

3D Global Virtual Teaming Environment

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Abstract

Based on research conducted at a large multinational corporation, we identified several unique requirements for global team collaboration. Our findings included that two-thirds of employees work on distributed teams and the same percentage also work on multiple teams. These and other data led us to seek a solution that would seamlessly support the complexities discovered while enhancing team and personal productivity. To adequately represent the complexities, we needed an object-oriented information workspace where the use of a 3D user interface allows users to retain multiple contexts. We chose an environment already developed by Intel Research, Miramar, as a prototyping vehicle

1. Introduction

This paper describes the exploration and use of an object-oriented 3D graphical operating environment (OE) to improve team and personal productivity. The 3D OE, called Miramar 2.0, provides an integrated visual environment that supports global collaboration across multiple teams as well as personalized organization of information and work. As a virtual team space, it provides a persistent place for teams and their artifacts, particularly when they are otherwise separated by time and space and cannot meet in a physical room. As an information space, it removes barriers between documents and applications, and provides a place to gather and arrange these artifacts into persistent work contexts. Fluid movement between team and individual work modes is critical to increasing overall value to the corporation.

In this paper we outline discovery of enterprise requirements that led us to formative insights and in turn to choice of the Miramar environment, its presentation, navigation, and manipulation models. We also describe the evolution from individual tool to

team environment, and preview work on resource contention.

2. Enterprise Requirements

Over the course of three years, Intel's Information Technology Group has defined and tracked a construct called "virtuality", something widely perceived about the environment but that had not metrics. The construct was operationalized with specific easily measured variables. [1], [2], [3]. A survey representing all job types, divisions and layers with a high response rate asked employees about their recent experience of working across five discontinuities of time zone, geography, organizational units, culture/ language, software tools/work processes. The sixth "discontinuity" of virtuality was individuals working across multiple projects. The findings confirmed and exceeded our sense that Intel is a highly virtual company; i.e. 2/3 or more of work activity is performed virtually along these dimensions. In terms of cross-cultural the figure is closer to 80%. These data were tracked over three years with a high level of consistency, and some trending data in specific areas.

Based on the study, there is no question that Intel not only has specific collaboration requirements, but that those requirements are basic to everyday employee productivity. I.e. work can't get done without adequate support for virtual collaboration. We also measured performance impacts according to Intel corporate values that all employees are intimately familiar with. Correlating those values with the virtuality variables we found some counterintuitive and some obvious findings. These helped us to prioritize technological areas where IT support would have the most impact. The most negative impact of virtuality was from diversity of software tools and work processes. Cultural differences showed some negative impact, partially due to comprehension of different native languages and dialects over the telephone. This highlighted the need for communication redundancy,

better visual representations and personal information context, as well as possible translation aids. This combination of media would be relatively simple, but integrated, and include voice, text, drawing, gestures, visualization, and emoticons.

Counterintuitive but valuable findings were that North South distance proved to have no significant effect on performance, nor did the fact that 20% of people have managers who are remote [4, 5]. In other words, people can seamlessly maintain relationships and morale at a distance, at least in the Intel environment. Working across organizational units was a performance positive. Over the three-year period of the study, satisfaction with enterprise collaboration tools jumped from 40-60% to the mid-80% level, a significant increase. As yet there has been no impact on perceived performance. That seems to remain steady as a rock, yet it is an obvious improvement target.

A segmentation of the tracking data in the third year suggests that neither the satisfaction nor the performance metrics will move at all without much greater attention to the needs of Intel's core productive work groups: hardware engineers. A separate analysis of their reactions to working across continents and cultures was negative in every respect, as opposed to a 50-60% performance satisfaction average by the enterprise in general. These figures need to move up; and they need to move up through delivering the right services to a specific population. Hardware engineers work with very large files and visualization objects, they work on segmented tasks that must combine downstream; and they must communicate product critical ideas across cultural barriers and time zone within tightly coordinated deadlines. We have identified these core users as the targets for the innovations provided in the collaboration vision and software solutions described below.

One of the chief issues found in a follow-up study we did of the effects of time separation [6] is that options for coordination mechanisms narrow rapidly and severely with more time zones [6]. Not only are the design and manufacturing engineering teams time zone challenged, but there are fewer affordances in their schedules for slips and misunderstandings. This situation is aggravated by the reduction of coordination mechanisms and the downstream impacts to manufacturing have not been assessed in our study.

