Applying Gestural Interfaces to Command-and-Control*

Todd Reily and Martina Balestra

The MITRE Corporation,
202 Burlington Rd 01730, Bedford / MA, United States
{treily,mbalestra}@mitre.org

Abstract. This whitepaper examines the applicability of gesture-based user interfaces in notional Command-and-Control (C2) environments of the United States Army. It was authored by a team of Human Factors Engineers at The MITRE Corporation, a not-for-profit research and development organization funded by the United States Government. Since MITRE resides in a not-for-profit advisory position to their federal sponsors, the research team was able to take an unbiased perspective driven solely by identified issues, the search for improved workflows, and practical opportunities for technology development. The goal of the effort was to inform the US Army community so that it can make responsible, needs-driven decisions regarding gestural interface technologies, and avoid the potential pitfalls that may arise from technology-centered or profit-driven decisions.

The problems focused upon by this research primarily revolved around the collaborative human workflows that occur within Command-and-Control environments. Specifically, the effort targeted US Army-based C2 environments, such as a notional fixed command center, a mobile command center, and the environment of the dismounted soldier in the battlefield. The primary issue is that the currently-implemented technologies, while independently sufficient, present constraints when distributed personnel are collaborating across them. The research team addressed this cross-platform issue by adhering to a Systems Engineering framework that required a holistic approach to the "system" of distributed C2 personnel and their technologies. The goal for the final output was to demonstrate how these technologies may come together as a system to support a more efficient, dynamic, and effective operational workflow than today's reality.

After carefully examining the field of current and emerging gestural interface technologies, and mapping them against available HCI-related research findings, the team concluded that US Army personnel may indeed benefit from effectively and appropriately implemented technologies from this domain. At a high level, gestural technologies offer C2 personnel an ability to conduct more efficient and collaborative workflows across distributed environments. The exact details of these workflows, including the key users, actions, and technology paradigms, are outlined in the content of the whitepaper. In an effort to be as prescriptive as possible, the research team decided that it would be valuable to include a sizable section within the whitepaper dedicated to instructing the user on how to implement gestural

* Approved for Public Release: 10-3988. Distribution Unlimited.

A. Marcus (Ed.): Design, User Experience, and Usability, Pt II, HCII 2011, LNCS 6770, pp. 187–194, 2011.

technologies for C2 application. In this section, they outline the key design patterns to selecting proper solutions and developing effective interaction design frameworks. The nature of this instructional portion ranges from high-level design principles and best practices down to detailed visual demonstrations of recommended gestures.

Keywords: Multi-touch & Tangible User Interfaces, Immersive Computing, Multi-modal Collaboration, Interactive Surface Interface, WIMP Interface, Graphical User Interfaces (GUI), Multi-Touch Surface, Tangible Interfaces, 3D User Interfaces, Wearable Computing.

1 Introduction

In this document we will first discuss a new method for designing the interaction mechanisms of new technologies for the command-and-control (C2) environment. We will then present the resultant operational framework of new concepts considering the environments, workflows, and known human-based issues experienced in C2 environments. We attempt to adequately address a subset of critical C2 issues and clearly present technically-plausible, gesture-based solutions in a novel way that would be understandable and beneficial to military sponsors.

To inspire our design and provide meaningful documentation for our sponsors we chose to create a visual narrative that took the traditional story-board process a step further with flash animation. It is generally accepted knowledge that the visual communication of novel systems and technologies is far more effective than attempting to describe the concepts in language-based detail. Furthermore, when developing new interface concepts, it is not only important to understand the functionality of the product, but to visualize the interactions it promotes. Interaction design is inherently visual, so the means of conveying that design should also be visual. Especially in an instance where the user group and scenario are highly unusual or inaccessible, as the active C2 environment is, visual animation provides an additional level of fidelity not necessarily found in static storyboarding. The visual narrative method allowed us to illustrate a cohesive case study that enabled our audience to understand not only the context in which these technologies could exist, but the possible dynamics, interactions and transitions between them. A primary goal for this project was to demonstrate interactive technologies as a unified system of components that support a collaborating set of users across a range of environments and workflows.

