The concept of outsourcing has been addressed from different vantage points by various researchers. The ACM Job Migration Task Force analyzed the impact of outsourcing on jobs [1]. This report and others examining the impact of outsourcing on employment have received significant coverage in the press. Wiederhold et al [12] look at intellectual property and tax implications when a software company operates in multiple countries.

This article takes an entirely different perspective. What are new computer-based techniques that can be employed to yield innovative solutions that can benefit both developed and developing environments? What is the long-term vision for conducting work in a global economy? Is there an end scenario for offshore outsourcing?

In order to make predictions about the long-term implications of the information revolution, let us look at the impact of the industrial revolution. When machines were first developed, they were scarce and costly; accordingly, the owners to utilize them on a round-the-clock basis, and employees were directed to work extended hours: 14 hours or even longer! When governments stepped in to create laws restricting the maximum number of hours worked each day, companies gradually responded by implementing a
three-shift system. The concept of shifts suited many categories of tasks, and was inappropriate for other categories. Agricultural implements and military goods could be produced quicker and at lower costs. But the shift concept was incompatible with activities related to many types of fine arts. If three artists worked in succession for 8 hours each on the same painting, then the master painter may consider the product to be worthless.

Raman Roy, an outsourcing pioneer, observes: “Distances have become meaningless now; geography has become history.” Today, we can transfer knowledge-based tasks to colleagues located in other continents on an instantaneous basis and at virtually zero costs, enabling them to continue the task on an incremental basis. In this phenomenon of “hybrid offshoring,” part of the work will be done onshore and part offshore utilizing the same notion of shifts.

**Optimized Hybrid Offshoring Model**

Consider the following scenario. A female white-collar professional works from 9 am to 5 pm in the US. At 5 pm, she transfers the incomplete task to a male colleague in Australia who works from 9 am to 5 pm based on the timing in his timezone. At 5 pm in his country, he transfers the task, as updated, to a female colleague in Poland who will do incremental improvements over the next eight-hour period, and then forward the work to the first professional in the US. When the latter comes in for work, she feels as if a magic fairy has been working for her while she was asleep!
The above distributed work scenario leverages both spatial and temporal separations by involving persons in different countries and by using the differences in time between these countries to be exploited to enable round-the-clock operation [4,5]. A similar scenario is utilized by globally distributed 24-hour call centers where incoming calls are automatically directed to the call center that is operational at the particular time. The success of such decentralized centers is made possible by several factors: voice-over-IP technology; inexpensive and widely available computer and communications infrastructure; absence of governmental restrictions on trans-border services; and the employees who help to present the appearance of a seamless company.

A call center represents structured work. At the other end of the spectrum is ill-structured work such as the types of tasks that have to be performed by President George W. Bush and other heads of states; we do not envisage the use of the proposed paradigm for such tasks. In between these two extremes, there is a growing number of semi-structured tasks where the 24-Hour Knowledge Factory holds increasing relevance. Some of these endeavors relate to the computer industry, such as management of global communications networks and design of VLSI chips. The vast majority of them relate to other industries, such as in finance, marketing, medicine, logistics, and law. Computer professionals will need to create the infrastructure to support distributed workforces, both for activities related to the computer industry as well as to other industries.
Research and Prototyping Efforts

Our research in this area commenced with a sponsored project aimed at developing new approaches that would enable quicker and cheaper development of specific satellites. We found that these satellites were being created as pieces of art, one at a time, with little knowledge being transferred from experience on one satellite to another. In order to mitigate this problem, we explored ways in which the information could be captured on an automated basis, then refined and distilled before being presented to the designer of the next satellite [10].