To put this into further perspective, time separation includes not just time zone differences, but also

different weekend days, different national and religious holidays, different amounts of flexibility in the workday, different communication bandwidths. Altogether, these differences add up to a mere 52 available overlapping "work days" per year [6].

This situation cries out for two kinds of adjustment: one is a management strategy for clustering time zone spans. The other is a software solution to create persistent work spaces with some backwards tracking of work activities so that downstream recipients of work in progress can replay and observe the path of decisions taken without waiting 24 hours to clarify in real time.

We can characterize the effect of this need to collaborate around the globe, jointly create content, and take action while managing multiple responsibilities across projects as the coordination of "group memory" [7]. This need is not reflected in today's collaboration tools that typically store documents in folders and rely on uncoupled or weakly-bound client applications to render and manipulate the information in the repository [8].

Group memory in the socio-technical workplace is organic: participants relate spatially to elements of information and documents in various states. This allows for more contextual synthesis of information. Rather than using a generic conference room or workspace that doesn't preserve the state of where work left off, many high-output teams adopt a "war room" approach, where salient documents and bits of information are posted permanently for reference, or change state to reflect the team's progress.

The other unique requirement the envisioned solution offers is seamlessness in multi-teaming; or within very large teams, coordination of streams of work product. These demographic and user observations led us to conclude that an object-oriented environment that fluidly supports multi-teaming (and therefore multi-tasking) and that helps users retain context by means of object relations and a 3D interface is the best way to accommodate the complexity of needs.

3. Solution Prototype

Given these needs, we are developing a research prototype called *Miramar* to empower a higher performing workforce. *Miramar* is a graphical operating environment for 2D and 3D applications,

analogous to the Macintosh and Windows environments for 2D applications. It provides a bounded 3D landscape in which users can organize documents, relationships, and tasks. Documents in the workspace can be enhanced with notes, integrated into concept graphs, put on transparent “bulletin boards” and otherwise organized for the task at hand.

If Google™, iBoogie™, et al are ways to *find* information, Miramar is a place to keep and organize it into context. Each Miramar workspace represents a contextual work unit such as a project; users can switch between them as a means for switching work contexts. 3D scenery “themes” help create a sense of identifiable space for each workspace.

The initial implementation of Miramar was a single-user “3D desktop” environment, designed as an expressive information workspace and application environment. During this phase, the presentation, manipulation, and navigation models were developed and refined through a succession of prototypes and user testing [9].

3.1 Global Collaboration in Miramar

Now, in the latest version of Miramar, “Miramar 2.0”, workspaces may be shared with others, effectively shifting the paradigm from “3D desktop” to “virtual project room,” where a team can share contextualized information simply by putting it in the workspace.

Unique collaboration characteristics [10] of Miramar 2.0 include the ability to see all “my” multi-team activities in one place, work without time and location boundaries, interact expressively with remote team members, and move effortlessly among business applications and team spaces. Usage scenarios include meeting in real time across space; knowing who is participating and their location and local time of day; working asynchronously on a shared document or project tasks while tracking progress; coordinating responsibilities across projects and meetings; and managing diverse tasks.

3.2 Expressive Interaction with Remote Team

Electronic Person [10] is our early mechanism for bringing more expression into the virtual collaboration environment, helping people to get to know each other better, and increasing social interaction and cultural awareness among team members who are not co-

located. Electronic Person bundles information about what individuals choose to share with others. It includes both static and dynamic profile data. For example, Electronic Person may include picture(s), location information, smart presence and availability data, a bio, a resume, an emoticon that reflects mood or emotions, and time of day. Electronic Person also serves as a launch pad to contact the associated person(s) via convenient communication channels such as instant messaging, email, soft or regular phone, and/or video.



Figure 1: Electronic Person

3.3 Game technology, but not a game

Psycho-physiological studies conducted at Stanford [11, 12] show that EEG and other physical indicators associated with attention, flow [13], and engagement increase significantly through visual and activity cues in 3D gaming scenarios. We are interested in translating these findings into a business environment, to increase stickiness, and therefore lower the threshold of usage effects for the team space. This recognizes the “play” aspect of work that are available through dialog, intellectual momentum and innovative “” that arise in co-located group settings [13].