It is essential that we discuss the motivation of this work, as the application of gesture-based technologies to command-and-control is a decision that is certainly up for evaluation. Gestural interfaces, especially multi-touch technologies, have existed for many years. Humans, whether civilians or military personnel, have shown to prefer gestural interfaces because they present an interactive language that naturally maps to their own experiences with the physical world. Gestural interfaces frequently allow for the *direct manipulation* of on-screen information instead of requiring intermediary tools and training. The result is frequently a swifter, more natural, and less error-prone interaction. Due the critical and time-sensitive nature of military operations, where errors and delays are risky and unacceptable, it is essential that we as engineers and designers examine the opportunities for appropriate implementation of gestural interfaces within these environments.

The remainder of this document discusses an example of what we consider to be the appropriate implementation of gestural interfaces to the C2 communication- and work-flow. We have organized our recommendations by operational environments beginning with a discussion of the technologies that appear in a representative Tactical Fixed Center (a fixed command and control center), followed by a notional Tactical Mobile Center (mobile command center frequently deployed into the theatre) and finally, the environment of a notional Dismounted User (soldier on the ground).

2 C2 Environment: Tactical Fixed Command Center

2.1 Overview of Fixed Tactical Center Technologies

Key players in the tactical fixed center include a team of Strategic Planners gathered around a meeting table, and data analysts, including an "Immersive Planner", at remote and/or independent work stations.

The Tactical Fixed Center receives guidance via video conference with the Strategic Command Center (a third entity – not considered in our recommendations – charged with setting the objective of the mission) that there is an opportunity to take control of a critical enemy location. The guidance is packaged in a dynamic digital plan that can be loaded onto a tabletop touchscreen surface when authorized strategic planning personnel initiate a session. Key personnel in the Tactical Fixed Center gather around the planning surface to view the mission objectives and imagery sent in the digital plan. Users then select and manipulate additional relevant mission and environmental data supplied and supported by the data analysts. Strategic Planners interact with the table via haptic inputs and by manipulating tangible objects representing different types of data and controls placed directly on the surface. This is heavily collaborative as experienced personnel with varying fields of expertise and motivation need to analyze, discuss, and agree on a proper course of action.

As the strategic personnel are discussing a potential plan, they realize that they need real-time ground-level clarification of a particular geographic area to understand the potential hazards and feasibility of the plan. They submit a request for information by identifying the area in question on the map and assigning it to the "immersive planner".

Fig. 1. Strategic Planning Personnel and Interactive Mission Planning Table

The Immersive Planner is a newly conceived role providing a data analyst the ability to interact with ground data in an immersive digital environment. The displays feature a virtual environment created from available mission-related and environmental data. The strategic planners' request from the planning table appears on the center display and a video chat window opens to allow for direct communication with the Strategic Planners. Using hand gestures, the Immersive Planner is able to navigate through the virtual environment specified by the strategic team and communicate her observations by flagging important areas. These areas of interest are then mapped back to the display on the Strategic Planning Table. The Immersive Planner can further detail her findings by chatting with the Strategic Planners in real time.

The Immersive Planner's location, findings, and corresponding environmental information (weather data, dismounted soldiers, etc.) can all be layered and displayed on the planning surface's map to provide situational awareness to the Strategists as they design the plan. During this activity, an ad hoc request may come in from the theater requesting real time support in an unknown area. The Strategic Planners may override the location of the Immersive Planner and "move" them to area of interest in their virtual environment to explore the area for potential hazards based on (close to) real-time video feeds. They may then relay their findings back to the Strategic Planners, or where applicable, directly to the dismounted soldiers.

With the insight from the Immersive Planner, the Strategic Planners are able to come to a consensus around an approved course of action. Documentation of the plan collected and recorded on the surface is sent forward to the Tactical Mobile. This allows the Mobile Center, as an outpost of the Fixed Center, to have access to the same information and situational awareness as the Fixed Center and Dismounted Soldier. We will explore this role further in subsequent sections.

2.2 Discussion

We believe that the Fixed Tactical Command Center can benefit from the implementation of innovative technologies that specifically promote *agile collaboration*. As demonstrated in the vignette above, we have chosen to showcase a combination of different types of technologies to accomplish this objective. In this section we will discuss each medium – the multi-touch surface, the Tangible User Interfaces (TUI), and the Gestural Interfaces – independently to develop an understanding of each technology and their capabilities.

