Visit to IBM Tokyo Research Lab, June 18,1991

Background

My hosts for this visit were Mr. Chihiro Sawada (Robotics Group) and Mr. Akira Okano, (CIM Technology Group). Also attending were Mr. Masayuki Numao and Mr. Keisuke Inoue of the CIM group. These are young researchers who work for Mr. Hazeki and Dr. Koda, whom I did not see on this visit. This group has close ties to Todai, both because the campus is nearby and because all are graduates. Mr. Okano was a student of Prof. Inoue, Mr. Inoue was a student of Prof. Kimura, and Mr. Sawada was a student of Prof. Miura. IBM TRL is a member of Prof. Kimura's new Product Realization project and one or more of these people attend monthly meetings of the industrial participants.

CIM to these people means more than Computer Integrated Manufacturing, since the latter implies communication, networking, databases, and so on. This research group focusses on advanced CAD, robotics, automated assembly, feature-based design, and Concurrent Design. Their views are very advanced and their knowledge of the research literature and the status of commercial CAD is very good. Their opinions on fruitful research directions and approaches are very similar to my own, as discussed below.

The topics we discussed were

- the status of their recent research
- their plans for the next phase of research
- recent work in micromachines

Informally we discussed the status of young engineers, salaries, cost of homes, commuting distances, style of communication in Japan and at IBM Japan in particular (slightly americanized, they said). [See IBM Fujisawa plant visit for more on this last point.]

Recent Research

For the past two or three years the CIM group has been developing a solid modeler for mechanical parts based on features and constraints, plus some assembly modeling and assembleability evaluation. [Okano] I was shown this work when I visited a year ago. In the intervening year, there has been no additional progress because Okano, the leader, has been busy converting it for use by designers in the factory. He is aware that Structural Dynamics Research Corp's recent I-DEAS solid modeler Release VI has both feature-definition capabilities and constraint modeling.

TRL's feature modeler is very similar to our own [De Fazio et al], capturing shapes of parts and form features, and expressing disassembly directions of assembly features in a database that accompanies each feature. (No commercial modeler can do this.) Assembly sequences are determined by a method again very similar to our own, in which the computer determines all the easy assembly constraints (such as parts completely trapped by neighboring parts), and the designer supplies the rest of the constraints. In the TRL system, assemblies are defined by means of mathematical solution of constraints: the designer designs each part and tells the computer which surfaces mate to which; the computer solves for the relative positions of the parts. This is more complicated than our method, which permits the user to name or click on the mating features directly. Mr. Okano notes that he has incorporated into his software our method for visualizing networks of assembly sequences and the accompanying techniques for editing sets of possible sequences and eliminating undesirable ones. [Baldwin et al] He has also added some assembleability evaluation capability.

The assembleability evaluation is fairly simple at this point. It seeks to determine when parts need extra fixtures during their assembly as well as how many screw or other non-simple moves are required. An algorithm selects the "best" assembly sequence. There is no assembly cost analysis. The scoring system for evaluation bears some similarity to the Hitachi method, which they purchased. However, their papers and discussions omit any detail about the Hitachi method due to proprietary restrictions, so I cannot tell if their software actually implements any of it. I believe, however, that they are dissatisfied with the Hitachi method and this is why they have tried developing their own.

Example scoring in the TRL system is relative to full credit for downward simple insertion, with some points off for upward insertion, more off for horizontal, rotating, or diagonal, and still more if a separate fixture is needed to establish or maintain special relationships between parts during assembly.

Their software also has, or will soon have, an expert system shell and some rules for simple ease of assembly judgements, such as determining if holes and pegs have chamfers on them. Such facts about individual features are fairly easy to determine and can be deduced from simple table lookups if the form features have been described in the database properly. However, I do not know how they store their features.

CAD in general at IBM seems to be based on CADAM, a two dimensional drafting system. About 70% of the designers use it; perhaps 30% use CATIA, a 3D solid modeler. Both of these are commercial products. CATIA is too hard to use, say the designers, who were trained in conventional drafting. The problem of difficult user interface to 3D modelers is widely discussed in Japan, not only at IBM, but no one has a really good solution.

According to Okano, shortcomings in CAD and in design evaluation methods have a common factor, namely that CAD, especially solid modeling, enforces the wrong kind of design methodology. One wants to begin with a complete rough layout that shows all the parts in approximate relative locations; then one wants to design each part in detail. CAD supports the second step but not the first. He feels this is one reason why products turn out to have too many parts: the designer begins designing single parts right away and does not see the whole product until too late.

