McGill

C e n t r e   f o r

Intelligent Machines

Newsletter

TWO NEW ROBOTS...

You must have noticed that two new creatures have established their quarters in the robotics lab (room 418). They are known as the Sarcos master and slave arms. These two machines form a state-of-the-art teleoperation system nominally working under bi-lateral control. Bi-lateral control means that the master and slave manipulators are controlled so as to provide the user with the sensation of working at a distance. The ideal model for such a system may be described as massless and infinitely rigid linkages connecting each joint of the master and of the slave to each joint of the master. The result of such an ideal model is the possibility of working at a distance since any displacement and force applied to either the master or the slave is accurately replicated by its counterpart, hence the word 'bilateral'. The origin of such systems can be traced to the mid-forties, (Goertz, R. C., 1952, 'Fundamentals of General Purpose Manipulators', *Nucleonics*, Vol. 10., No. 11, pp. 36-42) while stereo vision at a distance was also researched (Johnston, H. R., Hermanson, C. A., Hull, H. L., 1950. 'Stereo-television in remote control', *Electrical Engineering*, Vol. 69, pp. 1058).

The early telemanipulation systems were coupled mechanically. The master and the slave were connected to each other with a series of linkages, cable drives and gears. Because of their reliability, such systems are still routinely used in the nuclear industry. Nearly 43 years ago, Goertz wrote that "Electrically coupled master-slave system manipulators are also under development. All the mechanical linklages will be replaced with force reflecting positional servos." The fundamental article in this area was then written. (Goertz, R. C., Bevilacqua, F. 1952, 'A Force-Reflecting Position Servomechanism', *Nucleonics,* Vol. 10., No. 11, pp. 43-44). The last sentence of this article reads,

"More research and development is needed to improve the performance and develop higher-horsepower systems." Goertz got it right, the key to performance is closely linked to what might loosely be called the 'energy density' of the system. The higher the force generated by the actuators per unit of mass and unit of operating volume (together with the least dissipation) is the key to fidelity. The Sarcos system is the latest entry in the multiple-decade, historically rich, technologically and scientifically fruitful and diverse, line of research started by Goertz. To date, for systems of that scale, hydraulic technology is the only way to produce sufficiently high amounts of energy density, and this explains some the Sarcos system design. To support the operation, a hefty hydraulic supply has been installed in the computer room (room 414). The complete concept is driven by the need to provide a system that can achieve 'human replacement'. With this concept, the machine is sent to inhospitable places, and yet works more or less like a human would, thus simplifying the operational requirements. A cursory look at the system indicates that speed, strength, dexterity, and size approximate and even exceed what humans can do. For the technically curious, there are many features that distinguish these machines from conventional robots. First is the actuation and the instrumentation. Each joint includes a hydraulic vane type actuator fitted with a so-called jet-pipe servovalve. Such actuators have superior response and precision. The open loop response spans several tens of Hertz and in closed loop, flat response to several hundred Hertz can be teased out of them with proper feedback compensation. Such feedback compensation for hydraulic motors has already been under study at CIM for a while. Each joint is completely instrumented with a torque sensor (strain gauge) and a displacement sensor (RVDT). This holds for the master and the slave (it's bilateral!). The slave arm also has redundant sensing in its proximal joints (high resolution optical encoders)

for purposes of calibration experiments. Since the master and the slave have a total of twenty degrees of freedom (more on that later), forty sensor signals have to be processed. One other interesting feature which is difficult to describe in technical terms is the 'grace' of these arms when they move. One part of the answer is found when considering that the slave arm has a load ratio of roughly 1:1. This means that it can manipulate a load equal to its own weight. Compare this to a Puma electrical robot which achieves a dismal 35:1! The rest of the answer can be found in the detailed study of the actuator dynamics combined with the special multi-body dynamics of the manipulator. But there is no room to elaborate on this now.

Turning to the kinematics, the slave and the master manipulators each have ten degrees of freedom. Seven of them form the arm proper from the shoulder to the wrist. The kinematic arrangement, while somewhat conventional at first sight, offers many subtleties to the trained eye. These are justified by the type of job this type of manipulator has to perform (hazardous environments). There is no room to elaborate on this here, but I would be happy to explain this to anyone who is interested. The arm terminates with a gripper which in itself is a marvel of technology. It has three degrees of freedom, primary pinch, secondary pinch and thumb add/abduction. The whole architecture is designed to make it simple for an operator to learn how to use the machine. The gripper can approximate more power grip positions that people are familiar with. Standard tools sych as wrenches, screwdrivers, hammers, levers, powerdrills, etc... can be used by the system without modification. Of course, on the master side the slave finger motions are mapped to the motion of human hand fingers, in particular, the thumb and the index, while the other fingers are lumped in a power grip.

