Visit to Sony, September 5, 1991

Background

This visit was a followup to one on July 1. Our hosts were Mr Tohru Fujimori, General Manager of the Robotics Division of the FA Department, Mr Yasuyuki Yamagiwa, creator of the DAC assemblability evaluation system, Mr Junichi Kuzusako, Assistant Manager of the CAD/CAM group, and Mr Hiroshi Harimaya, Manager of system development in the Production Technology Development Group. We were joined for lunch by Mr Juzo Akiyama, who developed the first Sony robot about 10 years ago. A description of his strategy for developing Sony's family of assembly robots may be found in [Nevins and Whitney].

The main subjects of the meeting were DAC, Sony's preferences for CAD capabilities, early design methodology for videocameras, and robot assembly of precision mechanisms.

Design of Videocameras

A new camera requires about 30 - 50 mechanical designers, whereas a modification of an existing design requires about 10. All these people are university graduates and there are no assistants like draftsmen. Sony is the only company visited that has more applicants than it can hire. The exception is experienced manufacturing engineers, who are not produced by universities.

CADAM, a 2D drafting program, is used for 80% of the parts, while CATIA is used for the rest, to produce cosmetic designs of camera exteriors. Sony's own surface design software called FRESDAM is also used, along with a small number of seats of Pro Engineer and Design-base.

According to Mr Kuzusako, 3D systems are simply too hard to use, having about 100 commands compared to 10 for CADAM. They are also much too expensive, costing as much as ¥60 million per seat (clearly he has made a factor of 10 error here, since ¥60 million was $444,444 at that time) with all the features. So 3D is used only when the shape is too hard to make in 2D, or if stereolithography will be used to make a rapid prototype, to check interferences, do CAE, or teach robots offline. If 3D systems were simpler to use, say because feature-based design ("a very important idea") were incorporated, not only would many designers use them but their output would be understandable by the manufacturing people. At present, design and manufacturing people are separated and communicate by passing drawings back and forth.

DAC Assembleability Evaluation and Its Use in Fine Mechanism Design

Videocamera and tape recorder mechanisms can be very complex. (See Hitachi I&MSL reports.) Much simpler casette tape recorder/players were used as the example in this meeting. A design consists essentially of a base with parts stuck onto it from both sides. The direction of approach for the parts thus dominates the assembly design evaluation. Fastening method has next priority, while part shape is lowest.

A new design often starts with a goal such as to cut the number of parts by a factor of 2 from the previous design, or to cut the cost or weight. "By half" is the division's motto. The previous tape recorder design had a metal chassis and a circuit board. Most of the parts were attached to the chassis, including the motor. Wires were therefore needed between the chassis and the circuit board. Sony's next design used the circuit board itself as the chassis, allowing the motor to be attached to it directly and eliminating almost all the wires. This made assembly so simple that the unit is made in Malaysia by simple pick-place robots.

Detail design consists of making pencil sketches of multi-part mechanisms in exploded view form. At the early stage, many such sketches are made, and the assembly evaluation is one of the main criteria used to choose one concept over another. This makes Sony's DFA approach different from any of the others observed during this study. The part sketches are remarkably detailed. Thus fairly good DAC judgements can be made. Since one person accounts for 50 parts, he can make a significant portion of the design and evaluate it himself.

Sony's design methodology may be different from other companies' too. The common practice is to start with an assembly drawing or assembly sketch showing the final locations of all the parts in a unit. Sony's practice as illustrated to me is that the designer starts by making an exploded view of the parts. This is consistent with a remark Mr Fujimori made at the July 1 meeting, that designers consider assembly method and sequence during concept design, a remark I found hard to believe at that time.

Mr Yamagiwa made the point (commonly quoted in the US) that 75% of the cost of a product is determined by early design decisions, and DAC is therefore aimed at this stage. Mr Fujimori said that Sony has no data to back up this estimate, merely their feeling and an informal survey of their engineers. This is interesting because no one else has any data either; but everyone quotes this number!

One designer may be responsible for as many as 50 parts. At various times in the meeting, some people called this a reasonable amount for one person while others said it was "too many to remember." The conflict is between the older people who do not want anything to block the designer's creativity and the younger people who see the need for computer tools to replace the sketches.

Mr Fujimori points out that Sony has a database for common parts like screws and springs, but not for any of the important parts. These are radically different for each new design. Past designs are of little or no use in providing design data such as parts of nearly the desired shape. Since I had given a talk on feature-based design, he remarked that Sony's lack of part data "may be a shock to you."