Reducing the number of parts is a key assembleability evaluation technique. Several methods exist for judging if a design might have too many parts but no method exists for advising the designer on which parts should be eliminated. The same is true of any other evaluation, such as tolerances (see below). One can tell if a given assignment of tolerances permits assembly but no method exists for advising the designer on how to do the original assignment.

Research Priorities and Technology Transfer

Okano and his colleagues apparently have come to these conclusions more or less independently. I could not detect strong interactions with the factory or any attempt by upper management to encourage such contact. Management does not provide a research agenda and neither does the factory. The researchers do not actively generate research ideas by regular consultation with the factory, but instead use their own judgement and pursue their own goals. Transfer of the assembly modeling technology, like most of this lab's work, seems rather haphazard. Okano said that he merely gave a presentation on it to people at the factory one day and they expressed interest in having it developed for their use. Whatever pressure there is for increased producibility in designs apparently comes from the plant engineers, not from the product designers themselves. Moreover, any pressure for technology transfer at all seems to come from haphazard interactions or the whim of the researchers, who are judged each year by management on the basis of "good work," patents, publications, and technology transfer, apparently with about equal weight.

Yet no one else in IBM worldwide is studying advanced CAD, according to Okano. He was surprised to learn that CADAM, which is now owned by IBM, is planning a solid modeler. He told me that CADAM representatives were scheduled visit him on June 20, probably to review their work with the possible goal of including it in their next product release.

Mr. Sawada knew of Toyota's work in CAD, perhaps due to the group's contact with Prof. Kimura. He asked me if I knew about any plans Toyota was rumored to have regarding releasing their CAD as a product. [Toyota announced their intention to do so later tht summer.] I tried to pursue this point by relating advanced CAD to the product realization process. I described Toyota's drive to reduce the time needed to design a car and the importance of their CAD to this effort. I also related Toyota's feeling that faster product development was important to the company's long term survival. This story drew no comment from them at all.

So, while the group understands that the goal of concurrent design is to improve and shorten the design cycle, they do not feel any pressure from the company to contribute to the goal, except if they feel like it. The current design cycle consists of performance-oriented designers doing their thing, followed by a "pre-analysis for manufacture" performed by the plant engineers. This analysis results in requests for design changes, which adds a few months to the cycle. No one told me that this is a bad system or in dire need of improvement. Maybe if solid modelers were easier to use and CAD didn't take up so much of the designers' time, then they would have time to consider producibility. As it is, according to Okano, all their time is spent trying to meet performance goals, a typical situation.

New Research Directions

The group is currently in the process of developing its plans for future research. I had some difficulty determining any details. The emphasis will be on assembly. (They have no interest in machining, molding, or other fabrication processes.) A major theme is providing active advice to designers. This extends any existing work on evaluation or scoring of a design and hopes to provide particular suggestions for how redesign should proceed so as to improve assembleability, reduce part count, or improve tolerances. Another theme is improving CAD interfaces, most likely by extending feature- based design to include "analogical design." This term refers to reusable designs. Also, they want to explore the idea of "top-down design," meaning designing all of the parts of an assembly first in a rough way and then doing detailed design on each part. A fourth topic is sculptured surfaces. Finally, they are interested in helping designers evaluate tradeoffs that occur when product performance must be balanced against other factors, such as producibility. Peals of laughter greeted my question: "What do the designers do now?"

Reusable designs seem to have been given the most thought so far. Okano was quite clear in several of his points. First, current commercial CAD focuses on design of completely new parts. There is no library of previously designed parts, although he and others realize that feature libraries are a start in this direction. CAD also permits editing of existing parts, but his goal is to produce a design that is "similar" to one or more existing designs. Since designs involve many parts with interrelated constraints, a similar design might be one with slightly different constraints, or with some parts replaced by new ones while others remain the same. He referred to "experienced product data." By this he probably means data on parts that have stable process plans, assemblies whose tolerances have proven to be satisfactory, and so on.

I asked Okano if he saw analogies between feature based design and object-oriented databases, or between analogic design and reusable software. To each he answered "Yes" immediately. "I am currently reading papers on reusable code," he said. So his thinking is again very similar to our own. (He also said he was keenly aware of Prof. Inoue's new curriculum at Todai.)

