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AUTHORS

Dwain R. Faso, C.O., Manager, Research and Development, 3D Orthopedics, 11126 Shady Trail, Dallas, Texas 75229.

Mel Stills, C.O., Instructor, Orthopedics, South Western Medical School, 5323 Harry Hines Boulevard, Dallas, Texas 75235.

Swedish Attempts in Using CAD/CAM Principles for Prosthetics and Orthotics[1]

by Kurt E.T. Oberg, M.D.

SWEDISH CAT/CAM HISTORY

In the mid-70s, James Foort and some of his colleagues began to investigate the use of CAD/CAM principles in prosthetics and orthotics. Others had also started to work in biostereometrics. Some colleagues of mine in Sweden and myself had initiated investigations in order to find modern technology which could be used in prosthetics and orthotics. Reports on this subject had already been published and showed promising possibilities of new techniques to be used.

Interest in CAD/CAM, however, was very low in Sweden at this time. Prosthetists and orthotists were very skeptical of the value of this kind of technology as applied to the improvement of prosthetic and orthotic technique. Therefore, further attempts in developing CAD/CAM technology for prosthetics and orthotics in Sweden were dropped. This skepticism was understandable because at that time the new technique could not possibly give us as good quality results as was already possible with the traditional techniques.

THE ISPO WORLD CONGRESS IN LONDON

During the 1983 ISPO World Congress in London, it became clear to Swedish prosthetists and orthotists who attended the congress that CAD/CAM techniques really had something to contribute to the field. The exhibition showed hardware such as measuring equipment and a milling machine which gave an example of the automated socket fabrication technique. As a result of the London Congress, the interest in CAD/CAM for prosthetics and orthotics became quite high in Sweden.

SWEDISH ATTEMPTS

There is now a definite interest in Sweden and Scandinavia to implement CAD/CAM techniques into the prosthetic and orthotic field. The large company, LIC, which provides over 60 percent of the prosthetic and orthotic service in Sweden, and which also has started service in other countries, has a clear intent to adapt CAD/CAM techniques to their work. The first area to be involved will be the orthopaedic shoe service.

Another large prosthetic and orthotic service company, Een-Holmgren Orthopaedic Inc., is also following the work that is going on around the world in this field.

There are some counties in Sweden that run prosthetic and orthotic services themselves and they, too, are very interested in following and adapting CAD/CAM techniques. They have decided to seek co-operation with the work that is done by the College of Health and Care in Munksjöskolan, Jönköping, Sweden. My intention is now to present the research and development activities in Jönköping.

COMPETENCE AND EDUCATIONAL CONSIDERATIONS

The college runs the prosthetic and orthotic education programs for Sweden, Denmark, and Iceland. There are regular programs for orthopaedic engineers (2½ years), prosthetic and orthotic technicians (two years), and orthopaedic shoe technicians (two years). Various types and lengths of special courses are also offered at the school. The educational program is connected to research and development activities and divided into three laboratories. One laboratory is called the Unit for Applied Orthotics and is testing and evaluating orthotic appliances for the Swedish Handicapped Institute. Another laboratory is the Orthotics Laboratory, which has been involved in the development of prosthetic and orthotic devices for more than 14 years. The newest laboratory is the Biomechanics Laboratory, which I started two years ago.

There will be considerable consequences for a prosthetic and orthotic educational program when a technique like CAD/CAM is introduced into the orthotic and prosthetic field. The question for us is whether we should be passive and follow the development of techniques in different laboratories around the world, or whether we should be active in developing these techniques ourselves. The decision has been made that with regard to the resources and the competence we have in laboratories connected to the school, we should be active in development.

There already are some relevant resources available at the laboratories. At the Biomechanics Laboratory there is equipment such as computers, digitizers, image processing equipment, and lasers. There is also experience with digital measuring technique, computer programming and prosthetic and orthotic biomechanics. The Orthotic Laboratory has a machine shop and design office experienced in prosthetic and orthotic development and the development of various instruments.