Figure 2: Miramar 3D Collaboration Environment

3.4 Presentation, Manipulation and Navigation

In our user interface research, we often characterize interfaces, whether 2D or 3D, in terms of their presentation, manipulation, and navigation models, where the *presentation* model describes the look and layout, the *manipulation* model describes how to operate on elements, and the *navigation* model describes how to change your location or vantage point.

Let's take a look at these characteristics in Miramar:

Presentation. The Miramar workspace is a bounded 3D space, including a grid floor and decorative background scenery. (See Figure 2) Objects can be placed anywhere on the grid, but cannot be placed outside it. There is no collision detection (e.g., objects can move freely through other objects) but objects are constrained such that they are always upright and above the floor.

Below each object is the object's shadow. (See Figure 2) Unlike photo-realistic shadows, whose size and direction convey information about a directional light source, Miramar shadows were designed to convey information only about the position and orientation of the object. Regardless of any light source, Miramar shadows are always the same size as their corresponding "upright" object and are always located directly on the floor below.

The scenery and color scheme defines a Miramar workspace's *theme*. Each workspace can have a different theme, making the workspace more aesthetically pleasing and providing visual memory cues for that work context. We have witnessed *focus of loci* effects both anecdotally and during formal user tests, where users described the location of an object relative to something in the scenery (e.g., "over by the cactus").

Manipulation and Navigation. One major challenge of any 3D environment is in developing an effective model of navigation and manipulation. Early 3D environments [14, 15, 16, 17], de-emphasized navigation, choosing to have their users stay in a fixed location. We felt it important to let users move around in the space for the sense of immersion, yet wanted to avoid making them walk or fly around, as in 3D virtual worlds such as Croquet [18]. Our target audience is mainstream corporate users, so we could not count on "goggles and gloves" or other special input device –

not even a joystick; we had to create a navigation & manipulation model that used only the keyboard and mouse and did not require the user to walk / fly / drive around the workspace to access their information. To accomplish this, we created a gestural navigation model: to navigate to an object, you simply click on an object to select it, then hit the keyboard spacebar to "Get a good look at *object*," which smoothly animates you (actually your 3D "camera") to the selected object's optimal vantage point, as defined by the object. The camera animates smoothly to the destination, with slow-in and slow-out rate control, as in cinema photography.

In Miramar, the navigation and manipulation models go hand in hand, almost literally: navigational gestures are interpreted according to the current selection, which is part of manipulation. This applies both to coarse-grained motion, such as "Get a good look at *object*") and fine-grained motion, such as zoom in/out (which moves your camera closer to/farther from the object) and dolly left/right (moves to the left/right in an "orbit" arc, while keeping the camera looking directly at the selected object).

Size Matters. As mentioned above, the size and characteristics of the 3D workspace in Miramar were chosen to make it impossible for the user to become lost or disoriented, and constrained to keep objects and users right-side up. We also added two other features to keep users feeling "safe": a "Home" key and an "Overhead view" key.



Figure 3: Navigation and Safety Keys

At any time you can hit the Home key to return to a neutral, "safe" position (See Figure 3) or hit the End key to go to a bird's-eye overhead view (See Figure 4). Pressing the end button a second time returns you to

your previous position. Note that the size of the workspace grid fits perfectly within the viewport while the user is in the overview position.



Figure 4: Birds Eye View

3.5 General Capabilities

Within the workspace, Miramar is an environment for 3D application and information objects, providing the following services:

The 3D equivalent of a “window manager,” giving the user control over the space and actions for positioning, sizing, and rotating objects.

Operating environment services for rendering, animation, interaction, and storage, as well as services to install & register applications, manage user preferences, and control debug trace output.

Integration of 2D applications and documents. While everything within the 3D workspace is, of course, 3D, it was important for us to support legacy 2D documents and applications. To do this, we created a new window button, the so-called “send-back” button (Figure 5, which appears on the top-level windows of applications that Miramar understands via an extensible set of “conduits”).



Figure 5: Send-back Button

When the user pushes the send-back button, a 3D object is created that mimics the 2D window in 3D: the window appears to melt back into the 3D scene (See Figure 6).