It would seem that "top-down design" would be related to "analogic design" if one could come up with a high level description of a product that the designer then filled in with specific geometries and constraints.

Another problem on their agenda is tolerance analysis and synthesis. This is Mr. Inoue's project. He has been reading the literature but also has no concrete approach; or else he did not want to reveal it. The group has already rejected tolerance analysis via the worst case method and has opted for a statistical approach. This is the most common choice because the latter is tractable and the results are more economical in manufacturing.

One of the group's first steps was to buy and evaluate a commercial product called VSA, developed by a small US company. This program can do statistical analyses of tolerances by using a Monte-Carlo technique. IBM's evaluation is not complete but Mr. Okano said in his opinion it was a useful program for designers. However it has two drawbacks. First, it deals with dimensional tolerances, such as +/- specifications for distances, but does not deal with modern methods called geometric dimensioning and tolerancing (GD&T). The latter is supported by an international standard and attempts to provide ways to describe entire shapes or relations between surfaces, such as flatness, parallelism, concentricity, roundness, and so on, not merely individual distances.

A problem with GD&T, shared by all other methods, is that there does not exist at present a rigorous mathematical description of the various tolerance specifications. Several international standards committees are addressing this problem now but little progress has been made. The TRL people were unaware of this effort.

A shortcoming of VSA, according to Okano, is that it cannot really evaluate tolerances in assemblies. His reason is that VSA assumes surfaces are perfect, and that the mating surfaces on two parts are in fact the same surface. He cites tolerance specifications on surface roughness as proof that mating surfaces will not be the same. For precision assemblies such as disk drives, such distinctions can be quite important. He briefly described a situation in which a plant engineer complained that one of his problems was due to insufficient specification of roughness tolerances leading to assemblies that were out of specification.

Regarding the larger issue of design tradeoffs, Mr. Numao suggested that sensitivity analyses might be useful. "Similar to simulations in operations research," he said. I brought up the Taguchi method and asked what they thought about it as a design aid. They did not have strong opinions, indicating that they did not think it was widely used or in demand at IBM.

We had some informal discussion of concurrent engineering (CE). Mr. Okano asked about CAD vendors' claims that their product supported CE because one could design a part and automatically have the computer generate numerical control machining instructions. This is what used to be called CAD / CAM (computer-aided design / computer-aided machining). He agreed with this assessment. They feel that CE is like groupware in software engineering, that is, many programmers working on the same program. However, they agreed with me that mechanical product design is much more complex. Okano suggested that levels of abstraction and modularity were common themes. This remark, like others, indicates that he is the thinker in the group, seeking to find analogies in far-flung fields.

Micromachines

Repeating last year's visit, they showed me videos of micromachines that the robotics group has been making. These are linear actuators driven by comb devices, which are electrostatic actuators with the stator and motor interleaved like two combs with their teeth pressed together. The comb teeth are typically 4 microns thick. Last October's version is like the original UC Berkeley devices, exploiting mechanical resonance to create motion in the form of vibration at the structural natural frequency (typically 5 - 7 KHz). No other motion frequency is possible with this design since the force generated by the actuator is too small and needs the amplification provided by resonance. The January 1991 version is able to move deliberately rather than under vibration. The reason is that the gap in the actuator is extremely small, perhaps less than 0.1 micron, permitting larger forces to be generated.

The new design has two interesting features. First, it assembles itself under the action of another actuator built in series with the operating one. The details were hard to see in the video. The assembly motion consists of delicately sliding the moving part of the comb into the stationary part. Once this is done, the moving part can proceed to move under external control. The other feature is an elastic suspension that greatly improves rotational stiffness over earlier designs. This improvement was necessary since the small operating gap in this design would easily jam if a very slight rotation occurred during actuation.

Last year Mr. Hazeki expressed the hope that these actuators would find application in disk drives, perhaps for adjusting heads. However, I was told this year that no applications have been identified.

Final Observations

This group clearly is technically very competent and has a coherent vision about improved CAD, but it does not have much evident drive from within or spur from without to really apply their work to improving IBM's productivity. This is in sharp contrast to both Hitachi and Toyota, where the drive is right on the surface.

References

[Baldwin et al] Baldwin, D. F., Abell, T. E., Lui, M-c, De Fazio, T. L., and Whitney, D. E., "An Integrated Computer Aid for Generating and Evaluating Assembly Sequences for Mechanical Products," IEEE Trans Robotics and Automation, v 7, no 1, Feb 1991, pp 78-94

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