University of Florida
Department of Electrical and Computer Engineering

EEL 5666
Intelligent Machines Design Laboratory

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Final Written Report: GOPHER

Gopher is a robot which exhibits the following behaviors:

1. Wanders tabletop without falling off
2. Collects three disks, one at time, depositing them at “Home base” (an IR beacon)
3. Stops at “Home base” when all objects collected

The Gopher utilizes the MTJPRO11A controller board containing the Motorola MC68HC11 due to its small size, low cost, and popularity among the class. Due to time constraints, the TJ-PRO wooden platform was used in behavioral development while a custom platform was designed concurrently. The name Gopher comes from the common play-on-words to “go for” things.

Purpose

As shown in figure 1, the Gopher's function is to collect the disks, one at a time, and place them near the beacon. Originally I had hoped Gopher would never fall off the table, knock disks off the table, and cope with hardships such as disks being near the edge or bunched together, however, stayting on the table and finding the beacon proved to be difficults tasks, so most time spent developing behavior was on those tasks. Finding and gripping foam-rubber pucks proved to be fairly simple.

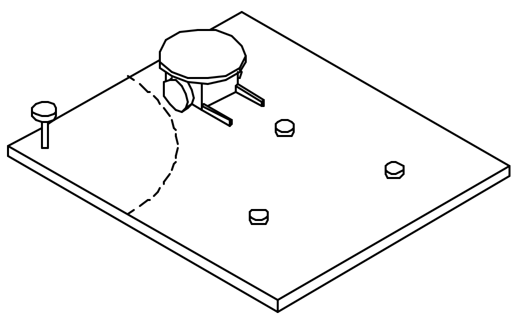

Figure 1. Gopher general concept.

Platform

The TJ-PRO wooden kit was used to develop behaviors and mechanisms, while a custom platform was designed concurrently. The picture below shows a nearly finshed Gopher with his test mule in the background. Notice the test mule is merely a TJ-PRO with cardboard attachments (glued in place). Later these cardboard pieces would become templates for Gophers wooden base parts. The gripper is able to open and close, and also raise straight up to avoid dragging pucks. It is described in the actuator section. Gophers special sensor is a laser (pointer) that surrounds the robot via mirrors. Pucks break the beam and CDS cells are used to detect the change in the laser light. This device is descibed in the sensors section. Also in the sensor section are table-edge-detectors, which are IR detectors mounted directly ahead of each drive wheel. Three more IR detectors are mounted near the top of the robot to serve as (beacon-seeking) eyes.