Design evaluation has several facets: ease of assembly, precision of the resulting part mate, and cost. Often these conflict, and precision may dominate, especially for shafts and capstans that guide tape. The parts of the tape recorder are all rather simple, and Mr Fujimori claimed that combining them to reduce part count and create "multifunction parts" does not create any cost penalties due to increased part complexity. Part count reduction therefore always yields a net savings. I gathered that the assembly cost estimation method in use is not very sophisticated.

Details and Demonstration of DAC

DAC means Design for Assembly Cost effectiveness. It is at least 7 years old and was originally a pencil-paper procedure because at that time few computers were available to designers, except for drafting. Even now, it can be used by referring to a single sheet of paper that lists a series of keywords describing the points the designer should keep in mind.

These 35 keywords are in three classes covering part shape, method of attachment, and direction of assembly. Direction includes considerations like space for fingers or tools. Method of attachment includes what kind of fastener (if any), how far the part must be pushed or twisted (if at all), what kind of screw head, and so on. Part shape includes general descriptions like "flat" or "cylinder," plus the largest and smallest dimensions, the weight, and whether the part is rigid or flexible. Other information in a general category includes whether lubrication or cleanliness is needed, whether the part is fragile, or whether a wire is attached to the part.

Mr Fujimori points out that "precision" of assembly is a critical factor. This really means how perpendicular a shaft will be to the base in which it is inserted. This is often more important than the exact location on the base. Press fits are deemed the most precise for their cost, although a shaft with a wide base fastened with 4 screws is more precise but more costly. Press fits are notoriously hard for people to accomplish and ordinary robots do not have the strength, so special high cost robots are needed. The ones in use are descendants of the first ones Mr Akiyama developed.

A more recent chassis design had a very thin metal base to save weight. Here press fits could not be used, so the shafts were riveted instead. This indicates that ease of assembly is unlikely to be the main criterion in many of these assembly steps

Mr Yamagiwa demonstrated the DAC evaluation using a program on an NEC personal computer. There are several windows onto which the designer enters data about each part in the 35 categories. The computer calculates the score and keeps various running tallies like total part count, average score, and estimated assembly time for each part. One can input various goals such as "no need to turn the product over" or "less than 4 screws." The computer will then prompt the designer if a goal is not achieved. Wide differences between assembly times are noted as "poor line balance." The fact that two short tasks in sequence could be given to the same robot or person is not taken into account.

Robot Assembly of Complex Mechanisms

Sony began robot assembly about 10 years ago with its own robots and now has several hundred in its plants. It also has a business selling robots and complete systems to other companies, including such rivals as Hitachi. Remarkably complex assembly moves are made by these robots in less than a second or two. Examples include threading a small rubber belt around several pulleys or inserting coil springs that need to be wound up during assembly to create preload.

Mr Fujimori points out several problems in such systems: Teaching the robots these intricate tasks takes time and can be positively dangerous since the parts are small and the programmer puts his head a few inches from the tool. Assembly cycle times are now as short as 2 seconds, so the loss of even 0.3 seconds at one station on a line can spoil the efficiency of the entire line.

So he would like an offline programming system driven by solid model data. His dream: "It works the first time." The problem with this is that the data are probably not detailed enough. The robot's dynamics, not easily modeled, plus the friction and inertia interactions between the parts, will make offline teaching too inaccurate.

His other dream is to have some kind of artificial intelligence built into the robot, its sensors, and its controller so that it could gradually learn a faster way of doing the task. An example is a shorter motion path that comes closer to an obstacle than originally taught. Another is a different assembly sequence. (Up to now Mr Fujimori had claimed that the product designers think up the best sequence, so software like I demonstrated for generating alternate sequences is of no particular use...)

As a first step toward both goals, Sony is developing a "computer-based manufacturing system." It will contain vision and robot tool changing, plus a top level control system run by Sony NEWS workstations. Vision will be used to aid the teaching process, while tool change will be used to permit a robot to do the work of another one that breaks down (requiring a different assembly sequence?). In the future, force sensing will be added to permit assembly the way people do it.

Reference

[Nevins and Whitney] J L Nevins and D E Whitney, Concurrent Design of Products and Processes, New York: McGraw-Hill, 1989, pp 48-52.