

## **Scientific Foundations for Service Engineering**

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The provision of services is a major component of our economy and our society. In the United States, greater than 70% of the labor force works in the service sector. Even companies known for manufacturing, such as car manufacturers, now make little if any profit from selling cars; their profits come from the financing and servicing of cars.

Services are critical in the public sphere as well. Both as individuals and as a society we depend on education, health care, police protection, emergency teams, and armed forces for our well being.

Providers of services have not been able to match the productivity growth of modern manufacturing. Service depends on communication between the “customer” and the “provider”, although these two terms do not capture the full range of the service economy. Intuitively, providing a service means answering the question “What do you want?” And providing a service effectively means answering the question “How can I help you?” It is this combination of *what* and *how* that makes service challenging. It requires a communication of imprecise needs and shifting attitudes.

Because some form of dialog is central to providing a service, it has been the province of people and not machines. Complex services depend on nuances and moods, and require adaptation to the idiosyncrasies of individuals. Automation has not significantly enhanced the productivity, consistency, and repeatability of services. It is easier to make one more computer on an assembly line than to teach one more child to read. The manufacturing process can be standardized, the learning process must be individualized.

Providing services today is more of an art than a science. We can train doctors to improve their bedside manner, for example, yet doctors vary greatly in their ability to communicate with patients, and medical errors based on miscommunication abound.

Accurate and reliable communication is essential to providing services, yet it remains a barrier to the development of the service economy. In simple situations, where the choices are limited and the necessary communication is unambiguous, the communication problems have mostly been solved. ATMs are effective at providing simple banking services, for example. And ordering a combo meal at McDonald’s has been reduced to picking from a short list and choosing a soda. However, the vast majority of services require greater understanding and communication.

### **Proposed Research Initiative**

One possible way to engineer better services is to gain a greater understanding of the limits of communication and cognition, with the goal of standardizing and automating what is codifiable, and clarifying the complementary roles of humans and machines in the provision of services. Another goal is to promote innovation by enriching the work

environment for service providers – freeing them from routine tasks, and focusing them on complex questions and interactions.

Cognition and communication are both essential. For example, consider the public service of security delivered by police. The mood of a crowd facing the police is complex and poorly quantified. How can the police most effectively get the crowd to disperse? How should the police communicate with the crowd? How can the police avoid panic and violence? Other examples include the cognitive states of patients, primary care doctors, foreign visitors, and almost any situation in which the service could be rendered useless, unnecessary, redundant or hopelessly complex due to the mischaracterization of the state of the person being served.

Beyond the human-to-human service roles, the use of machines to deliver more complex services will be founded upon better ways to build more sophisticated understanding of the served. The effectiveness of the ATM machine, or the self-service check-in counters, is based upon the reduction of the information acquisition to a menu-driven system. More complex services are unlikely to be reducible to this type of menu system: witness the frustration that phone system menus induce.

Complex services will likely need a combination of standardized and customized components. Standardization and subsequent automation have driven productivity growth in manufacturing and has the potential to do so for services. However, the boundaries between what can be standardized and what must be customized are unknown, and similarly the boundary between standardization and automation.

Standardization requires codification and representation of cognitive states and information, as well as the ability to sense and deduce them from the structure of the interaction and from environmental observation. This requires research that can measure the state of the person more precisely, engineer the service system to avoid the development of misunderstandings, and detect and recover from errors. This will lead to the ability to deliver “designer services” to individuals based on shared understanding. The automation will enable a higher level of productivity for services.

### **Timeliness**

Research on engineered services will build on the considerable progress in cognition and neuroscience that is starting to unravel how we make decisions, and starting to build better understanding of human cognitive states in terms of neurophysiologic quantities. We have also developed computational tools in computer science that can be used to develop theoretical and algorithmic capabilities for the automated components of service delivery. “Empirical economics” has also shed light on how human decision making deviates from the purely rational and has laid the groundwork for a more realistic view of human behavior and cognitive capabilities.

## **Research questions**

This research depends on advances in many disciplines, crossing a number of the NSF directorates. Here are some examples of fundamental research questions related to this topic.

- How do we reason about incomplete information in service encounters? How do we identify communication gaps and misunderstandings as the situation dynamically unfolds?
- How do we develop “error correcting” communication without the irritating redundancy that frustrates the person being served?
- What are the design principles for service systems? How do we know what type of representation is sufficient to reason about the cognitive state of the individual? Do limits on representation suggest fundamental barriers to the automation of services?
- How do we measure and quantify the cognitive state of individuals in service contexts?
- How do we make terms such as “misunderstanding,” “conceptual gap” and “mutual understanding” precise and operational?
- How do we use advances in cognitive science and neuroscience to build more sophisticated automated service systems?
- What are the limits, in terms of formal concepts of decidability/computability, for different representations of the underlying cognitive state?
- Are there “impossibility theorems” that determine the limits of shared understanding that can be derived from axiomatic representations of negotiation and shared decision-making?
- What are the algorithms needed to compute representations of shared understanding, diagnosis, debugging and revision?

## **NSF Role**

NSF is a natural home for the engineering of services based on fundamental scientific understanding of human cognition and knowledge representation. The relevant scientific fields include biology, chemistry and physics which contribute to neuroscience; computer science, mathematics and engineering for information processing; and social and behavioral economics for cognition. But engineering enables the focus on service delivery that directs the science towards innovative outcomes and system delivery.