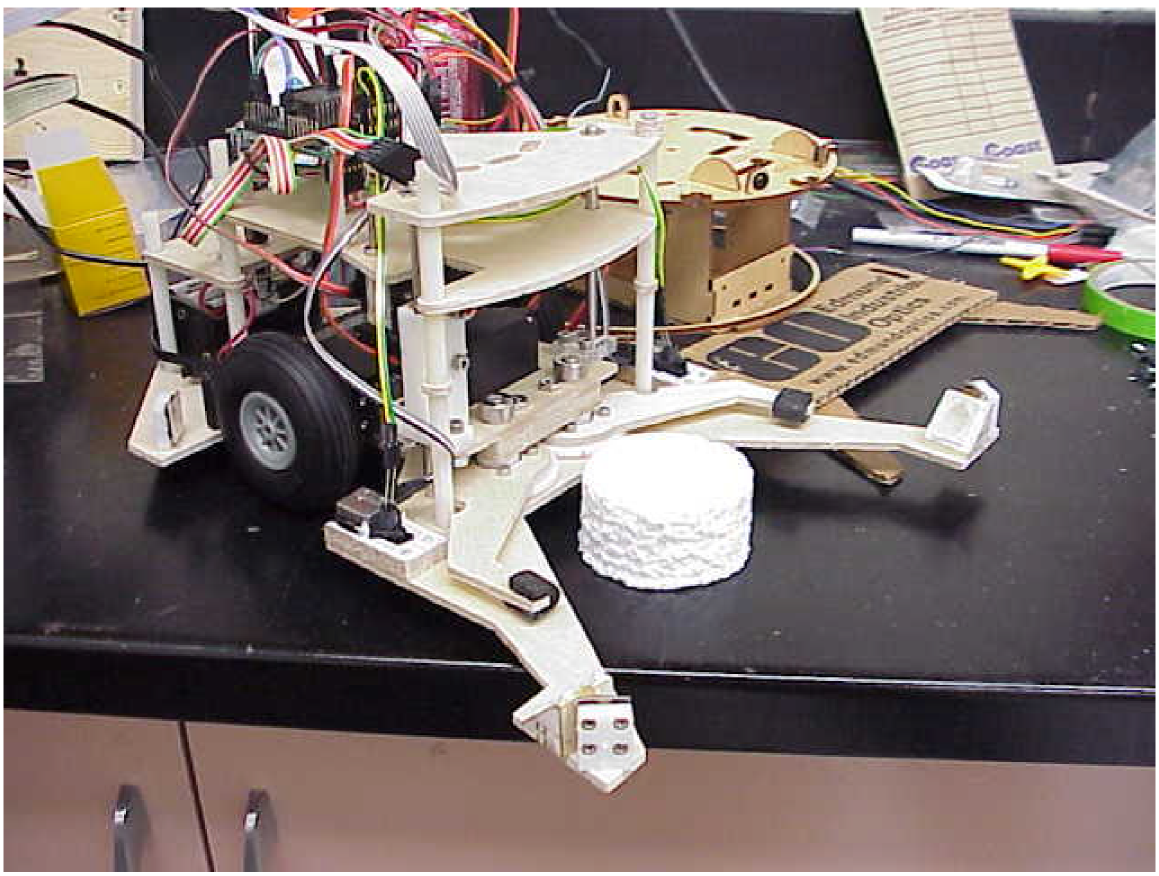

Figure 2. A nearly finished Gopher and his test mule in the background.

Sensor Suite

The following table lists Gophers sensor suite, after which each sensor is descibed in more detail.

Qty	Type	Function
3	IR Detectors	Beacon Detection
2	IR Detectors	End-Of-World (Table Edge Detection)
3	CDS Photocells	Object Detection via Laser Beam

Table 1. Gopher sensor suite.

The IR detectors used to find the beacon are Sharp IR cans and are hacked to produce an analog output according to the Mekatronix TJ-PRO manual.

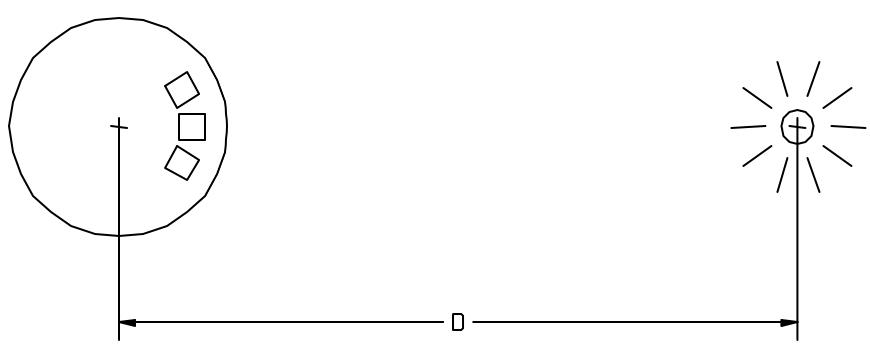

Figure 3. Beacon Detection.

D	*ANALOG*
1’	123
2’	121
3’	115
4’	102
5’	95

Table 2. Typical analog vaules from an “eye” looking directly at the beacon.

The creation of the beacon was critical to being able to seek it out. In one configuration, the beacon was detectable at 10’, but the robot could not distinguish 1” from 12” at close range. On the other hand, to get good resolution “up close”, the maximum range dropped to 5’. The beacon was made from two high-output IR LEDs, a 6V, 300mA power supply, a 555 timer (to get a 40kHz modulation), and a wooden base. A paper shield was glude over the output slot to try and smooth out hot and cool spots in the IR field.

