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Virtual Laboratories and Virtual Worlds

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Abstract. Since we cannot put stars in a laboratory, astrophysicists had to wait till the invention of computers before becoming laboratory scientists. For half a century now, we have been conducting experiments in our virtual laboratories. However, we ourselves have remained behind the keyboard, with the screen of the monitor separating us from the world we are simulating. Recently, 3D on-line technology, developed first for games but now deployed in virtual worlds like Second Life, is beginning to make it possible for astrophysicists to enter their virtual labs themselves, in virtual form as avatars. This has several advantages, from new possibilities to explore the results of the simulations to a shared presence in a virtual lab with remote collaborators on different continents. I will report my experiences with the use of Qwaq Forums, a virtual world developed by a new company (see http://www.qwaq.com).

Keywords. sociology of astronomy, methods: numerical, methods: laboratory

1. Introduction

A year ago, I was vaguely familiar with the notion of virtual worlds. I had read some newspaper articles about Second Life,† which seemed mildly interesting, but I had no clear idea about what it would be like to enter such a world. All that changed when I was invited to give a popular talk on astronomy, in Videoranch‡, another much smaller virtual world. I realized how different this type of medium of communication is from anything I had tried before, whether telephone or email or instant messaging or shared screens. There was a sense of presence together with others that was far more powerful and engaging than I had expected. I quickly realized the great potential of these worlds for remote collaboration on research projects.

Since then, I have explored several virtual environments, with the aim of using them as collaboration tools in astrophysics as well as in some interdisciplinary projects in which I play a leading role. By and large my experiences have been encouraging, and I expect these virtual worlds to become the medium of choice for remote collaboration in due time, eventually removing the need for most, but not all, long-distance travel. The main question seems to be not so much whether, but rather when this will happen. My tentative guess would be five to ten years from now, but I may be wrong: the technology is evolving rapidly, and things may change even sooner.

In any case, I predict that ten years from now we will wonder how life was before our use of virtual worlds, just like we are now wondering about life before the world wide web, and the way we were wondering ten years ago about life before email.

2. What is a Virtual World

Twenty years ago, there was a lot of hype about virtual reality, with demonstrations of people wearing goggles for three-dimensional vision and gloves that gave a sense of

† http://secondlife.com
‡ http://www.videoranch.com

touch. These applications have been slow to find their way into the main stream, partly because of technical difficulties, partly because it is neither convenient nor cheap to have to wear all that extra gear.

In contrast, a very different form of virtual reality has rapidly attracted millions of people: game-based technology developed for ordinary computers, without any need for special equipment. About ten years ago, on-line 3D games, shared by many users, made their debut. In such a game, each player is represented by a simple animated figure, called an avatar, that the player can move around through the three-dimensional world. What appears on the screen is a view of the virtual world as seen through the eyes of your avatar, or as seen from a point of view several feet behind and a bit above your avatar, as you prefer.

In this way, a virtual world is a form of interactive animation movie, in which each participant plays one of the characters. Currently, many millions of players take part in these games, the most popular of which is World of Warcraft†. In addition, other virtual worlds have sprouted up that have nothing to do with games, or with killing dragons or other characters. Players enter these worlds for social reasons, to meet people to communicate with, or to find entertainment of various forms. Currently the most popular one is Second Life (SL).

A lot has been written about SL, as a quick Google search will show you. Businesses have branches in SL, various universities including Harvard and MIT have taught classes, and political parties in the French elections earlier this year have been represented there. SL has its own currency, the Linden dollar, convertible into real dollars through a fluctuating exchange rate, as if it were a foreign currency. In many ways, SL functions like a nation with its own economic, social and political structure.

3. Virtual Spaces as Information Tools

The world wide web has revolutionized global exchange of information. The notion of global connectivity has been novel, but the arrangement of content has not proceeded much beyond that of the printed press, with an element of tv or movies added. The dominant model is a bunch of loose-leaved pages, which are connected through a tree of pointers, allowing the user to travel in an abstract way through the information structure. As a result, it is often difficult to retrace your steps, to remember where you've been, or to take in the whole layout of a site.

In contrast to the abstract nature of the two-dimensional web, virtual worlds offer a very concrete three-dimensional information structure, modeled after the real world. While these worlds are virtual in being made up out of pixels on a screen, the experience of the users in navigating through such a world is very concrete. Virtual worlds call upon our abilities of perception and locomotion in the same way as the real world does. This means that we do not need a manual to interpret a three-dimensional information structure modeled on the world around us: our whole nervous system has evolved precisely to interact with such a three-dimensional environment.