College of Health and Care, Jönköping, Sweden		
Prosthetic and Orthotic Education for Sweden, Denmark, and Iceland		Research and Development
Orthopedic Engineer	Research Connection	EFTO Unit for Applied Orthotics
Prosthetic and Orthotic Technician		Orthotics Laboratory
Orthopedic Shoe Shoe Technician		Biomechanics Laboratory
Special Courses		

Relevant Laboratory Resources for CAD/CAM

Biomechanics Laboratory	Orthotics Laboratory
Equipment: —Computers —Digitizers —Image Processing Equipment —Lasers	Equipment: —Machine shop —Design office
Experience of: —Digital Measuring —Computer Programming —Prosthetic and Orthotic Biomechanics	Experience of: —P&O development —Instrument development

CAD/CAM PHILOSOPHY OF THE BIOMECHANICS LABORATORY

The philosophy of CAD/CAM in prosthetics and orthotics at the college and at the Biomechanics Laboratory can be expressed by the following criteria:

1. *The complete system should be available for each prosthetic and orthotic service shop.*

   The alternative is a centralized organization where central units are put in place for the fabrication of the prosthesis from data and measurements taken at the clinics and sent to the central workshop. With this kind of centralized organization, the whole advantage of the CAD/CAM technique cannot be fully utilized. Patients change for various reasons and it is important to use the CAD/CAM system when there are changes or when modifications are necessary. This can increase the effectiveness of the service quite a lot. It also enables the prosthetist and orthotist to have a better control of the whole process when making a device.

2. *The system should require moderate investment.*

   This criterion is only a consequence of the first criterion.

3. *Equipment of a very high specification (able to work to extremely close tolerances) should be avoided.*

   Very high specification is generally not needed, but if it does not increase costs, it usually does no harm. However, machines or computer programs which are too generalized (that works to too coarse tolerances) can increase the cost of the system tremendously and consequently should be avoided.

4. *Individual 3-D shape sensing should be the basis for control of the numerically controlled (NC) milling machine.*

   This is necessary in order to allow for individual variations that might occur, instead of working from more standard shapes, which is a simple but less effective way to work.

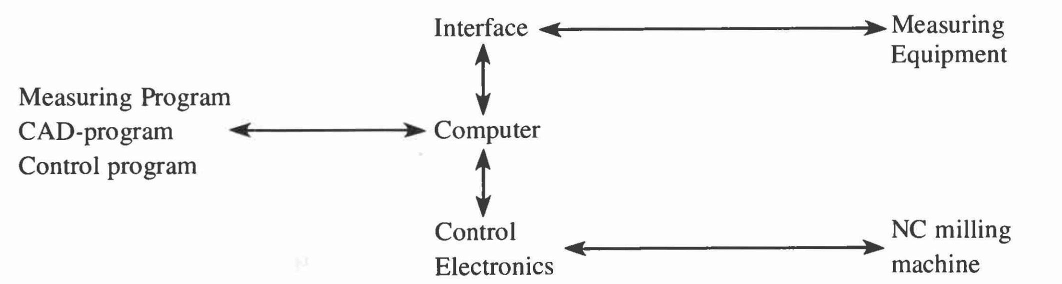
Criteria on CAD/CAM in Prosthetics and Orthotics

- A complete system should be available for each P&O service shop.
- The system should require a moderate investment.
- Too high specification of equipment should be avoided.
- Individual 3-D shape sensing should make the basis for the control of the NC milling machine.

OBJECTIVES OF THE CAPOD SYSTEM

There are potential possibilities for the use of CAD/CAM techniques in the whole prosthetic and orthotic field and the development that has been initiated at the Biomechanics Laboratory in Jönköping therefore uses the name CAPOD as

The Principal Parts of the CAPOD System



an acronym of Computer Aided Prosthetic and Orthotic Design. The objective of this project is to develop a CAD/CAM system which fulfills the criteria mentioned above. The objectives of the CAPOD system are as follows:

- To develop a CAD/CAM-system for prosthetics and orthotics as one complete unit based on a micro computer.
- The cost of the system should remain within the range of US$30–40,000.
- To allow commercially available video image processing equipment to be adapted for 3-D shape sensing.
- To encourage the development of a specially designed NC milling machine, costing less than US$12,000.

Specification of the Measuring Equipment

- Videorecording of a laser illuminated contour of the limb at increments of one one-hundredth of a turn.
- Transfer the videogram to the computer via MicroSight image processing system with 256×256 pixels per picture.