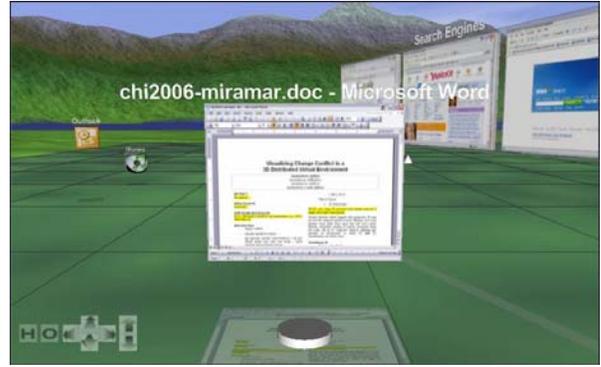


Figure 6: 2D Object represented in 3D

Double-clicking this 3D object reverses the process: the object is smoothly animates forward, and is overlaid with the original Windows window. Thus, the user gets the full benefit of organizing legacy application documents in the 3D workspace, while retaining the full capabilities and performance of the native Windows application.

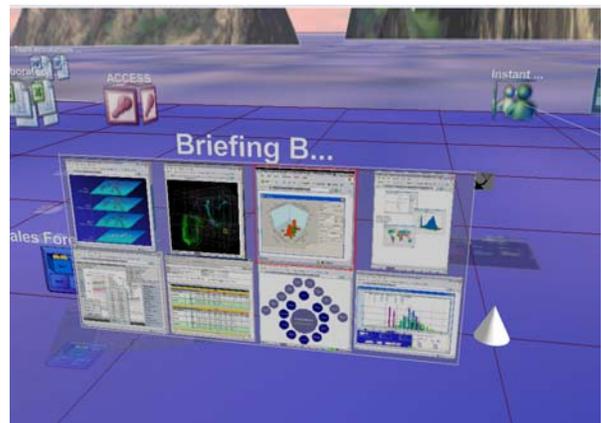


Figure 7: Bulletin board organizes objects

Organization tools. The Miramar “Bulletin Board” is a container, (See Figure 7) organizing documents and objects onto a transparent grid, which can be resized or “rolled up” to take less space. Bulletin Boards and other visualization objects enable Miramar workspaces to scale up to thousands of objects.

Object Linking. A Miramar link (See Figure 8) represents a relationship between two objects. Interestingly, the original Miramar prototype was built on top of a strongly-typed object database, and as such, Miramar links were strongly-typed and directional.

While this was useful for constructing a formal knowledge-base, users wanted a simpler mechanism for linking objects in the workspace. Now links can convey a casual, optionally named relationship between two objects, and are also useful as navigation aids: brushing on a link displays the name of the object on the other end of the link (especially helpful when that object is out of view) and an arrow control; clicking the arrow navigates you to the object at the other end of the link.

As an additional capability that in time could be incorporated into this environment we are piloting TaskTracer, a software tool developed at Oregon State University's Electrical Engineering & Computer Science's Machine Learning group. TaskTracer has shown us that pretty much it is "elephants all the way down" in the sense that not only are people on multiple teams, doing multiple tasks, but that that "tasks" are not so easily identified with an application. Rather, they span multiple applications. The result on the display of a normal multi-tasking individual is an inordinate number of clicks, window switches, searches in different domains, all of which make the average information worker into an information Houdini as part of getting the daily job done! [19]. Factoring in the number of projects Intel employees tend to be on [1, 2, 3], an exponential set of possible linkages and organizational overhead appear. Object linking becomes not just convenient but essential in this context. In other words, the employee desperately needs the kind of pattern creation and information linkage that the proposed environment offers, but has learned to put up with a huge amount of "bricolage" or "pasting up" as part of their tacit skill set [20].

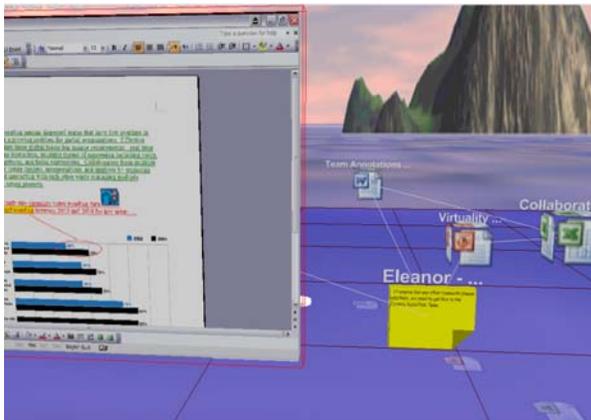


Figure 8: Object Links, Annotations and Metadata

Object annotations and other metadata. Every object can have text notes and other metadata associated with it as name/value attribute pairs since objects in the scene really are first-class objects, complete with interfaces that enable programs and scripts to operate on them.