Remembering where you have seen something, storing information in a particular location, getting an overview of a situation, all those functions are far more natural in a 3D environment than in an abstract 2D tree of web pages. One might argue that the technological evolution of computers, beyond being simply 'computing devices', has moved in this direction from the beginning. The only reason that it has taken so long is the large demand on information processing needed to match our sensory input.

† http://www.worldofwarcraft.com

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Fortunately, the steady increase in processing power of personal computers is now beginning to make it possible for everyone to be embedded in a virtual world, whenever they choose to do so, from the comfort of their own home or office. As long as you have a relatively new computer with a good graphics card and broadband internet access, there are many virtual worlds waiting for you to explore. Some of them, like Second Life, offer a free entry-level membership, only requiring payment when you upgrade to more advanced levels of activity. Getting started only requires you to download the client program to your own computer; after only several minutes you are then ready to enter and survey that virtual world.

4. Virtual Spaces as Collaboration Tools

Email and telephone have given us the means to collaborate with colleagues anywhere on earth, in a near-instantaneous way. Yet both of them have severe limitations, compared to face-to-face meetings. In neither medium can you simply point to a graph as an illustration of a point you want to make, nor can you use a blackboard to scribble some equations or sketch a diagram. Three new types of tools have appeared that attempt to remedy these shortcomings.

One approach is to use video conferencing. Each person can see one or more others, in a video window on his or her own computer. While this gives more of a sense of immediate contact, compared to a voice-only teleconference call, it is not easy to use this type of communication to share any but the simplest types of documents.

Another approach has been to give each participant within an on-line collaboration access to a window on his or her computer that is shared between all of them. Whatever one person types will be visible by all others, and in many cases everybody is connected through voice as well, as in a conference call.

The third approach, the use of a virtual world, not only combines some of the advantages of both, it also adds extra features. Unlike a video conference, where participants have rather limited freedom of movement, virtual worlds offer the possibility of exploring the whole space. And in some worlds at least, everybody present in a room can gather in front of a shared screen that is embedded in the virtual world, in order to discuss its contents.

5. Qwaq Forums

After exploring a few different virtual worlds, I settled on Qwaq† as the company of choice for my initial experiment in using virtual spaces as collaboration tools. Qwaq is a new start-up company that provides the user with ready-made virtual offices and other rooms, called *forums*. There you can easily put up the contents of various files on wall panels. Whether they are pdf files, jpeg figures, powerpoint or openoffice presentations, or even movies, you can simply drag them with your mouse from your desktop onto the Qwaq screen and position them on a wall within the virtual world shown on your screen. As soon as you do that, the file becomes visible for all other users present in the same virtual room. The rooms persist between sessions: when users later visit the same room, your files are still there to be seen.

In addition to such useful files, that can be watched and discussed by a group of users, Qwaq also allows web browsers to be opened in a wall panel. In that way, any piece of information on the web becomes instantly available for perusing by the participants in

† http://www.qwaq.com

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a Qwaq forum. This is not only convenient, it helps give the people present a sense of embedding and actual presence in the room, given that their whole discussion takes place in the same virtual space, without a need to jump out of Qwaq into other applications. And watching movies together, avatars can even enjoy meta-virtual presentations within their virtual environments!

One of the most interesting features is the presence of blackboards and editors in wall panels. In this way, users can illustrate their discussions with drawings and they can type their main points directly into a file that can be jointly edited by those present. Later, each user can easily download a copy of that file onto their own computer.

Almost all of our discussions are held through direct voice communication. While there is an option for text chatting, the advantage of using a headset with a microphone to directly talk to each other is so large that we hardly ever use text. The main exception is to exchange a few words while someone is giving a lecture, in order not to interrupt the speaker, or to ask a question to the speaker which can then be answered in due time.

The underlying software environment used in Qwaq is Croquet, derived from Squeak, a language based originally on Smalltalk. Unlike the more traditional server-centered virtual world architectures, Croquet is based on peer-to-peer communication, with potentially far better scaling properties. Alan Kay, a pioneer of the 2-D windowing system for personal computers, was the primary visionary behind the Croquet system, which now has accrued a thriving community of open source contributors.

