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The industrial environment contains problems of practical importance. To exploit that environment, an industrial research group must accept the responsibility for forming strong and useful relationships with the rest of the company of which it is a part. Opportunities for contributing to both the industrial and academic worlds stem from the many product-related problems for which existing science offers no solution, but which suggest new scientific directions.

I am very pleased and proud to be here to celebrate 25 years of the contributions of the Mathematics Department. Twenty-five years in industry is a very long time, and not many mathematics departments have survived that long. This one has survived and prospered, which I think is a great tribute to the people in it. So I would like to thank all of you for the work that you have done over the years.

I am going to talk about science in industry.

When science really started out to become a separate force in industry, the dominant thought in a lot of research centers after the Second World War and in the 1950s was that it would be an enclave of academia in industry. To the extent that there was coherent thought, it was that. The thought was that companies would play the role of an enlightened patron. I may be oversimplifying the concept by putting it in this very short form, but I think that was really the case.

I do not think that approach usually works. Even if some company could be persuaded, briefly, to play the role of the enlightened patron, it is probably not the right way to do mathematics or science in industry because it does not exploit the industrial environment. That environment is very, very different from a university.

Let us just pause and reflect for a moment on what the dominant forces in the industrial environment are. One thing that is often discussed is the profit motive as opposed to the nonprofit university. This is true, but it understates a more complicated reality, because what you actually see in industry are people animated by the need to build, to design, and to sell competitive products. The profit is a by-product of that activity. So when you meet people from industry, it is building and designing that they actually have on their minds.

The industry environment is a significant one on a world scale. If you just count people, or count square feet, or look at the piles of machinery, for example, it is a large piece of the world's activities. It contains almost every sort of activity that you could want: physics in almost every form, from the electromagnetic problems posed by the rapid motion of a printer head to hundreds of others. Chemistry appears, even in our industry, in a critical role in plating baths, and electrical engineering in the design and construction of circuits, more physics in the transistors, and so on.

I am not going to try to enumerate here what is essentially an endless list, but merely to remind everyone that the industrial world is large and complex, and might reasonably be supposed to contain, within it, an enormous and challenging and suggestive group of problems. I think it is fair to say that the industrial world contains problems which are of practical importance, and potentially of scientific importance, either through the efforts those problems demand for their solution, or because the attempts made on them suggest still other things.

Over the years, we have certainly seen this environment interact with mathematics and more generally with science in at least two ways. The one that reflects the traditional view is that some existing mathematics is seen to apply to a practical problem. As a concrete example of this, I would take Roy Adler's work on ergodic theory, which then connected up with an unsolved problem in encoding data for use on disks. A second mode of interaction is perhaps the more usual one in reality, and that is the one in which the problem itself suggests and drives the mathematics, which then changes and takes on a life of its own. Sam Winograd's early work on the number of levels of logic required in arithmetic units was definitely suggested by an environment in which people were, in fact, trying to design adders and multipliers out of logic units. In a very natural way that work then grew and extended itself. It evolved from this question of how long does it take to do an add, to taking adders and multipliers themselves as basic units, and then asking about more complicated things such as the evaluation of polynomials and later the multiplication of matrices. That field of trying to understand, in a fundamental way, the amount of work, arithmetic work, that needs to be done to deal with arithmetic functions, has flourished because of the impetus given to it by the environment. Historically, there were precursor attempts on these problems, but they left no continuous line of succession. The difference, I think, is the presence of an enormous stimulus from the computer industry.

Another example of this type, of the mathematics evolving to suit the situation and having a life of its own, is the ASTAP work. The need to do calculations about electrical circuits in a reasonable amount of time led to the study of sparse matrices, which then, in turn, have developed a life of their own. And, of course, since I have the podium, I am going to mention that the work which Paul Gilmore and I did years ago on stock cutting led, in turn, to something called the asymptotic theory of integer programming.

In all these examples, there is a real contribution to the industry and a contribution to mathematics at the same time, and this, in my opinion, is a viable, symbiotic relationship for part of a mathematics department and the industry that it works with. I say in part because I also believe that there is an equal need for the department to be part of the academic world and contribute to academic mathematical subjects.

Now, if we do accept a view that mathematics or science in industry should profit from the environment, while contributing to it, this raises the problem of how to obtain that interaction with the environment. That is neither automatic nor easy, nor is it solved by the fact that a group is in a company. In fact, in the 1960s—which is an era within the last 25 years that we are celebrating—the prevalent view, again slightly overstated, was "Let's put a research center somewhere on a hill and the ideas will sort of flow down from it." Most of those research centers are long gone. That is not something that works. Forming a strong and useful relationship with the company of which you are a part is not automatic. It takes work. There are many things that one can do, and one of the first things you might think of is to invite parts of your company in to see what you are doing. Another way is to advertise the skills and insights which you have. These notions, although superficially attractive, are, I think, fundamentally wrong; and connected with this, I notice that in most cases where research has failed, people blame other parts of the company for not using the ideas or talents which are available from research.

I think the key and decisive step away from what I have just been describing is for the research organization to accept responsibility for that interaction, and to go out and make it happen. Do not think the other parts of the company will do it, and do not blame the other parts of the company for not doing it. We, in research, will be the beneficiaries; we have to do it. In my opinion, this department, over the last 25 years, has learned how to do it, and I congratulate them on the effort and the achievement.

In part, we want a department that is oriented toward and reacting to its industry. In part, we want a department that is a part of the university world which is, in the case of mathematics, of course, the dominant force. My remarks so far have been about industry in general, not the computer industry, but this particular industry does have some characteristics not shared by others. One of those characteristics is that it tends to grow about 15% a year, and I certainly hope that that characteristic will continue because it simplifies our lives enormously. However, that is not the main point. There are two things about the industry: One is that computers are arguably the great event of our time. They are changing the world around us, yet we do not understand their activities in any fundamental way. We do not understand, in any basic way, why certain problems take a long time to compute. We have some limited success in understanding the arithmetic aspects of computing, but that level of understanding of the rest, which is most of it, lies ahead, in my opinion, as a major and exciting challenge.

The second different aspect about computers is that computers have the potential to add to the way mathematics itself is done. It is a new medium for creating mathematics and the medium has an effect. For example, if you were to imagine what mathematics would be like were paper nonexistent, and the only way of recording mathematical thought was carving in stone with a chisel, I would venture to say that in such a world, the only theorems that could be proven would be ones with short proofs. I think there is no question that the medium affects the development of the subject and that computers in their modern aspects, with large screens, complex printing capability, interactivity, and the ability to do enormous searches very rapidly, can and will add a new dimension to mathematics itself. So, our industry is different in those two ways.

I congratulate the department on its evolution. I look forward to seeing progress on fundamental understanding of computers and to seeing them affect mathematics in the next 25 years.

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