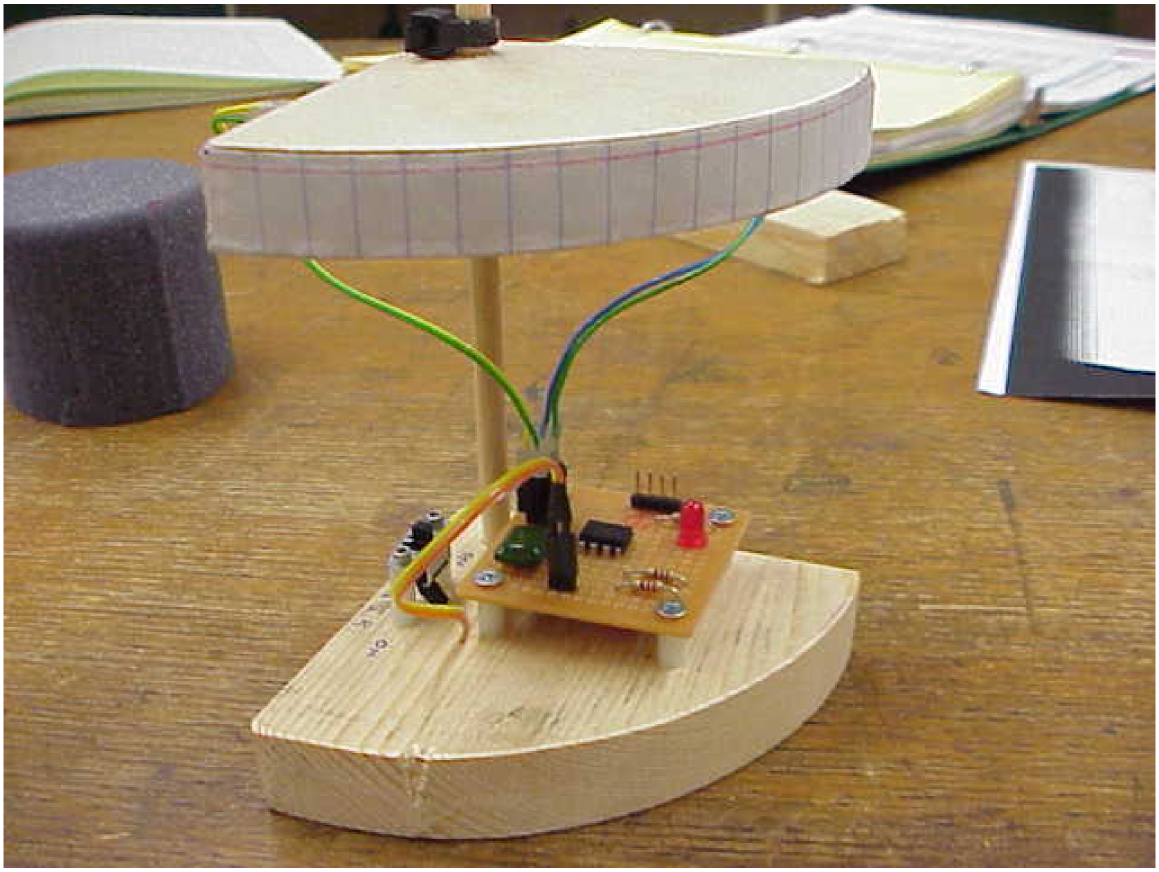

Figure 4. The IR Beacon.

The edge detectors are downward looking IR cans and are hacked in the same manner as are the “eyes”. In addition, each edge detector has an IR LED mounted directly to the detector. This produced a very robust detector. When suspeded about ½” over the table the IR can is nearly saturated over nearly any surface (value = 127, typically.) When the detector passes off the edge the IR from the LED is dissipated out ward to the floor, and hence the analog value drops significantly (to about 90). An ambient room seems to generate values in the 80’s usually for all the Sharp cans.

Since Gopher cannot "see" the pucks at any appreciable distance, the development of the special sensor (a class requirement) is to allow Gopher to detect the pucks when they are encountered in close proximity. This sensor was developed from a laser pointer, some mirrors, beamsplitting glass plates, and CDS photocells.