6. Two Experiments

After I learned about Qwaq, at the MediaX† conference at Stanford in April 2007, I started two independent experiments by launching two independent initiatives, or in Qwaq terminology, two 'organizations'. The first Qwaq organization, later called MICA, was aimed at my astrophysics colleagues. The second organization, called WoK Forums, was aimed at a widely interdisciplinary group of scholars.

† http://mediax.stanford.edu/

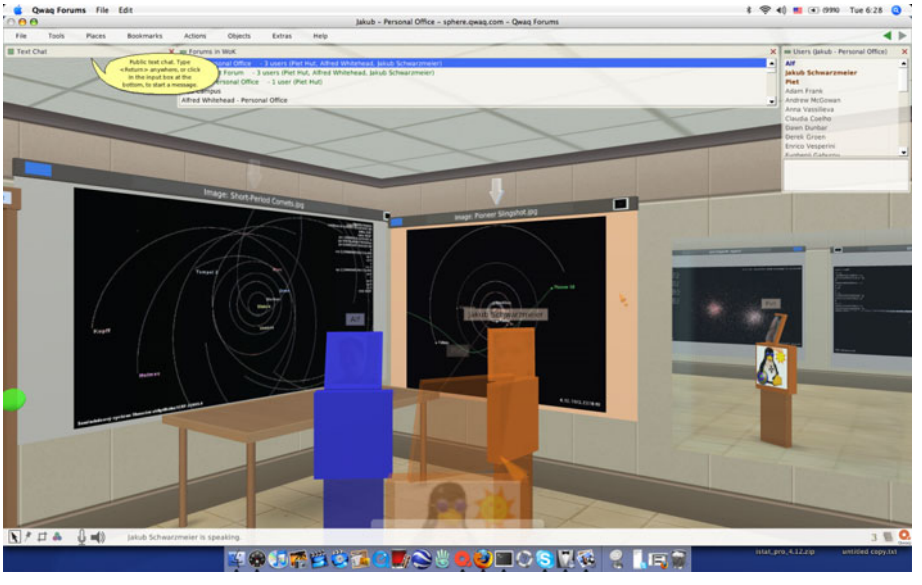

Figure 1. An early MICA meeting.

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6.1. *MICA*

MICA stands for Meta-Institute for Computational Astrophysics, with *meta* derived from the term *metaverse* which is sometimes used to describe virtual worlds. During a couple months in the summer of 2007, we started to explore the use of Qwaq Forums. One function was to simply provide a meeting place for people to talk informally, a place that can play a role similar to that of a drinking fountain or a tea room in an academic department. Other activities were the organization of seminars and meetings focused on particular topics of research.

An example of the latter was the MUSE initiative, which stands for MUlti-scale MUlti-physics Scientific Environment for simulating dense stellar systems. During the MODEST-7a† meeting in Split, Croatia, all participants of the workshop were given an account in MICA, to give them a chance to follow up their discussions and collaborations after the end of the workshop.

6.2. *WoK Forums*

WoK stands for Ways of Knowing‡, a broadly interdisciplinary initiative that was started in 2006, with the aim of comparing the scientific approach to knowledge with other approaches such as those of art, spirituality, philosophy and every-day life. For half a year now, starting in the spring of 2007, we have had daily meetings in WoK Forums, with many in-depth discussions about notions such a using your own life as a lab.

Figure 2. A recent WoK Forums meeting.

Currently we have about two dozen active participants, mostly from Europe and North America, attending on average one or more meetings a week. They range from leading figures in fields such as cognitive science, psychology, medicine, physics and finance, to graduate students and postdocs as well as independent scholars and other professionals.

† http://www.manybody.org/modest.html
‡ http://www.waysofknowing.net

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7. A Tale of Three Surprises

When I started the two Qwaq organizations, MICA and WoK Forums, in May 2007, I did not know what to expect in any detail, given the novelty of the medium of virtual worlds as a collaborative tool for academic investigations. However, I had some rough picture of what I thought was likely to happen:

- a quick start for my astronomy group, a slow start for my interdisciplinary group;
- virtual worlds as a way to facilitate existing collaborations;
- an emphasis on using tools: web browsers, 3D objects, etc.

To my great surprise, all three expectations turned out to be wrong. What happened instead was:

- my interdisciplinary group took off right away;
- I found myself and others creating new collaborations;
- 3D presence was far more important than specific tools.

