discard unrelated decisions, encode pre-conditions, and highlight the next action to take. For Kirsh, space also naturally encodes linear orders: items arranged in a sequence can be read off as the order they are to be used in. We observed similar orders in approach control with stacks and arrival sequences. In [4], Harper et al highlight how these arrangements encode an ordered set of tasks to perform: “ATCO work is not like an assembly line in which a recurrent sequence of steps has to be followed through, but one in which the work consists of putting the tasks to be done into a sequence of steps that can be followed through”. These spatial orderings implicitly connect the two timescales we mentioned above: taken as traffic sequences, they correspond to the planes flying in real-time, but as tasks to perform, they also correspond to the control timescale. To be as precisely on time as possible, controllers also rely on their knowledge of action duration according to various contexts (including their own cognitive load): «*It’s your internal clock, you know how long it takes you to perform standard actions.*»

Experimentation of time-based mixed tools

Based on this analysis, we explored how to turn these implicit relationships into a more explicit design of virtual temporal objects.

Some tools enable computation (Fig. 4), others facilitate conflict management (Fig. 7a) [3]. Interactive tools enable to evaluate time and distance directly from the radar screen (Fig. 7b). Such tools are meant to add explicit time-related information to the already spatially structured linear orders. Time can also be visualized as dynamic, providing a sense of passing time through information that evolves visually, such as a timer to manage wake turbulence (Fig. 8), or progress bars (Fig. 5). We see these tools as complementary instruments to support phasing between the two timescales that we described above. What we observed however is that while controllers quite efficiently rely on their own skills, using physical and spatial tools both to adapt to real time and to schedule their actions, they also liked real-time, tactical control oriented tools that help program timing or actions, such as countdown timers [2]. In

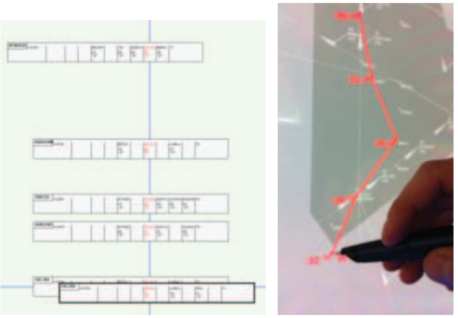

Figure 7: a) a timeline representing several flights heading to a common beacon to analyze potential conflicts; b) computation of the time needed for the drawn trajectory. The controller draws a polyline with the pen onto the radar screen where the estimation of time and distance to reach it is displayed next to the related nodes.

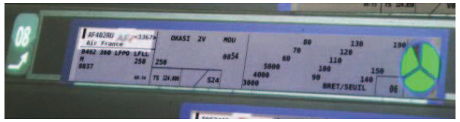

Figure 8: wake turbulence take-off timer (green circle): the next departing plane has to wait for the AFR608 (indicated as heavy (H)) to move away.

anticipation mode, approach controllers are in fact not so much interested in explicit time, but rather on ordering: «*You don't care about arrival time, what matters is that they [the planes]… are in a sufficiently spaced out and coherent order… not too close, not too far…* ».

Conclusion

Through the design of the Strip'TIC prototype, we were able to experiment various designs for the support of temporal processes in ATC. Main needs include the ability to anticipate events by being able to figure out their time or location. Complementary real-time and tactical features help the controller to improve its feeling of passing time to trigger actions accordingly

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