Figure 4 shows the layout of the laser pointer and the optics. The laser is first steered along the right side of Gopher with a mirror. 30% of the laser is split at the first beam-splitter and directed into a CDS photocell. The remaining 70% of the laser is steered across the front of Gopher and into another beam-splitter. 50% of the existing 70% (net 35%) is directed into the second CDS photocell. The remaining 35% of the laser is steered along Gopher's left side and into a third CDS photocell. So, each CDS cell is receiving roughly 1/3 or the original laser.

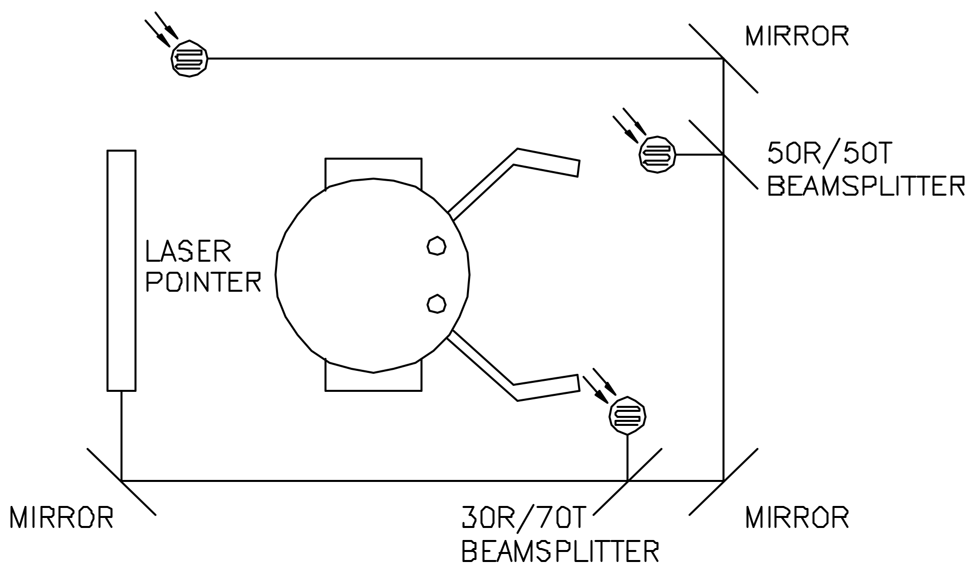

Figure 5. Laser Layout.

Pucks are detected when a segment of the laser is blocked. For example, blocking the beam between the second mirror and the 50/50 beam splitter, simulates the presence of an object just in front of Gopher's gripper (see Figure 5). This case will cause the last two CDS cells to go dark. This condition is labeled "1 Lit" in the data table, since only the first CDS cell would still be illuminated by the laser.

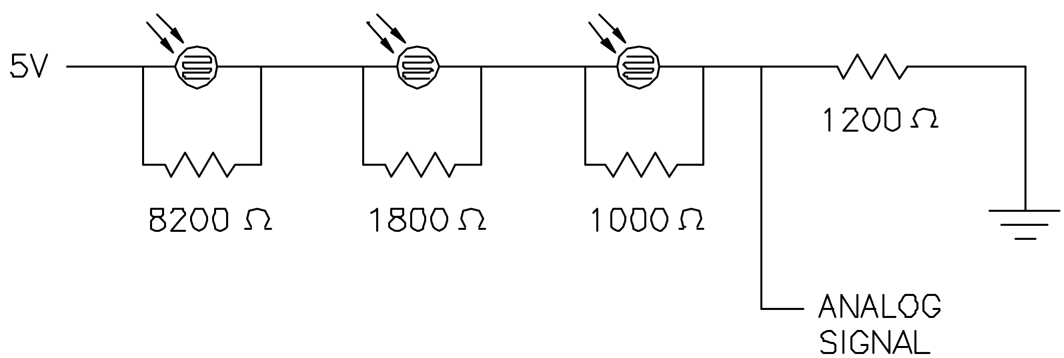

Figure 6. Analog circuit for Laser and CDS cells.

The data in Table 3 shows the analog values that result from interrupting the laser in any one of three locations. "3 Lit" corresponds to no detection.