7.1. *First surprise*

I had expected that the computational astronomers whom I had invited to MICA would quickly take to the new environment. After all, most of them had many years of experience working with rather advanced computer tools, and many had designed and written their own code and toolboxes. In contrast, many of the broadly interdisciplinary researchers that I had gathered were not particularly computer savvy. I was wondering whether they would have any interest at all in getting into a new kind of product that they first would have to download, and then would have to learn to navigate in.

I was wrong on both counts. The latter group showed an immediate interest. Even though I had started slowly with weekly meetings, there was strong interest in more frequent gatherings, and soon we began to meet on a daily basis. In contrast, the former group, for whom I had started off with a daily 'astro tea time' showed little interest initially, and most meetings found me being in the tea room all by myself.

It took a while before it dawned upon me what was happening. The main reason was that widely interdisciplinary activities do not have any traditional infrastructure, in terms of journals, workshops, societies and other channels to fall back on. Those people interested in transcending the borders of their own discipline, not only into the immediately adjacent discipline but into a range of other disciplines, have very little to lean on. By offering a forum for discussions, I was effectively creating an oasis in a desert, attracting many thirsty fellow travelers.

In contrast, many of my astrophysics colleagues complain that nowadays there are already too many meetings and joint activities, and that it has become increasingly harder to find time to sit down and do one's own original research, amidst the continuing barrage of email, faxes, and cell phone conversations. For them I had created yet one more fountain in a fountain-filled park.

However, once my astro colleagues started to trickle in, many of them did find the new venue to be of great interest. And I had a trick to increase the trickle: threatening to close MICA sufficed to catch people's attention, and to increase attendance. Switching from the initial daily meetings to weekly meetings also helped considerably. Having a dozen people in a room discussing the latest news in computational astrophysics clearly is a lot more fun that being by yourself or with just one other random person during a daily tea time.

Meanwhile, the daily WoK Forums meetings continue to attract between half a dozen to a dozen participants on a daily basis, and the attendance continues to grow.

7.2. *Second surprise*

I had expected to kick start my virtual world activities by bringing in existing teams of collaborators, offering them the chance to continue what they were doing already, but in a new medium. Perhaps this new approach would later attract other individuals, who might be interested in joining or in starting their own projects, but that was not my initial objective.

Rarely in my life have I so completely misjudged a situation. Getting an existing group to make the transition to a totally new mode of communication turned out to be effectively impossible. Trying to change given ways of doing things provoked far more resistance than I had expected, in both my astrophysics and my interdisciplinary collaborations. Simply put, that just didn't work, period.

This became so obvious, very early on, that I had no choice but try a completely different tag. I went through my address book, and gathered names of people who just might have some interest in trying out a new medium, providing them with some bait, at the off chance that they might bite. I had no idea what criterion to use, in order to attract potential players, given the novelty of the new setup, so I just threw my net widely, waiting to see what would happen.

Roughly half the people I contacted did not reply. Of the half that did reply, roughly half told me that it all sounded fascinating but that they had no time in the foreseeable future to engage in new fun and games. Of the people who did want to give it a try, more than half quickly got discouraged after trying once or twice, and not getting immediate gratification one way or another. But many of those who remained at the end of this severe selection process were wildly enthusiastic, considering themselves to be pioneers in a whole new world.

Even in retrospect, I could never have predicted whom of my colleagues would fall in the ten percent group of early adopters. I still do not see any clear pattern or set of characteristics separating those who rushed in right away from those choosing to remain sitting on the fence. Many of those of whom I had been convinced that they would embrace virtual worlds did not, and quite a few whom I had contacted without much expectation turned out to jump in right away. In fact, for some of the early players I had not anticipated their interest at all. I had contacted them mainly so as not to make them feel left out when they would hear that I had contacted their seemingly more promising friends!

Given this randomly hit-or-miss way of collecting early players, any notion of starting with existing teams rapidly went out the window. What I wound up with was a bunch of enthusiastic tourists, eager to look around in the new virtual world that opened up unexpected horizons, with doing any kind of real work seemingly far from their mind. They were lured into a new adventure, with new toys.

