SUPPORTING COLLABORATION IN THE NATIONAL AIRSPACE SYSTEM WITH MULTIMODAL, ASYNCHRONOUS COMMUNICATIONS

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ABSTRACT

Feedback on flight performance and contributing factors is essential to develop awareness of where inefficiency exists in the National Airspace System. However, even when inefficiencies are identified it may require collaboration between organizations that are part of the NAS as knowledge and control are distributed. Sometimes asynchronous collaboration is necessary or desirable. Research in other application areas has shown a multimodal approach is often effective and preferred for asynchronous collaboration. The potential to combine better feedback with multimodal asynchronous communications in this flight performance analysis context is described here and data is presented showing that both airline dispatchers and FAA traffic managers consider this approach useful.

Keywords: Multimodal messaging; asynchronous communication; the National Airspace System; situation awareness; annotations; computer-mediated communication; cooperative problem solving.

INTRODUCTION

Smith et al. (1995) described successful cooperative problem solving for flight planning involving the Air Traffic Control Systems Command Center (ATCSCC), the Traffic Management Units (TMUs) at Enroute Centers, and the airlines' Airline Operations Centers (AOCs). Based on a series of structured interviews, observational studies and a focus group, four factors were outlined that seemed to have contributed to the successes that were identified: (1) developing a shared understanding of high level goals, problems, constraints, and solutions; (2) distributing responsibilities to a number of different individuals; (3) incorporating feedback and process control loops into the system; and (4) selection of staff. They further suggested three goals for improving the cooperation within this application area even more:

1. Cooperative technology should use intelligence in ways which aid human decision makers without sacrificing their goals and needs;
2. Cooperative technology should help facilitate information exchange between individuals at very diverse locations and with diverse skills, goals and backgrounds;
3. Cooperative technology should have the capacity to help individuals build interpersonal relationships with the people they must work and coordinate with.

In this paper, efforts are described that have occurred since these goals were stated that appear to help achieve these conditions. In particular, the development of a post operations flight analysis tool and a supporting multimodal asynchronous communications tool are described that provide better feedback and facilitate discussion of the information produced.

BETTER FEEDBACK IN THE SYSTEM

Air traffic is increasing rapidly, meaning that methods for safely improving efficiency in the National Airspace System (NAS) are becoming increasingly more important. As part of Free Flight Phase I the Collaborative Decision Making (CDM) program (Federal Aviation Administration, 2000) has involved developing a collection of tools that help address this situation by: (1) allowing the Federal Aviation Administration (FAA) and participating airlines to electronically exchange and analyze flight, NAS capacity, and status information; (2) enhancing the Traffic Flow Management (TFM) process; and (3) monitoring and analyzing the performance of the TFM system. One tool that has been developed under this program is the Post Operations Evaluation Tool (Metron, Inc., 2000). This performance evaluation tool supports identifying areas of NAS congestion or inefficiency using a variety of metrics including departure, en route, and arrival delays, and filed versus actually flown flight tracks. Users access, filter, and produce visualizations of the archived flight information contained in the system's database using interactive charts, tables, and geographic displays. Analysis results can be aggregated into groups by departure and/or arrival airports, filed arrival fixes, departure/arrival times, National Route Program (NRP)/non-NRP, departure and/or arrival centers, and user class. A collection of data mining tools optionally assists the user in recognizing patterns and trends within the data. Some of these patterns include airborne holding, arrival fix swaps, and flown routes that differ significantly from the routes filed. The Post Operations Evaluation Tool can integrate FAA data with airline flight data (such as predicted vs. actual fuel consumption) to produce a more complete picture of what is happening in the NAS.

The need for better archiving and interfaces to flight data was demonstrated in the research cited earlier. It was noted that the ATCSS would sometimes take screen captures of their Aircraft Situation Display (ASD) at the time that a particular flight would pass through an area on a number of occasions, when a particular route had not been approved. As was stated by a participant: "We're taking pictures to guarantee that they're not blowing smoke and we will forward these pictures back to the facilities manager and say: 'This is consistently happening. Please tell us why. We don't see it here'." Thus, the Post Operations Evaluation Tool automates archiving this type of data for later analysis – either providing hard evidence for what is already suspected or supporting the discovery of unknown patterns. Further, the approach taken with the Post Operations Evaluation Tool is consistent with the first goal started in the research cited earlier. This tool reduces problem solving search processes by sorting and aggregating large amounts of data within flexible categories, but the user defines the search, determines the categories, and selectively applies heuristic data mining algorithms.

BETTER COMMUNICATION AND DECISION MAKING IN THE SYSTEM

The Post Operations Evaluation Tool provides more data and useful representations for aggregated data, thus improving situation awareness about what is systematically happening to particular collections of flight instances, but often the control to make changes and the knowledge necessary to find solutions to the problems highlighted by the tool is distributed. Thus, it is extremely useful to be able to communicate about the results that were found.