It is not by chance that we decided upon a collaborative planning surface to demonstrate the technologies in this section. We want to find an analogy for the common operational task of personnel gathered around a table formulating a course of action because we wanted a medium that would align with known traditional workflows. We chose to exemplify multi-touch, TUI, and gestural technologies where they enhanced common workflows, behaviors, and expectations.

3 C2 Environment: Tactical Mobile Center

3.1 Overview

Four soldiers are stationed in a notional Mobile Tactical Operations Center. They receive a message from the Fixed Tactical Command Center regarding a mission update. The objective of the team in the mobile center is to augment and support the flow of communication and guidance between the strategic planners in the Fixed Tactical Command Center and the Dismounted Soldiers in the field. They also control the coverage of a small unmanned aerial system (UAS) which can provide real-information to the mission.

Before the message arrived, three of the four soldiers in the vehicle were monitoring the operational picture on tablet displays within the vehicle. The displays are rugged tablet devices that can be removed and re-mounted in any of the various docking stations throughout the vehicle. Docking locations include the passenger dashboard, the sun visors, the back sides of the front seats, and even on the outside of the vehicle. The visual interface of the tablets is similar to the software being run on the table in the Fixed Center (aside from the lack of tangible objects). This means that users in the Mobile Center have much of the same information available to them in the same formats as in the Fixed Center, which facilitates collaboration and minimizes misunderstandings.

One soldier in the Mobile Center is piloting a small UAS that was launched from the vehicle earlier in the day. He sits in the specially-equipped passenger seat featuring a dashboard-mounted console for controlling and monitoring small UAS's. The console also provides a location for the soldier's tablet to maintain situational awareness as he is piloting the UAS.

Once a plan has been distributed to dismounted soldiers (see next section), the Mobile Center acts as a conduit between the Strategic planners and those executing the plan. As information brokers between the two entities, they are responsible for ensuring that the dismounted soldiers have the right information uploaded to the forearm-mounted display, and that the Fixed Center is kept abreast of the events in the theater so they will be prepared to provide assistance should it be needed.

3.2 Overview of Tactical Mobile Center Technologies

While the technologies employed in the notional Mobile Center are very different from those seen in the Fixed Center, they capitalize on many of the same interaction techniques. In the following section we will describe how recommendations for tools used in the Mobile Tactical Center can use the same interaction techniques. Because we wanted the design guidelines presented in the Fixed Center to be a reference for those mediums regardless of application, we will only contribute design suggestions where there are completely novel interactions to be discussed.

The soldiers in the notional Tactical Mobile Center use personalized and rugged haptic tablet computers featuring multi-touch interfaces. As explained in the overview of multi-touch technologies in a previous section, this medium was chosen to promote efficiency and enable agile collaboration (for a detailed explanation of this, see the previous section outlining multi-touch technologies). Multi-touch interfaces are a particularly intuitive medium for viewing, interacting with, and manipulating data. On the basis of its inherent usability merits alone, it is recommended that the soldiers in the Mobile Tactical Center have access to multi-touch technologies in an adaptable form factor. Tactically manipulating data directly instead of using the metaphorical proxy of the mouse minimizes mistakes and time wasted in the physically constrained, high-risk, high-stress environment of the Tactical Mobile Center.

4 C2 Environment: Field of Battle

4.1 Overview

The final environment in our workflow features a notional dismounted soldier in the field of battle utilizing gestural technologies. The priorities of this position are clear: optimize situational awareness for the Fixed and Mobile Centers, avoid threats, and complete the operational goal within the necessary bounds. The dismounted soldier workflow is high-risk and time-critical, so the technology designed must be as unobtrusive and efficient as possible.

Fig. 2. Images from Field of Battle environment

During our concept animation, we see the Dismounted Soldier initiate a request for Close Air Support. To do this, he activates the arm-mounted display by removing the protective cover. He first sees a main menu that features the ability to create a request, leave a visual tag, see the mission plan, or place a voice call directly to the Tactical Fixed Command Center. In this case, he makes a request to initiate a Close Air Support sequence. This action launches a map view that contains the updated target set and the required path of entry which was determined by the Tactical Fixed Center, including the Immersive Planner.