After a while, though, many of the tourists began to settle down, and they started to behave more like neighbors. They began to get to know each other, although many of them had never met in real life. Among the MICA participants, there were some old hands in computational astrophysics, but there also was a freshly minted PhD in the field of education, Jakub Schwarzmeier† from Pilsen, in the Czech Republic, who happened to have written some astrophysical simulations as part of his educational research. The MICA snapshot above shows the room that Jakub created, with me visiting him together with Alf Whitehead who is a graduate student in astrophysics in a remote study course in Australia while making a living as a manager of a team of Ruby programmers in Toronto. Both Jakub and Alf had independently contacted me by email, without having

† http://home.zcu.cz/˜schwarz1/index.html

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met me in person, less than half a year before I started MICA, offering their help with my ACS‡ project, so it was natural to invite them into MICA.

Finally, some of the tourists that had turned into neighbors finally began to turn into collaborators. Seeing each other regularly, and becoming familiar with each others' interests, they began to spawn new ideas, some of which led to new projects, with little connection to the original motivation for them to enter the virtual world where they had met. This has happened repeatedly in my interdisciplinary organization, even though there the discrepancy between people's background and interests was the largest. In my astrophysics organization, the first mile stone was reached when Evghenii Gaburov and James Lombardi started to write a paper together within MICA, Evghenii in Amsterdam, Holland, and Jamie in Meadville, Pennsylvania, USA, which led to a preprint in July 2007 (Gaburov *et al.* 2007). As far as I know, this is the first astrophysics paper that has an explicit acknowledgment to a virtual world as the medium in which it was created.

7.3. *Third surprise*

I had expected that the main attraction of a virtual world would surely be the lure of toys: being able to design and build 3D objects, to use web browsers in-world, to travel through output of simulations, all that good stuff. The Qwaq software designers had already put an attractive example of a simulation output in their world, in the form of a simple model of an NaCl crystal. I had expected my fellow astronomers to quickly come in with their galaxy models, following in the footsteps of the Qwaq folks.

I also had thought they would quickly start playing directly with the software offered by Qwaq. In addition to existing applications, Qwaq offers possibilities for scripting new ones, using Python, and the underlying Croquet offers even more ways to get into the nuts and bolts of the whole setup. I had expected my colleagues, especially students with more time on their hands, to come in to play like kids in a candy store.

Once more I was wrong. In a place full of toys, it was the place itself, not the collection of toys, that formed a magnet. The main attraction for coming into Qwaq Forums was presence. Presence in a persistent space, a watering hole that quickly became a familiar meeting ground, this is what was felt to be the single most important aspect of the whole enterprise. Everything else was clearly secondary.

It goes back to the difference between the abstract nature of the two-dimensional world wide web, versus the concrete sense of 'being there' that we get when we enter a virtual world. Hundreds of millions of years of evolution of our nervous system, in all its perceptive, motor, and processing aspects, have prepared us for being at home in a three-dimensional life-like spatial environment.

Sharing such an environment with others turned out to be a factor that was far more important than I could have guessed. I, too, was amazed to experience the difference between a meeting in MICA or WoK Forums, on the one hand, and being part of a traditional phone conference with the same number of individuals, on the other. Teleconference calls are among the least pleasant chores to be part of, in my work. It is not always clear who is talking, there is often little real engagement, and the whole thing just feels uninspired, leading the participants to doodling or reading their email or being otherwise distracted.

In contrast, a meeting of half an hour in a virtual world feels totally different. There is a palpable sense of presence. You can see where everybody is located, people can move around and gather in front of a blackboard or poster or powerpoint presentation, and you can even hear where people are, through the stereo nature of the sound communication.

‡ http://www.ArtCompSci.org

8. Conclusion

8.1. *Lessons learned*

Of the two groups that I have invited into virtual spaces, interdisciplinary researchers were the most eager early adopters. Astrophysicists were much slower to get started, but once they were in and saw the potential of this new medium, they could quickly use the infrastructure they already had in their own field to produce new results, such as writing a preprint within a virtual space.

Individual early adopters in both groups did not come in as teams. Instead, they met whoever else was there, behaving first as tourists, then as neighbors, and only later as potential collaborators, spontaneously creating new research projects. In this way, everything that happened in virtual spaces was serendipitous; trying to get existing projects moved into virtual spaces encountered too much resistance. But even these serendipitous activities took place only after significant encouragement. To get a group of people to adapt to a new medium seems to take a considerable and ongoing amount of prodding, using whatever carrots and sticks one can find. Trying to organize any type of new activity in academia resembles the proverbial challenge of 'herding cats.'