The second and third goals stated in the introduction of this paper emphasize the importance of information exchange at a distance between individuals with different knowledge and goals, and of building interpersonal relationships. The successes that Smith et al. reported were in part attributed to the interactions that occurred during phone calls when routes were requested: "This permits much richer interactions [than text-based], increasing the likelihood that a shared understanding of the process will

develop. It also increases the likelihood that personal ties will develop, enhancing cooperation". However, telephone calls can also be disruptive and there is still the issue of sharing display images that a normal telephone connection doesn't support. As one participant said, "a phone call's time consuming. A picture is worth a thousand words". There therefore appears to be significant incentives to try to develop an efficient and effective asynchronous communications system that supports discussion of computer display images, while maintaining voice communications for the interpersonal relationships it seems to help develop.

Related Research

Research regarding the interaction between images and annotations referring to them is relevant here. So too is research on multimodal communications as different sensory channels are necessary to interpret messages composed of images annotated with both visual markings and voice based references. The following is a brief description of some of the most relevant research:

Faraday and Sutcliffe (1998) studied how people fixate between text and that to which it refers in an image using eye tracking. They reported that subjects didn't always look at the correct place immediately after viewing a reference and therefore recommended placing the reference and the referent close together when possible to help with the search process involved. They also developed a system that allows dynamic references where selecting the reference causes effects such as symbol appearance, highlighting or animation to direct the user's attention to the referent.

Wojahn et al. (1998) studied the impact of comment placement in a collaborative writing task. They found that subjects communicated more problems when comments were inserted within the text and in a vertical window with comments aligned horizontally to the referent than when the comments were placed in a horizontal window below the text.

Neuwirth et al. (1994) compared the nature and quantity of voice and written comments produced in each mode, when reviewers gave feedback to writers. They found: (1) reviewers used more words in voice than text mode during the same time period, but that the same number of annotations was made on average. The additional words were attributed in part to providing more reasons why the reviewers thought something was a problem and for polite language that mitigated the problem; (2) evaluations of reviewers were less positive when reviewers produced written annotations than spoken; and (3) comments about low-level mechanics were preferred in text.

Daly-Jones et al. (1997) conducted a study where 'manager-secretary' pairs were asked to complete an asynchronous appointment-scheduling task and an equipment-booking task in three conditions: *Fax-only* involved using Microsoft Paintbrush; *Voicefax* involved using Lotus Screencam (an application that allows synchronized voice and pointing to be recorded by creating a 'movie' from the output on the user's computer display over time while recording and synchronizing any audio input) with a Paintbrush image; *Voice-only* involved just audio. For both sending and receiving, voicefax was rated most useful, then fax-only, then voice-only. Subjects took the same amount of time to complete the tasks in each condition, but fewer messages were sent with voicefax.

Bargeron et al. (1999) studied subjects using the Microsoft Research Annotation System (MRAS), a system with steaming video and personalized annotations that are tied to portions of the video and shared. In their study involving three conditions: text-only, audio-only, and text and audio, participants felt it took more effort to listen to audio than to read text. One subject stating, "I read much faster than I or others talk. I wanted to expedite a few of the slow talkers." They also found that audio annotations for video didn't work well as the video had to be stopped to create or listen to an audio annotation.

Francik et al. (1991) developed another system that supported synchronized voice and pointing, called FREESTYLE. It was designed for problem solving, planning and design, but they found that it tended to be used for very structured processes, for signature processes and electronic distribution of scanned-in paper documents. Ultimately, although users liked the synchronized voice and pointing, FREESTYLE failed to obtain widespread use with stated problems including the lack of training and that it often failed to achieve a critical mass of users.

In summary, both Faraday and Sutcliffe, and Wojahn et al. provide evidence of benefits from placing annotations close to that which they refer. Neuwirth et al. and Daly-Jones et al. provide evidence that voice based communications can lead to more extensive descriptions of problems and better interpersonal relationships. Daly-Jones et al. and Francik et al. provide evidence that synchronized voice and pointing can be particularly efficient in problem solving and also "appealing" to users, but Neuwirth et al. and Bargeron et al. also show that text-based communications is sometimes preferred, and Francik et al, demonstrate careful matching of the task to the tool is important as is training and the selection of users.

