Part II: SUMMARY of COMPLETED PROJECT

The purpose of this grant was to support equipment for a new undergraduate laboratory course, entitled "An Undergraduate Teaching Laboratory for Industrial Robotic Manipulation." Funding consisted of $75,000 from NSF and $75,000 in matching funds from CMU's Robotics Institute. In addition, we were able to convince all manufacturers to discount their equipment, sometimes heavily. Consequently, the "effective matching funds" were much better than the formal 1–1 ratio seen in the budget.

The goal of the course was to provide undergraduates with hands-on experience in fundamental manipulation and vision tasks, to better educate our future engineers and industrial managers in the techniques of Industrial Manipulation. We proposed to purchase three robot workcells, with suitable software and vision. We have done so, as described next.

We had originally proposed to purchase three Zebra Zero robot arms. However, as we indicated in our interim report, preliminary trials with one of our research Zebras showed that this robot was not suitable for an undergraduate laboratory. The robot would break too easily. Instead, we decided to work with ADEPT and SONY systems. These have proven to be very reliable.

In our first year of teaching the course, we purchased an ADEPT/GENEX flexible feeder workcell. This workcell consists of a four-degree-of-freedom SCARA-type arm, a three-level recirculating feeder, and a vision system. The workcell represents state-of-the-art parts feeding technology.

In our second year, we acquired a SONY SMARTSystem. These normally are extremely expensive, but we managed to acquire, by talking directly with Sony Research in Tokyo, a good used system for about 10% of standard cost. This system, like the Adept system, contains a four-degree-of-freedom SCARA arm. It also includes a SONY APOS parts orienter, and various feeders for circulating parts pallets. The system came with a working demo for a subassembly of the SONY Walkman. This system is representative of a high-tech industrial system in actual use.

Finally, in our third (current) year, we purchased another ADEPT system, consisting of an arm and a vision system.

In summary, we have three similar platforms. Two platforms are nearly identical, including nearly identical software and vision support. One of these two platforms has the added benefit of a recirculating feeder. And the third system is taken directly from a factory floor. We believe we have thus assembled the state-of-the-art in robotic manipulation technology. We were lucky to enter the market right after some new systems came on line, and thus were able to purchase equipment better than what we envisioned in the original proposal.

Part III: PUBLICATIONS

There have been no publications to date, but it is too early for that. We are currently in our third year of teaching the course. Although the grant has expired per se, the equipment is whole and healthy. We intend to keep the course running in the future. Moreover, we intend to percolate the benefits of the course down into the earlier undergraduate robotics courses, by making the equipment available for advanced projects in those courses. As time progresses, we expect eventually to construct a laboratory textbook, and disseminate that book to other universities, as proposed. We have in fact already disseminated some of this knowledge verbally.

Finally, our purchasing and testing efforts have had an unexpected indirect dissemination effect. Those efforts have placed us in touch with various vendors and integrators. As a result we have had offers from local integrators to come and give guest lectures in the course. And others have suggested that we direct our students to them for future robotics jobs. The goal of spreading the word, expanding our students' robotic horizons, and establishing ties between universities and industries, was one of our main motivations for creating the course. Such dissemination of knowledge is hard to measure, but we are definitely happy to see it.

We list here some of the projects that students have undertaken in the course:

1. A chip sorter. The system would recognize different chips on a circuit board, remove the chips from the circuit board, and sort them into chutes for recycling.
2. A robotic sculptor. The system would carve shapes from foam, based on CAD models. The robot used a Drumel tool for the actual carving.
3. A golf-playing robot. Given a hole, a golf ball, and obstacles, the robot would use its vision system to hit the ball toward the hole, repeating the process until success.
4. A Lego builder. The system used the recirculating feeder and vision system to sort and orient Lego blocks, then used the robot to build a structure from those blocks.
5. One of the current student projects is to build a robot drawing system; the robot is supposed to sketch images it sees with its vision system.
6. One of the current student projects is to build a robot that can write cursive script.
7. One of the current student projects is to arrange dominos in various cascade patterns, then tip one of the dominos and let the cascade begin.