In the case of satellite, the designers were located at different places in the US. As such, one was attempting to transcend issues related to geographic separations. As the research progressed, we found that overcoming issues related to temporal separations could yield greater benefits. At one major US company, programmers would work for a month, and then send the code to a different group, within the US, for testing. As programming capabilities abroad became more visible, someone mooted the idea of getting the testing done in India. Eventually, the concerned persons decided to get the testing done every day, or every night, depending on how you look at it. Basically, a programmer sends the code for testing at the end of each workday. The testing is performed on the opposite side of the earth, and the results become available to the programmer at the beginning of the next workday.
The effectiveness of the endeavor can be enhanced by using multiple teams to perform different types of activities as shown in Figure 1. In this figure, the different teams work on different aspects of the same problem. A more authentic example of a 24-Hour Knowledge Factory involves the same task being handled on a successive basis by different teams around the world. In order for the work to be transferred from one collaborating center to the next, one-third of the globe away, the key challenge is to develop new techniques that will allow such transfers to occur quickly and for the new set of workers to become knowledgeable about what the preceding team did. Between

Figure 1: Time Difference is a Major Asset – Not an Impediment [10]
one set of workers relinquishing work and resuming work, two others teams have worked for 8 hours each. So, at the time of resuming work, each team needs to know in detail what happened in the intervening 16 hours; and they need to acquire this knowledge quickly!

At MIT, we developed a concept demonstration prototype, KNOWFACT (from Knowledge Factory), for sharing semi-structured knowledge [10]. In a 24-hour knowledge factory environment, stakeholders, designers and engineers are faced with the absence of traditional face-to-face interactions for discussing ongoing activities and making crucial decisions. In order to mitigate the problem, KNOWFACT was designed to calculate the utility of any proposed system change, in response to different “what…if..?” questions from the stakeholders. KNOWFACT comprises of two key modules: the Decision Rationale Module (DRM) and the Decision History Module (DHM). DRM uses web-based inputs from individual stakeholders to define the overall characteristics of the end-product or en-service, with the system details being added on an incremental basis. DHM automatically captures historical information on ongoing activities. The combination of DRM and DHM leads to an evolving knowledge repository that contains all the essential key information, including that from the most recent shift of work. DRM ensures that the opinions of individuals who are not currently at work get equitable representation as compared to individuals who are currently working, despite the temporal and spatial separations that characterize the 24-hour Knowledge Factory environment. When endeavors are repeated, individuals are provided
with comprehensive knowledge of previous efforts. This facilitates knowledge to be shared between teams working at different locations around the world.

**Figure 2: Architecture diagram for KNOWFACT system architecture [10]**

At the University of Arizona, we have developed a prototype, Multimind [2], after studying interpersonal dynamics of software development. In software engineering, the overall endeavor is broken down, on a recursive basis, into a comprehensive set of modules and classes, each of which can be ideally comprehended by a single individual. This individual can be deemed to be the “owner” of the particular module, through the process of coding, testing, and maintenance. In a 24-Hour Knowledge Factory environment, the single ownership model constitutes a performance bottleneck because work during 16 of the 24 hours of the day occurs at centers that do not possess direct, synchronous communication with the owner of the concerned module or artifact. With the conventional principle of one owner for each artifact, necessary changes must wait
until the owner's site turns on, causing time delays for related activities at the other two collaborating centers.

To mitigate the above problem of asynchronous communication delay, compounded by issues of differences in language and culture, we developed the concept of composite persona (CP); a CP appears as a single individual to the outside world, but is actually comprised of three persons, with one person at each of the collaborating sites. As each site turns on and off, the role of the CP moves from one member of the CP to the next. Different CPs handle different modules, though a one-to-one mapping between modules and CPs is not required. Each CP acts as a single entity with frequent communications between members within each CP, and less frequent communications with other CPs. The concept of the CP provides major benefits in terms of: smoother handoff between neighboring sites; increasing trust between members of these sites; accelerating the process of convergence on issues needing decisions; providing 24-hour access to other developers who may have urgent questions on the particular module; localizing lateral communication between owners of different modules; and increasing organizational resilience in terms of loss of knowledge when one member of the team resigns abruptly.

Multimind is governed by three design principles: automate everything that is possible; store everything that is possible; and provide the human operator with the key information only, with the remaining being accessible on an as-needed basis. Accordingly, Multimind stores all e-mail messages that the individual sends or reads, all web pages that the person views, and all searches that were initiated. All activities are
time stamped and logged into a comprehensive knowledge repository that evolves over the lifetime of the project. Further, the development system tracks changes at the level of semantic (parse tree), rather than naïve text. When the current worker encounters a change made by the predecessor, the development system queries the knowledge repository to reconstruct the sequence of knowledge operations that were performed earlier.