C-SLANT

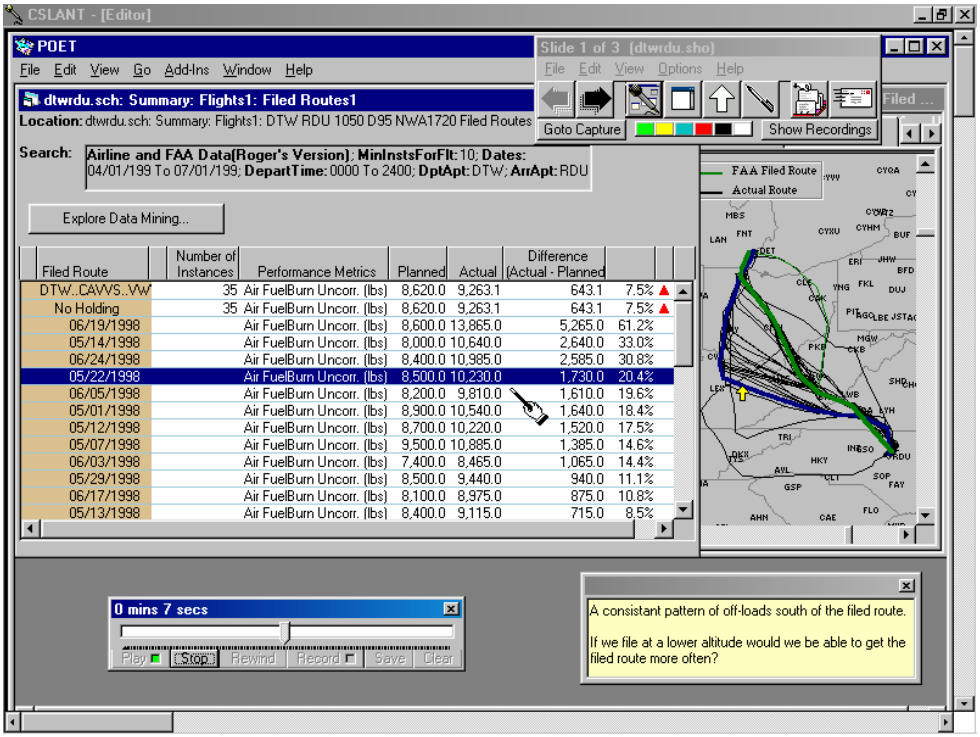

Figure 1. Annotated C-SLANT slide showing archived data in the Post Operations Evaluation Tool

Chapman et al. (2000) describe the design of the Collaborative Slide Annotation Tool (C-SLANT), a computer supported multimodal asynchronous communications application that was developed to support discussion of Post Operations Evaluation Tool results, supplemented by related data such as weather. Using C-SLANT the context of a message is formed by taking one or more computer screen snapshots and then these images are annotated with synchronized voice and pointing; pen marks; text-based notes,

and arrow markers to produce a "slide show". However, C-SLANT is more a messaging system than a presentation system, with threaded voice comments and responses over asynchronously shared displays. The message produced is small in terms of file size relative to the approach taken by systems that rerecord the entire screen every fraction of a second because each image is stored once and only the pointer's position is continuously recorded. To further reduce the file size a standard compression algorithm is also applied automatically by C-SLANT. The main interface window with buttons and a pull-down menu is a separate movable window to allow as much of the screen as possible to be used for the captured image. Text boxes (conceptually "sticky notes") are also moveable for the same reason, and so that they may optionally be placed close to that which the text contained refers. Figure 1 shows an annotated C-SLANT slide involving a screen capture of archived data from the Post Operations Evaluation Tool that provides evidence of systematic rerouting to the southwest for flights from Detroit to Raleigh, Durham.

DISPATCHER – TRAFFIC MANAGER COLLABORATION FIELD EXPERIMENT

In a recent field experiment 36 AOC dispatchers from Northwest Airlines used C-SLANT and the Post Operations Evaluation Tool data to create messages for 36 ARTCC traffic managers at eight different centers about performance issues for flights between 9 different city pairs. The traffic managers were then asked to respond. Of particular interest was how well the synchronized speech and pointing would work for this context compared to text-based annotations. The communications themselves are now being analyzed, but the results of two questions on a questionnaire used, summarized in Table 1, shows that all 69 participants who completed the questionnaire did not consider C-SLANT difficult to use. The majority also thought that it would be at least fairly useful in their work. (Some dispatchers indicated that they thought it would be more useful to ATC-Coordinators who more often communicate with the FAA.)

How easy/difficult did you find this software to use?	*Very easy*	*Easy*	*Neutral*	*Difficult*	*Very difficult*
Text mode dispatchers	8	7	2	0	0
Text mode traffic mangers	8	8	1	0	0
Voice & pointing dispatchers	2	11	4	0	0
Voice & pointing traffic managers	12	6	0	0	0

How useful do you think this kind of software might be in your work?	*Not useful at all*	*Not very useful*	*Neutral*	*Fairly useful*	*Very useful*
Text mode dispatchers	0	0	2	9	6
Text mode traffic mangers	0	1	4	8	4
Voice & pointing dispatchers	0	3	3	9	2
Voice & pointing traffic managers	0	0	2	4	12

Table 1. Questionnaire results for usability and usefulness

The impact of mode differences in the questionnaire results may be due to the task itself seeming to be harder for the dispatchers creating the initial messages than the traffic mangers responding. Thus, the

extra time for reflection and easier editing that comes with text composition would be most beneficial for the dispatchers, whereas the efficiency of voice and pointing would be better suited to the task performed by the traffic mangers. There was an unfortunate side effect of allowing participants to place the text boxes anywhere on the screen in that text boxes were often left covering data (for instance, 66.6% of the dispatchers covered data on their first slide although there was always room to avoid this).

CONCLUSIONS

Tools such as the Post Operations Evaluation Tool help to improve situation awareness of what is happening to collections of flights in the NAS. Multimodal asynchronous communications tools such as C-SLANT appear to help improve the awareness further by supporting sharing of the results found and discussion of what is causing those conditions as well as alternative actions for improving performance. Initial results from a study involving significant decision makers in the NAS working with real data suggest they consider such a system both useful and usable.

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