The system can be controlled digitally at high rates to support research in advanced robot control, while the basic operation is analog. The system can support a variety of research projects given its superior performance and exquisite force control. For example, we are developing methods to perform teleoperation from other geographical locations (first will be the Canadian Space Agency, in Saint-

Hubert) using a force-feedback hand controller and a graphic simulator. Various control algorithms are under investigation, for example, a new technique to control impedance, that is its visco-elastic properties. Practically, this allows the robot to behave like a programmable six dimentional mass-damper-sping system in Cartesian coordinates. The slave will also be used to study the performance of various hand controllers interfaced to the arm. Gravity compensation algorithms are also being developped for the two arms. An approach for advanced teleoperation whereby a task is divided into automatically and manually controlled directions with force feedback reflected to the operator is being researched. The controller results from a real-time simulation of a 'virtual mechanism' connecting the master and the slave arms.

Professor Buehler is doing work in automatic grasping and takes advantage of the gripper's capabilities. This research includes the development of specific sensors (proximity and touch) and of new control algorithms. Professor Papadopoulos is currently planning to use the system for his research on force control in the presence of environments with unknown impedance properties. There is also work on system identification of the hydraulic motors in the planning.

Submitted by Michel Doyon and Vincent Hayward
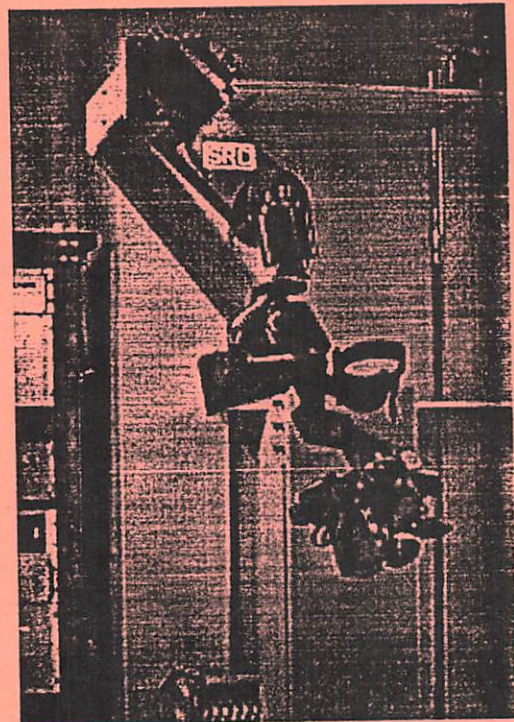
NEWS AND EVENTS

☞**Prof Levine** announced that he has requested and been granted a one year sabbatical from McGill starting September 1, 1995. He says that he will be staying in Montreal and will probably be spending a lot of time at McGill. **Prof. Jorge Angeles** will take over as Acting Director of CIM in September.

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Hats off to...

☞ On April 28, 1995, **Hamid Reza Mohammadi Daniali** successfully defended his Ph.D. thesis entitled *Contributions to the Kinematic Synthesis of Parallel Manipulators* which addressed singularity, isotropy and direct kinematics of parallel robots using dual-number algebra. Complimentary reports from the examiners and an appreciative and friendly committee (6 of the 7 members were from CIM) resulted in his nomination to the Dean's Honor List.

Hamid extends his thanks to Profs. Zsombor-Murray and Angeles for their support and guidance as well as to his colleagues at CIM who provided him with excellent facilities and a friendly environment. He said that his stay here was a pleasant and fulfilling experience. He will be around for a while longer but he will soon go back home to Iran and look for a job. Congratulations, Hamid!

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☞**After** 6 years at CIM, **Marco Petroni** announced that he finally has something to contribute to the newsletter! He sent us the following, "Earlier today, I successfully defended my PhD thesis entitled *Improved Processing and Classification Techniques for Infant Cry Vocalizations*, which was done under the supervision of Prof. Malowany and with the collaboration of Prof. Johnston from Nursing. BTW, although I have been with CIM for 6 years, I had been working on my PhD for just over three years, the other 2.5 years were spent working on a Master's.

Employment? Well, since the end of January, I've been part of the Speech Technology-Development team at Bell-Northern Research on Nuns' Island. I'm really enjoying myself at BNR and with the seemingly large number of ex-CIM students at BNR, one could almost call this "CIM on the Island." ;-) Anyhow, I leave CIM with a lot of good memories, for instance, the friendly rivalry between "the Veterans" and "the Rangers", and the not to be forgotten McRCIM Hockey Pools with the annual visit to Sergio Momesso's, (a native NDGer who now plays for the Vancouver Canucks) Dad's restaurant for those world-famous subs! Seriously, though, CIM has indeed been a great place in which to work and I thank those who have and who continue to make CIM the great place that it is." All the best, Marco!