Computer

Victor, Victor Technologies, Inc.
CPU Intel 8088
256 Kb RAM
2 × 1,2 Mb Floppy disk
or 10,6 Mb Hard Disk and 1,2 Mb Fl.d.
Monitor 12″
80 × 25 characters
Resolution 800 × 400 pixels

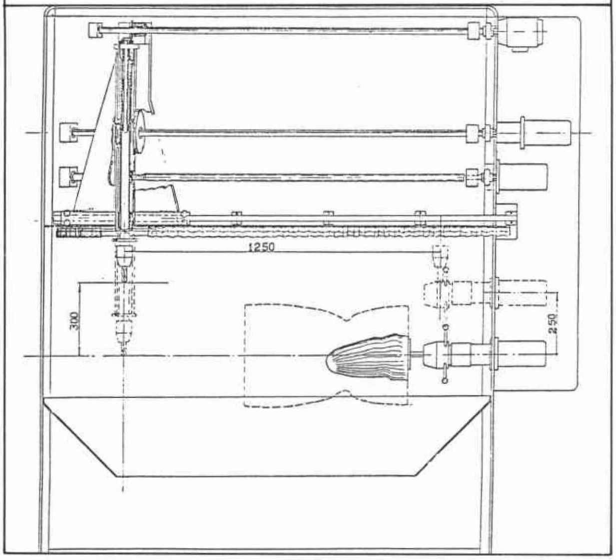
TECHNICAL SPECIFICATIONS AND PROJECT STATUS

The principal parts of the CAPOD system will be a micro computer that controls both the measuring of the limb shape and also the NC milling machine by means of a measuring program, a CAD program, and a control program. Almost all these computer programs must be custom written. The fabrication cost of the whole system is estimated to be about $35,000.

The principal of the shape sensing scheme is generally the same as that developed at the West Park Hospital in Toronto. The plan is to take a video recording of a laser illuminated contour of the limb at increments of one one-hundredth of a turn. The videogram will then be transferred to the computer via the MicroSight image processing system. The software in the computer then takes care of data reduction and will define the surface of a limb as a set of digital coordinates. The custom made CAD program will then modify the shape as specified by the practitioner in a manner that corresponds to the plaster cast rectification process that he does today. At present, a Victor micro computer from Victor Technologies, Inc. is being used. This computer is equipped with an intel 8088 processor and has an internal memory of 256 Kb, which can be expanded to 896 Kb. It has 2×1, 2 Mb Floppy Disk, but a Hard Disk of 10,6 Mb is more likely to be used in the future. The monitor is 12″ and has a graphic resolution of 800×400 pixels.

It has been found that commercially available numerically controlled milling machines are not suitable in this application. They are too overspecified for our purpose and the objectives of the CAPOD system cannot be fulfilled with such machines. Early on it became quite clear that for our purposes, a specially designed milling machine had to be developed. After some investigations, a design proposal, as illustrated by the schematic drawing, has been developed. The cutting is controlled by the same type of coordinates as were used during the measuring proce-

NC-Milling machine for CAPOD System



Principal Parts and Cost of the NC Milling Machine

3 stepper motors with control electronics	SEK	30,000
Cutting motor with converter and toolchuck	SEK	5,000
Chuck for the model	SEK	2,000
Gearheads, transmissions and bearings	SEK	18,000
Custom made parts and chassis	SEK	40,000
Assembling	SEK	8,000
	SEK	103,000
	US	$11,000

dure, i.e., the model will rotate in steps of one one-hundredth of a turn. The X and Y coordinates of the cutter are then controlled by coordinates corresponding to the X and Y coordinates of the measured and modified contour. The travel of this stroke is such that models of torsos and whole legs can be made. An important feature of the machine is the high speed which has been achieved through the use of stationary motors. By using stationary motors and transmissions to power the cutter, the moving parts have quite low mass, which gives a low inertia and allows high speed. It would be possible to cut a model of about 30cm length in two minutes. It is estimated that the fabricating cost of such a machine would be $10,000–11,000. Fifty percent of that cost is commercial parts—for instance, the control electronics for the stepper motors and the complicated transmissions. There are a few custom made parts, the whole chassis and assembling of the machine, which make up the other half of the cost.

The specification of the system has been worked out in co-operation with the orthopaedic technical departments in Gothenburg and Borås. They are also deeply involved in the educational program. The development work has come into a practical and detailed phase, and the whole team is very enthusiastic and anxious to fulfill the objectives and make the CAPOD system a successful system.

FOOTNOTE

[1] Paper presented for American Academy of Orthotists and Prosthetists Annual Meeting and Scientific Seminar, San Francisco, January 30–February 1, 1985.

AUTHOR

Dr. Oberg is Director of the Biomechanics Laboratory Jönköping City Council, Munksjöskolan, Box 1030-S-551, Jönköping, Sweden.