providing the self-discipline workplace to let people fulfill the team goals. The bottom line: it's about people doing meaningful work, giving them a meaningful life, which is a great life. What is a great life? It is a life of great satisfaction, achievement, and striving toward excellence—making a difference.

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GELERNTER, DAVID, *Mirror Worlds: Or the Day Software Puts the Universe in a Shoebox: How It Will Happen and What It Will Mean* (New York, NY: Oxford University Press, 1992, ISBN: 0-19-507906-X, $17.95).

Mirror Worlds is based on a bold assertion: "You will look into a computer screen and see reality." Unfortunately, information systems and computer science writings often are loaded with bold assertions, many of which are untrue. This leads us to ask:

- What are mirror worlds?
- How are mirror worlds built?
- How do mirror worlds help us see the "whole"?
- What data are used for mirror worlds?
- Can mirror worlds exist?
- What is the role of mirror worlds in IS teaching and research?

What Are Mirror Worlds?

Gelernter (p. 3) defines mirror worlds as "software models of some chunk of reality, some piece of the real world going on outside your window. Oceans of information pour endlessly into the model ... so much information that the model can mimic reality's every move ..." A mirror world traps the mirror image of an organization or group of organizations in a computer model, embedded in a model of the organization's environment.

In some cases, a mirror world captures the "right now" state of a project or organization: What is going on inside the organization at this point in time? Since it contains a model of the organization, a mirror world can also to simulate the organization under certain environmental conditions.

How Are Mirror Worlds Built?

Gelernter (p. 28) indicates that there are five key ingredients in the development of a mirror world: a deep picture, a live picture, agents, history, and the knitting together of the other four ingredients. *Deep (and layered) pictures* indicate that the mirror world has many levels, into or out of which the user can zoom. Typically this means "drill" down capabilities from one level to another, much in the same way Microsoft Excel® "Pivot Tables" allow the user to drill down on a set of organization accounting numbers, by year, by region, etc. Mirror worlds capture dynamic aspects of organizations. *Live pictures*, based on current sensor data, show the user what is going on in real time, right now, and how the world is changing over time. Computer *agents* represent agents or actors in the real world. Typically, agents are intelligent. However, their behavior can be based on simple rules, such as "process first-in, first-out." Mirror worlds also include a history of the organization. History can include past data gathered about the organization. However, Gelernter also notes that case-based reasoning or "finding precedents" from the organization's past can also be used as part of the modeling. But perhaps the most important is how these four ingredients are knitted together. Mirror worlds are based on knowing individual agent behavior, but without knowing exactly what organizational behavior will emerge from the interaction of those independent agents. As a result, mirror worlds have "emergent" behavior based on the interaction between semi-autonomous

agents. Knitting the ingredients together consists of having a program or set of programs that has agents interacting with each other, while using contemporary data feeds from ongoing organizational processes. Deep and live pictures give us different views of the model.

How Do Mirror Worlds Help Us See the "Whole"?

Managers cannot make sound decisions unless they view their organizations in their larger environment, but too often they are caught with an ant's view of the world. Gelernter (p. 30) notes, "Mirror worlds are devices for showing you the big picture." Mirror worlds attempt to capture the "whole thing." Too often people get stuck with an ant's view—"damned likely to get stepped on" (p. 31). Mirror worlds facilitate "top-sight" or "whole-sightedness" since they provide deep, multilayer pictures, and capture the emergent behavior of a set of interacting software agents. Top-sightedness "comes from a far overhead vantage point, from a bird's eye view that reveals the 'whole'..."(p. 52).

What Data Are Used for Mirror Worlds?

A wide range of sensors can gather data. In commerce, much sensor data are likely based on financial data. Data available in real time can facilitate mirror-world modeling to study the organization's situation, and to potentially provide an executive's dashboard for what is going on in the organization. As a result, data from electronic data interchange, web pages, or other electronic exchanges could provide input to a mirror world. Accounting data, generated on a daily basis, also could provide key inputs into a mirror world.

Can Such Mirror Worlds Exist?

Jump ahead ten years and see if Gelernter was on target. Research at the Santa Fe Institute and Los Alamos National Laboratory has generated a number of start-up companies doing work in complex adaptive systems theory, building what Gelernter might call "mirror worlds." Melymuka (2002) reports "companies are beginning to use complex adaptive systems to plot future business scenarios." Melymuka describes Procter & Gamble's (P&G) use of mirror worlds. P&G built a model of its supply chain in order to address questions such as "What if supermarkets and other customers shared information about planned product promotions that might change their supply needs?" Using this model and asking key questions has led to the realization of millions of dollars of potential savings.

Jump one more year and Anthes (2003) also reports on P&G's use of mirror worlds. Procter & Gamble reports saving $300 million annually because of its ability to transform its supply chain. In addition, reportedly, SAP, the large enterprise resource planning software firm, whose software is used by P&G, is now experimenting with using mirror-world-type capabilities. Now prototype mirror-world-like capabilities apparently are being built into SAP's supply chain software to meet the needs of P&G and other advanced supply chain firms.

Further, Anthes (2003) provides a glimpse of P&G's supply chain of the future, based on the mirror world. In that vision, in the year 2008, end-to-end replenishment of a box of Tide® laundry detergent drops from the current four months to one day. As part of the new world, a world of intelligent agents interact with each other. Flexi-plants replace specialized production plants; software agents watch weather for its impact on transportation problems; software agents bid for materials and production runs; agents at retailers guide shipments to those whose inventory is low; software agents capture information about sales at customer locations and analyze the data; and smart shelves tell retailers when to retrieve more product from the back room.

What Is the Role of Mirror Worlds in IS Teaching and Research?

Much of the discipline of information systems concerns processes and flows of information, often referred to as "best practices." Mirror worlds provide a way to generate and test best practices

at P&G. Mirror worlds today generate the best practices that will be taught tomorrow. Mirror worlds anticipate the systems and best practices of tomorrow. When we are studying supply chain best practices, I have found that it is useful to review the current best practices associated with P&G's supply chain (Clark and McKenney 1995), and then review how those best practices are likely to change.

Mirror worlds are likely to be categorized as "computer science," "intelligent agents," "artificial intelligence," or "knowledge management," each with good reason. As a result, research in mirror worlds is likely to come from those academic disciplines. Computer science is likely to examine architectural and design issues such as deep, multilayer pictures of the organization. Intelligent agent researchers examining the use of intelligent agents in such systems are likely to examine issues such as how different intelligent agents impact the system differently. Artificial intelligence researchers are likely to examine alternative representations to, or approaches for, representing agent intelligence. Knowledge management researchers could analyze knowledge representations or use of knowledge. Other research could investigate issues associated with building mirror worlds, such as understanding emergent behavior of such systems, understanding the role of accounting generated history in mirror worlds, or validating and auditing such models.

But in the same sense that one of the primary goals of mirror worlds is seeing the emergent whole, mirror worlds are more focused on organizations and the problems that organizations face, and they are less focused on particular technologies.

Mirror Worlds ...

Mirror worlds provide the hope of anticipating what will happen and monitoring what is happening, as it happens. Mirror worlds provide the ability to generate and test new best practices for their emergent impact.

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