3.6 Going Multi-user

Transforming Miramar from a single-user environment to a multi-user environment required significant changes to the Miramar storage model, the development of a wire protocol, the addition of presence information and communication between users, and change-conflict resolution mechanisms. Taken together, they transform Miramar into a distributed virtual collaboration operating environment – like a massively multi-player game, but for doing work. Users may work from many different workspaces, hosted on any number of machines, including their own. They may choose to make their workspaces open to others or private to themselves.

Architecturally, Miramar 2.0 is peer-to-peer, with workspace data fully distributed among the participating user's machines. For each workspace there is a host machine that is a "master" but the software on all machines is the same; any machine can host a workspace without installing server software.

The one place that a "server" is required: the versioned-document repositories. Documents added to a workspace are versioned in an off-the-shelf version control system. Currently we're using Subversion, but most any equivalent system would do. Keeping documents in a global repository makes them accessible to non-Miramar users and makes it possible to reference the exact same document from multiple Miramar workspaces.

Managing change conflict. Miramar works both online and offline. When offline, you have full access to your documents, and you can still add documents to the workspace, move and link objects, etc. When you are back online, the changes are merged. If others have made conflicting changes, you can see the conflicts and choose how to resolve them.

Currently we're investigating ways to visually communicate these conflicts and let users resolve them. Figure 9 shows a "stretchy" between two conflicting positions of the same document object. They may resolve the conflict by accepting one or the other position, or both, if that's appropriate.

Preliminary user testing indicates promise for this type of approach when the number of conflicts is small and the delta between the conflicts is sufficient to see the “stretchy” between the two positions. The stretchy method was also more favorable for the synchronous case, where it gave immediate feedback about two users trying to move the same object at the same time.

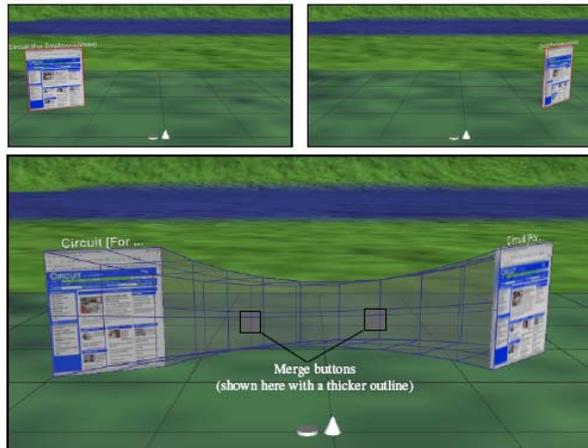


Figure 9: Visual Feedback in Miramar

In the asynchronous case (e.g., offline/online resynchronization) users needed more control over what conflicts were visible. This difference is likely due to the fact that, when a user comes online; all changes are synchronized at once. Due to the length of time and number of changes made before synchronization, the number of conflicts that appear simultaneously is far greater than in the synchronous case.

4. Conclusion

Changes in the global business environment are apparent in many dimensions. They are regularly reported and analyzed in the business press. Our own study of Intel employees confirms the generalizations found in the marketplace and gives us an idea of how Intel is trending in terms of distributed teaming. We have described an approach for understanding the organizational situation, and have responded to it as information technology researchers and designers. We now have a strong concept of the desired user experience. We have identified social and technical factors involved in remote teaming, and defined core team collaboration processes.

Since interactions that people previously conducted face to face happen increasingly over the network, it is

critical that collaboration tools maintain context and interactivity to promote fluid and sustained communication. This requires interoperability of tools, architecture, and processes as well as new capabilities never imagined when collaboration applications were first invented.

Our architecture provides the foundation for global team collaboration processes and capabilities that integrate with business applications.

Establishing enterprise-scale core collaboration solutions that allow some customization into specific business process contexts increases the value of information technology to the business.

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