Unlike current software techniques that focus on horizontal decomposition of tasks, Multimind is designed to facilitate vertical decomposition of work. Consistent with the theme of the 24 hour knowledge factory that emphasizes vertical decomposition, collaboration occurs in a “high cohesion” gear that involves sustained knowledge transfer and communication between members of the collaborating sites. All events, as well as all atomic operations of all project objects, are recorded using LifeStreams [3], a chronologically ordered WORM object database. A worker can view the rationale behind the state change by querying the knowledge repository for all the events based on the timeframe when the state evolved. The results, shown in Figure 3, are categorized by event and prioritized by relevancy.
Figure 3: All objects modified in last 24 hours can be viewed in context of evolutions.

Related technologies for the 24-Hour Knowledge Factory include: User-Monitoring Environment for Activities (UMEA) [6] and Time Machine Computing [9].

Commercial Harbingers of 24-Hour Knowledge Factory

Examples from industry of harbingers of the 24-Hour Knowledge Factory come in several flavors: some involve globally distributed work, others involve two centers, and still others involve more than three centers. The examples here are illustrative, not exhaustive, in nature.

In Massachusetts, McDonalds is testing a new way to take orders. You drive in and speak in your order. This order is taken by a human operator located in another state and connected to the test site via electronic links. Today, this operator is located within the US. Over time, the order could be taken by individuals abroad, working during day in
their respective countries. Similarly, Siemens AG uses automated tools that can be monitored and handled from any geographical location; the traditional factory environment is transformed to a virtual “knowledge factory’ where operation continues without factory workers having to work the night shift at any location.

The mobile industry firm, WDSGlobal, used extreme programming concepts, Virtual Network Computing (VNC) and video conferencing to support a round-the-clock software development project, with sites in the US, UK, and Asia. During the initial stages of the project, the transmission of a daily work summary constituted the handoff process; later this was expanded to include additional items. The project faced difficulties created by cultural differences and by long delays when downloading version control software from remote locations. One key lesson from this project is that the participating teams should be of equal size; otherwise the largest team tends to dominate.

Two parallel software teams were studied at IBM [11]. All the members of the first team were located at one place in the US. For the other team, one-half of the members of the team were based in one city in India, and the other half at one place in the US. The two teams reported to the same manager, were involved in the development of similar products, and were closely monitored over a one-year period in terms of use of email and other electronic communications techniques, adherence to schedules and milestones, quality of intermediate and final deliverables and products, and allied parameters. Based on various objective measures, the overall performance of the two teams over the one-year period was found to be virtually identical. In fact, the distributed team performed
better in terms of: superior documentation and retention of history; enhanced ability to share short term tasks; more structured definition of work tasks and distribution of work items; and higher quality of knowledge repository created for recording rationale for all important decisions.

Office Tiger, based in multiple countries in North America, Europe, and Asia, provides banking and financial services on a consultancy basis. The unique aspect is that it uses these distributed resources to complete one-third of its assignments in less than three hours! A sophisticated management information system, called T-Tracks, is used to collaborate between geographically dispersed locations.

In the above cases, the challenge for the computer community is to design, develop, and deploy the IS infrastructure that can be utilized by these industries in order to perform their respective endeavors at lower costs and with shorter turnaround times. The challenge is also to develop new ways for storing and leveraging process rules and knowledge so that one does not need to reinvent the wheel every 2-3 years [7,8]. Ideally, one would like to use the same IS infrastructure to provide 24-Hour Knowledge Factory capabilities to diverse arenas; in reality, the IS infrastructure may need to be adapted to address the specific requirements of different endeavors.
Conclusion

Offshore outsourcing can lead to faster development of new products and services through the use of the “24-Hour Knowledge Factory” concept. This paradigm involves the use of three or more teams of workers located at different places around the world, with members of the global team working on the project around the clock. Each member of the team works the normal workday hours that pertain to his or her time zone, and then a fellow team member located in a different time zone continues the same task. This hybrid offshoring model can lead to strategic and economic advantages to all participants in the endeavor [5], and is expected to be utilized by an increasing number of diverse industries over time.

References


