Thoughts on Becoming the First Kumagai Professor of Engineering

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What I said at the invocation dinner:

I am greatly appreciative of the professorship established by Kumagai Gumi and highly honored by the confidence placed in me by Stanford for electing me to this professorship. As I hinted in the essay in the brochure, I value highly this relationship with one of the world's premier enterprises engaged in building things. But I also see significance in the fact that Kumagai is a Japanese company because I have high respect for Japanese art.

One might ask what does art have to do with engineering research and teaching? I think there is an important connection! A teacher in a photography class I took said "composition is organization plus simplicity." And a famous American photographer, Edward Weston, once said "composition is the strongest way of seeing." I especially like the composition of much Japanese art—its strong organization and clean simplicity. A Japanese friend said the phrase *Konso de shibui ho ho* describes this quality.

But composition is also important in research and in writing about research. Paraphrasing Weston, we might say that "composition is the strongest way of knowing." My attitude toward engineering is that it is not sufficient for our constructs merely to work well —they must be elegant, they must be as simple as possible, and they must be well organized. In short, they must be well composed! There is a very practical reason for adhering to these aesthetic standards. The reason is that if our research is ever to be used by others it must also be able to be taught. People do not easily remember nor learn overly complicated things, and if no one remembers or learns about the results of our research, our efforts will have been wasted. But people are especially attracted to elegant engineering ideas just as they are to elegant art.

So in my efforts to invent more versatile and useful robots, I always try to seek the most elegant designs. Of course, I don't always succeed; good composition is a goal that is to be sought even if it cannot always be attained. The Kumagai chair will always remind me of the connections between engineering and art, and I thank the donors for the opportunity they have given me to put extra emphasis on *Konso de shibui ho ho*.

What was printed in the brochure accompanying the dinner invitation:

Computer science, like other branches of engineering, is concerned with building and understanding large, complex structures. This new professorship links computer science, whose constructs are among the most intangible yet complex of all, with civil engineering, which produces the world's physically largest man-made things. Much has

already been achieved through this kind of partnership, and much more will surely follow. Before a skyscraper or airport can be built from concrete and steel, mountains of "softer" structures, such as detailed plans, project charts, and databases, must be produced and used. And these softer structures are the very stuff of computer science.

My own interest in engineering derives as much from a passion to understand as from the excitement of invention and construction. It is not often realized that an important side-effect of engineering is better scientific knowledge. Engineers, in their efforts to build things, invent the very concepts that scientists then use to explain and understand the physical world. Examples abound: not until the mechanical pump was invented was the action of the heart understood; aeronautical engineers invented the concepts now used to explain how birds and insects fly; radar and sonar were invented before we understood why bats squealed. The eighteenth-century Italian philosopher, Giambattista Vico, said it best: "Certum quod factum," we are certain only of what we build.

Of course, Vico's phrase has obvious meaning for engineers. We are never absolutely sure that our buildings or our computers will perform as designed until they are built and used. But to me, the phrase has a deeper meaning. My research is focused on building intelligent robots—robots that will be able to perceive the world around them, to learn, to plan, to act, and to communicate with other robots and with humans. Such robots will have many of the abilities of humans, and therefore some people believe that we must first understand how humans perceive, think, and act before we can build robots that do so. They believe that this understanding will come from research in psychology, linguistics, neurophysiology, and philosophy. I am sure these disciplines have much to say to us roboticists, but I don't believe we will really understand how humans perceive, think, and act until we have first invented and built robots that can!

To be sure, the robots that I am working on will be useful. Research in Stanford's Center for Integrated Facilities Engineering, of which I am a member, is already exploring how teams of robots might be employed in site preparation and in construction. So, I hope it is gratifying to the Kumagai Company that I, as the first Kumagai professor, am contributing to the invention of such machines. But I also hope it will be pleased to learn that I think that research on robots will also provide us with a deeper understanding of the mechanics of that most complex of all structures—the human mind.