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Transputer Controller for a Laser Guided Linear Slide

磁気浮上機構へのデジタル制御の応用

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Background: The Laser-Guided Linear Slide at IIS

This experiment consists of a magnetically levitated linear slider with six active control channels, four for levitation and two for lateral guidance, all of course contact-free. The sensor system is a new and original invention[1),2)].

For a conventional active magnetic levitation a sensor (usually eddy current or capacitive) measures the air-gap between track and slider. This makes precision of the linear movement largely dependent on the accuracy of the sensor target.

In our system vertical and lateral displacements are measured with respect to laser beams pointing in parallel direction to the track from the front. The system basically uses corner cubes on the slider which is thus entirely passive and needs no power source. Measurement is done with three four-segment photosensors fixed to the stator, near the laser source. Five of the six kinematic degrees of freedom of the slider are detected, the sixth being the movement along the track.

A system of assigning control channels to the many magnets had to be found. The current system needs 16 power amplifiers independent of the length of the track, it is possible to reduce this number.

Furthermore, analog electronics was developed, consisting mainly of signal processing for the sensors and of the power amplifiers. Finally our model in Tokyo was equipped with a fairly complex fully coupled multi-channel analog controller and with electronics for switching the magnets according to the position of the slider along the track.

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Digital Control for the Laser-Guided Linear Slide

Analog control is not optimal for this system. Tuning of at least a dozen or more feedback coefficients is delicate as the magnetic bearing system is highly unstable open loop. Furhermore it would be desirable to compensate for any imperfection in the optical alignements and the mechanical setup. Such effects are easlily detected by the very sensitive (0.1 micrometer order) laser photodiodes and can thus in principle be compensated. This would make a relatively coarse setup possible. For instance, non-parallelity of the optical beams, offset errors, non-symmetry and variations of the actuators along the tracks can be fully compensated by a clever digital control.

A visitor at our Lab, Prof. Sinha form the University of Reading (England), proposed to invite someone from Tokyo to come for about two months to his lab and to realize a Transputer based digital control. Transputers are powerful microprocessors with a special architecture highly suited for parallel applications. They include serial links (2-wire connections) with dedicated onchip communication hardware and software thus achieving a more efficient operation for parallel processes than e.g. signal processors. I was interested in comparing them with signal processors in an actual application.

There was the possibility to cover the travel and living expenses by the Miyoshi Foundation. So we built a complete laser guided linear magnetic suspension system at the Kawakatsu Lab (Fig. 1), which I took to London in my suitcase, including 16 channel amplifier and sensor electronics. I was surprised (and disappointed) to see, that I was not held up at the airport security checks with so much "suspicious" equipment.

Building a Transputer Controller for the Linear Slide.

The Univesity of Reading is located in a marvelous park having belonged to a British Lord in the 18th century. The campus includes dormitories, ponds, and forests with rare species of trees. It is only an hour from London by train, 40 minutes form Oxford and a 2 hour bicycle's ride from Windsor castle.

The work on the Transputer controller was carried out with the great help of Peter Moerk from the Universty of Miskolc (Hungary) who was staying at the Reading Lab for one year. The outline of the controller is shown in Fig. 2. The plant has 5 input channels and 8 output channels (four in vertical direction and four in horizontal direction). As the carrier moves along the track, the output control channels are switched to the appropriate amplifer channels. This is done by assigning the 8 control channels to the appropriate amplifier channels over analog switches.

The control can be distributed among the T225 Transputer (integer arithmetic) on the external control board and the foating-point T800 Transputer on a card in the host PC.

After assembly the boards had to be debugged with a logic analyzer. There were surprisingly few problems for boards of such complexity and they all worked in a very short time.

In the last few days the software was written. After some not so simple debugging (no help from the manuals!), timer interrupt and multichannel capabilities were added and the speed could be improved to levels comparable with DSP systems (about 25 microseconds per channel for a 2nd-order control). Finally, the controller could be tested for one

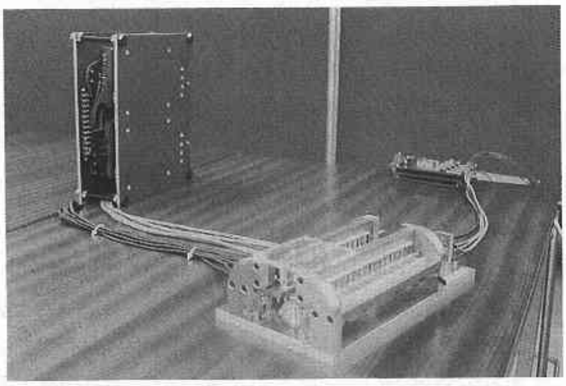

Fig. 1 The laser-guided linear magnetic suspension system for high-precision positinning

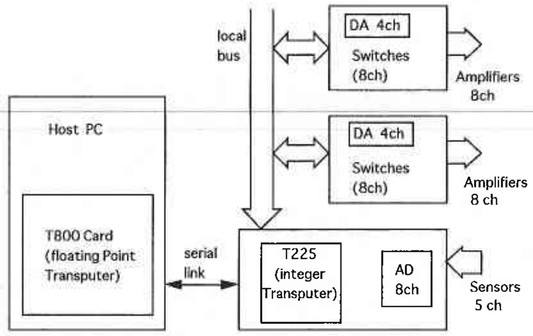

Fig. 2 Transputer controller for the linear magnetic suspension system

degree of freedom.

Assessment of the transputer system

The control program in its present from is a success although, due to lack of time, it has not operated for all channels. Its performance fully meets our high expectations. The pleasant surprise was that it is possible to realize such a controller (8-channel fully coupled with sampling rates in the 100-microsecond order) in such a short time. It is possible to run the 2nd-order control with limited cross coupling on the T225 alone, i.e. without the T800 PC-card. This makes the system extremely attractive in price and development effort, compared to a DSP-based system.

The problems start when going on from this point: As soon as the control algorithm becomes more complex, requiring either higher order or floating-point, the total cost is again comparable to a DSP system.

Since the Transputer system is strongest in parallel operation mode, it is highly dependent, to what extent the control task allows parallel processing. Although the linear slider is parallelizable to a certain extent, it is still quite manageable by a single signal processor, as demonstated subsequently. Therefore the conclusion would be that for this particular application, both Transputer and DSP are about equal. For an application requiring more parallel processing than this, e.g. for certain tasks in robotics control, Transputers will have an edge due to their serial links and clever hardware design.

There was one more problem with the Transputer system. The software, although including some beautiful basic ideas for parallel processing and data exchange, is not enough user friendly. Free choice of software is not supported as well as with signal processors. The manuals are poor.

A signal processor control of comparable cost to the T800-T225 Transputer system has then been realized for the linear slide.

Conclusion

Hardware and software of a Transputer-based multi-channel controller have been realized in the relatively short time of just five weeks. It has been demonstrated that under certain circumstances (low order controller) the performance of a Transputer controller is about equal to a signal processor system of comparable cost and that the transputer controller can be applied to this particular system.

Control of the laser guided linear slide can be parallelized to some extent, but it is clearly not an application where the transputer will be superior. Finally a signal processor system was applied for the control of this system. It allows easy compensation of manufacturing tolerances. The result is a system which can achieve position accuracy down to the limit of sensor accuracy, i.e. in the 0.1 micrometer order for a system operation in vacuum.

The direct comparison of DSP and Transputer on an actual control plant has been most valuable for our further research in advanced mechatronics.

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