If he chooses to, the Dismounted Soldier may want to utilize the heads-up display attached to his helmet to receive an "augmented reality" overlay of the mission plan or even just to receive visual indication of alerts or changes in plans. The Dismounted Soldier would need the ability to just "flick on" the mission plan for a brief second in order to aid in decision-making, and then quickly turn it back off to avoid potential distraction. The content on the HUD could even be a semi-transparent, in-context overlay of the Immersive Planner's virtual walkthrough. This could help to guide the

Dismounted User in times of urgency or distress because it would not require the cognitive task of translating directions into actions.

Various lower-ranking dismounted soldiers may wear a small wrist-mounted device that looks similar to an interactive watch. However, this device is also a simple communication mechanism that can display critical and succinct pieces of information, such as a warning icon, a "go ahead" icon, etc. It also allows the soldier wearing it to send out calls for help (e.g. "danger!") or simply tag his or her location. This device would also feature tactile feedback to grab the attention of the wearer when necessary. In an effort to support open communication back to the Tactical Fixed Center, this wrist-mounted mechanism would allow soldiers to directly add geolocated military iconography to command center software with the simple click of a button.

Finally, the Dismounted Soldier may carry an "augmented reality flashlight", which would be a data-enabled flashlight device that would allow a user to project mission data onto any surface in the environment for single-point overlay of contextual information. At appropriate times, this may be less invasive than a HUD as the data would be projected onto the target, instead of being displayed inches from the user's face.

4.2 Overview of Dismounted Soldier Technologies

The primary means of communication for the Dismounted User group leader in our scenario is a flexible interactive display integrated into a fitted forearm sleeve of their uniform. The lightweight sleeve features a protective flap that can be fastened over the display to prevent damage caused by battlefield elements, such as dust and dirt. The device gives the soldier the ability to view the latest course of action, receive and send messages, request guidance or support, leave digital "tags" in the environment, and connect via voice to necessary personnel and environments. The device also exchanges data with external devices, such as laser range finders and GPS mechanisms. Closing the flap prompts the device into a passive "sleep" mode, since battery power is likely at a premium. Of course, this device is simply conceptual, but is represents a possible mechanism supporting the Dismounted Soldier's workflow in a convenient and intuitive manner.

Other dismounted soldiers in the environment wear a small "single point" wrist-mounted device whose form factor is similar to a watch. This device is a simple communication device that can display critical and succinct pieces of information such as a warning icon, a "go ahead" icon, etc. It also allows the soldier wearing it to send out calls for help (e.g. "danger!") or tag his or her location. This device would incorporate tactile feedback to grab the attention of the wearer when necessary.

The Dismounted Soldier may want to utilize the heads-up display attached to his helmet to receive an "augmented reality" overlay of the mission plan or even just to receive visual indication of alerts or changes in plans. The Dismounted Soldier would need the ability to just "flick on" the mission plan for a brief second in order to aid in decision-making, and then quickly turn it back off to avoid potential distraction. The content on the HUD could even be a semi-transparent, in-context overlay of the Immersive Planner's virtual walkthrough. This would help to guide the Dismounted

User in times of urgency or distress because it would not require the cognitive task of translating directions into actions.

5 Conclusion

In the past decade, the emergence of Apple's iPod/iPhone product lines and the Nintendo Wii have propelled gestural interfaces to be commonplace tools used in many homes in this country. While the usage of these consumer products may appear unrelated to the needs of military personnel, one must consider the reasons people choose products employing these technologies over others. People prefer gestural interfaces because they present an interactive language that naturally maps to their own experiences with the physical world. If a user wants to select an object with a traditional computing device (e.g. mouse and keyboard), they have to manage a set of cognitive and physical "rules" for the relationships between their desired action and their hands, mouse, keyboard, and objects on the screen. With a multi-touch or gesture-based interface, the user interacts directly with their desired object or action – a perfect correlation to real world interaction. The result is a swifter, more natural, and less error-prone interaction. It is this fact that brings us back to our exploration of gestural technologies for command-and-control environments. Due the critical and time-sensitive nature of military operations, where errors and delays are risky and unacceptable, it is essential that we as engineers and designers examine the opportunities for appropriate implementation of gestural interfaces within these environments. We hope this document addresses those opportunities and provides valuable guidance and recommendations for the implementation of these technologies.