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☞**Michael Langer** announced that he has been offered a post-doc at NEC Research Institute in Princeton, New Jersey, starting in September. His office mate **James Elder** has already accepted a post-doc position there. Mike said "CIM did very well: there were two positions at NEC and we got both of them! (Steve Zucker is beaming with pride.)". Good luck, Mike and James!

Michael sent us other some exciting news, he and his wife **Corinna** are expecting !! The due date is June 7. Its a boy, and Lucas Jakob Langer is his name.

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☞**Ex** CIMites **Santanu Roymulik** and **Shailendra Mathur** have left M3I and joined Virtual Prototypes and Softimage respectively. What a network...expanding all the time!

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☞**Congratulations** to CIM mechanical maestro **Eric Martin** and his wife **Dominique**, who collaborated successfully this past April 6th to give birth to their new son, **Philippe**. (to big brother Charles' delight!) Eric seems to be surviving quite well with the new responsibility, which makes one wonder if maybe Dominique put more effort into the delivery than he did...

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☞**A**nd another Welcome to the World goes to **Philippe Doyon**, the bouncing baby boy born to CIM's own **Michel Doyon** and his wife **Linda**. This past April 15th at 11h15, young Philippe got his first glimpse of the world and decided to stick around. Since he was already a strapping 7 lbs 2 oz. lad, he figured he could handle modern society without too much trouble, and has done just that so far. The proud parents are also doing well and are enjoying their new-found increase in waking hours.

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☞**T**om Mackling impressed his girlfriend **Jennifer** so much with the vast intelligence of his Theorem Proving program that she agreed to marry him. This past April 8th they became husband and wife and report that so far they have not had any children.

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☞**M**ore marital news: CIM system administrator alumni **Michael Lee** reports that he and his fiancee **Barbara** were married in Manhattan early last month. He says that the wedding was a brief ceremony in front of a friendly Justice of the Peace who looked like he had married plenty of people before. No, he wasn't a bigamist, he was just good at his job...

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☞**A**nd speaking of marriage, preparations are well underway for **Marc Bolduc's** wedding this coming July. Hiring musicians, finding caterers, bribing in-laws and the like are all part of this sacred institution. Marc says he is really looking forward to it, at least, that's what he says when there's no one around who might report otherwise to his fiancee **Annie**...

Articles & ideas are welcome. Please send them by e-mail to the editor. Deadline for publication is the 7th of every month.

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* MUSIC LOVERS ALERT *

Michael Kelly and **Anna Lin**, with the rest of the members of **Musica Orbium**, under the direction of Patrick Wedd, will be singing a program of British music on Sunday, May 14th, 7.30pm.

Location: Eglise St-Germain d'Outremont, corner Cote Ste-Catherine and Vincent d'Indy, metro Edouard Montpetit. Admission is free, a freewill donation is requested.

Famous Quotes...

- Seen on Pavlov's door: "Knock. Don't ring bell."

- Do not meddle in the affairs of wizards, for they are subtle and quick to anger.
Do not meddle in the affairs of dragons, for you are crunchy and taste good with ketchup.

- Winner, "Papers I wish I hadn't written" contest: Montagnino, Lucian A., "Test and Evaluation of the Hubble Space Telescope 2.4 Meter Primary Mirror" *Proc. SPIE, Large Optics Technology*, Vol. 571, August 1985

- When a cat is dropped, it always lands on its feet. When toast is dropped, it always lands butter-side-down. I propose to strap buttered toast to the back of a cat [butter facing up]. The two will hover, spinning, inches above the ground. With a giant buttered-toast/cat array, a high-speed monorail could easily link New York with Chicago. -- Omni

- "The juvenile sea squirt wanders through the sea searching for a suitable rock or hunk of coral to cling to and make its home for life. For this task, it has a rudimentary nervous system. When it finds its spot and takes root, it doesn't need its brain anymore so it eats it! (It's rather like getting tenure.) "
Daniel Dennett, *Consciousness Explained*

Submitted by Oliver Astley, complements of his father

CIM TOP TEN

Top 10 Signs Summer is Just Around the Corner

10 Bolts of static electricity in the labs decrease to only 4000 Volts

9 CIM's favourite systems programmer Mike Parker makes the switch from winter sandals to summer sandals

8 Fewer snowball fights in the robotics lab

7 Shorts, shorts and more shorts

6 CIM seminar room moved to top of Mont Royal

5 The sound of sun-seeking, fun-loving frolickers almost drowns out the sound of the SARCOS robot hydraulic pump

4 Instead of wandering around in the McConnell lobby deciding where to go for lunch, hungry CIM folk wander around outside deciding where to go for lunch

3 McGill staff are getting ready to spend their Fridays at the beach

2 CIM coffee fans switch their intravenous coffee distribution system over to solar power

1 Two words: CIM Softball!!

Submitted by Paul Mackenzie