The main attraction of meeting in a virtual space has turned out to be the shared presence in a persisting space that the participants sense and get hooked to. After a number of meetings with various stimulating conversations, the regulars want to keep coming back to the familiar setting, where they know they can meet other interesting people, old friends as well as new acquaintances. Being able to visit such a space at the click of a button is a great asset. Whether at home or at work, or briefly logged in at an airport, the virtual space is always there, and with enough participants, chances are that you will meet people whenever you log in. It can function like a tea room in an academic department, but then in a portable form, always and everywhere within reach, a curious mix of attributes.

One major obstacle that I have encountered is the fact that the earth is round. Never before have I been so conscious of the fact that we all live in different time zones. Spatial distances may drop away, when people meet in virtual spaces, but temporal zone changes don't. In my interdisciplinary group, where we have experimented for several months now with daily meetings, I was forced to introduced meetings twice every day, in order to accommodate the fact that the participants live on different continents. In addition to time zone restrictions, some participants prefer to log in from home in the evening, others from work during the day. Scheduling a weekly colloquium has been rather difficult, with some people forced to get up very early and others having to stay up till late at night.

As a result of all this, the critical mass needed to sustain a 'tea time' where enough people show up spontaneously is much larger in a virtual space than it is in an academic department. With ten people in a building, and a fixed tea time at 3 pm, chances are that at least five people show up at any given tea. With twice-daily meetings in a virtual space, and many participants showing up only once a week, you need more like a hundred people in total, to guarantee the presence of five people per meeting. And if the attendance often falls below five, there may not be enough diversity to attract regular attendance.

Trying to organize people to attend events in a virtual space has something in common both with running a department and with organizing a workshop. Like the former, it requires persistent management, unlike putting together a workshop that is a one-shot event. And even though it is much easier to establish a virtual space, compared to getting the funding and spending the time to build a physical building, it is also easy to underestimate the time it takes to establish an attractive infrastructure. Try to image what it would be like to run a never-ending workshop, and you get the idea.

In the short run, there is no ideal solution to the management problem. Trying to run things purely by committee is unlikely to work, nor will it be easy to find a single individual willing to do the brunt of the work needed to set up and maintain the infrastructure of a purely virtual organization for academic research. Progress is likely to come from some kind of middle ground, with a small core group of enthusiasts willing to spend significant amounts of time getting things going, in a typical 'open source' kind of atmosphere, setting the tone by their personal example.

8.2. *Next steps*

So far, the two organizations that I have founded, MICA and WoK Forums, are still very much in their initial phase where people are getting to know each other and are getting to know the virtual environment and its possibilities. What will happen next is difficult to predict. As always in a new medium, the most interesting developments will be those that nobody expected. Even so, there are a few obvious next steps.

One thing-to-do is to create some form of library or archive, containing a chronicle of what has happened in a given virtual space. After people give lectures, it will be good to keep at least their powerpoint presentations. When people hold discussions, it would be great to catch their conclusions in a type of wiki or other structure for text that is easy to enter. It would be great if a whole session in a virtual space could be captured on video, and stored for later viewing within a room in that same virtual space.

For computational science applications, such as large-scale simulations in astrophysics, virtual spaces can be at the same time places for people to meet, and places where those people can run their experiments. With individuals represented as avatars, it is natural for them to enter virtual laboratories where they are running their simulations. Instead of the scientist sitting in front of the computer and the simulation taking place at the other side of the screen, there are many advantages in letting the scientist enter the screen and the simulated world directly. By traveling through a simulation, one can become much more intimately familiar with the details of a simulation.

Finally, here is one more intriguing possibility. If researchers who are geographically remote start writing code together within a virtual space, we can literally capture all that is said and done while writing the code. By keeping the full digital record of a coding session, and indexing it to the lines of code that were written during that session, future users of that code will always have the option to travel back in time to get full disclosure of all that happened during the writing. Many of us, struggling with legacy code that was written decades ago, would be happy to give a minor fortune for the possibility of making such a trip back in time. This approach to massively overwhelming documentation is in the spirit of what Jun Makino and I have suggested on our Art of Computational Science website†, as a move from *open source* to *open knowledge* (Hut 2007).

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† http://www.ArtCompSci.org