Condition	Bright Room	Dim Room	IMDL Lab
3 Lit	140	141	142
2 Lit	120	116	111
1 Lit	85	81	78
0 Lit	61	53	47

Table 3. Analog values for 4 puck detection conditions (analog range: 0-255).

The beamsplitter is a small glass plate (about $20 each). In the photo below, the laser come in from the left, 50% is reflected upward into the CDS cell, and 50% passes straight through.

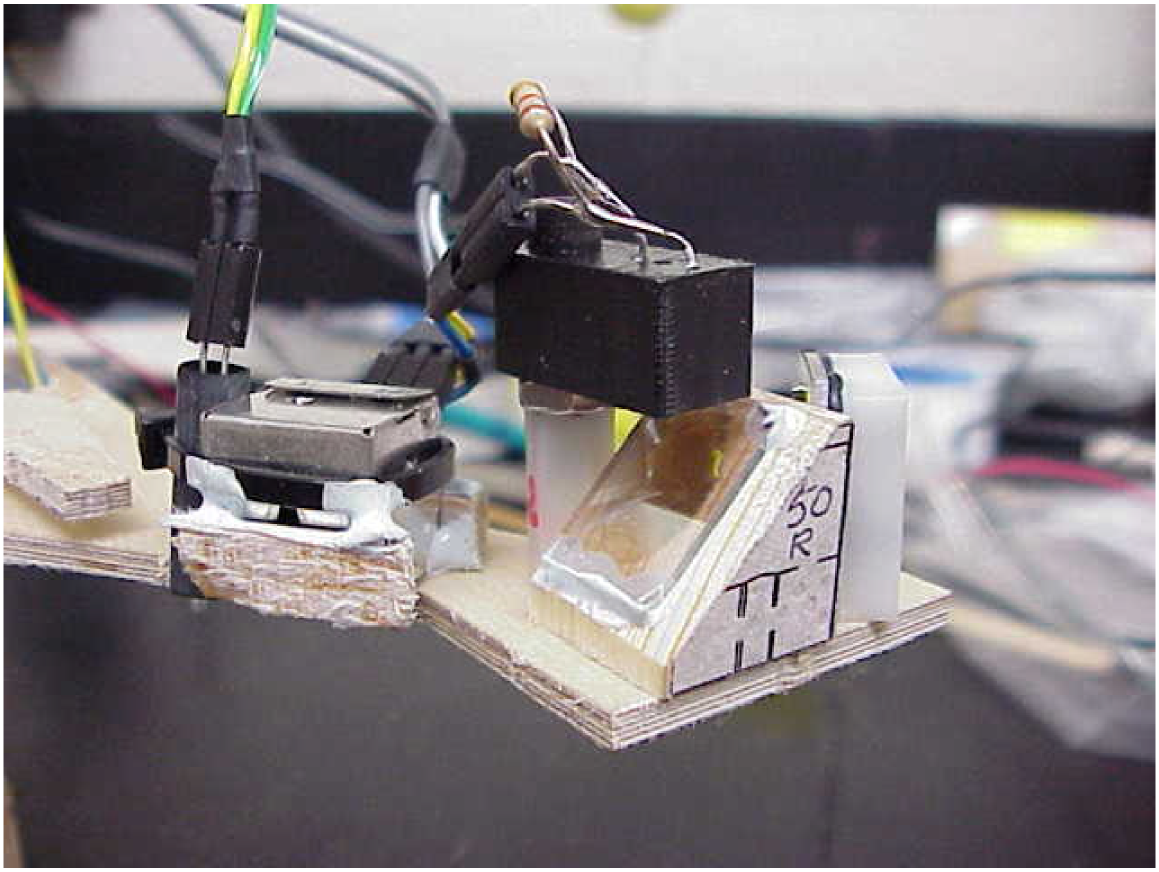

Figure 7. Beamsplitter and CDS cell assembly.

The laser is aligned with mirrors. Each mirror mount has four screws that pass through small rubber O-rings. The mirror has threaded holes to accept the screws (the mirror was cut from a scrap hard disk platter.) Tightening or loosening the screws allows the mirror to gimble on the mirror mount (see figure 8).

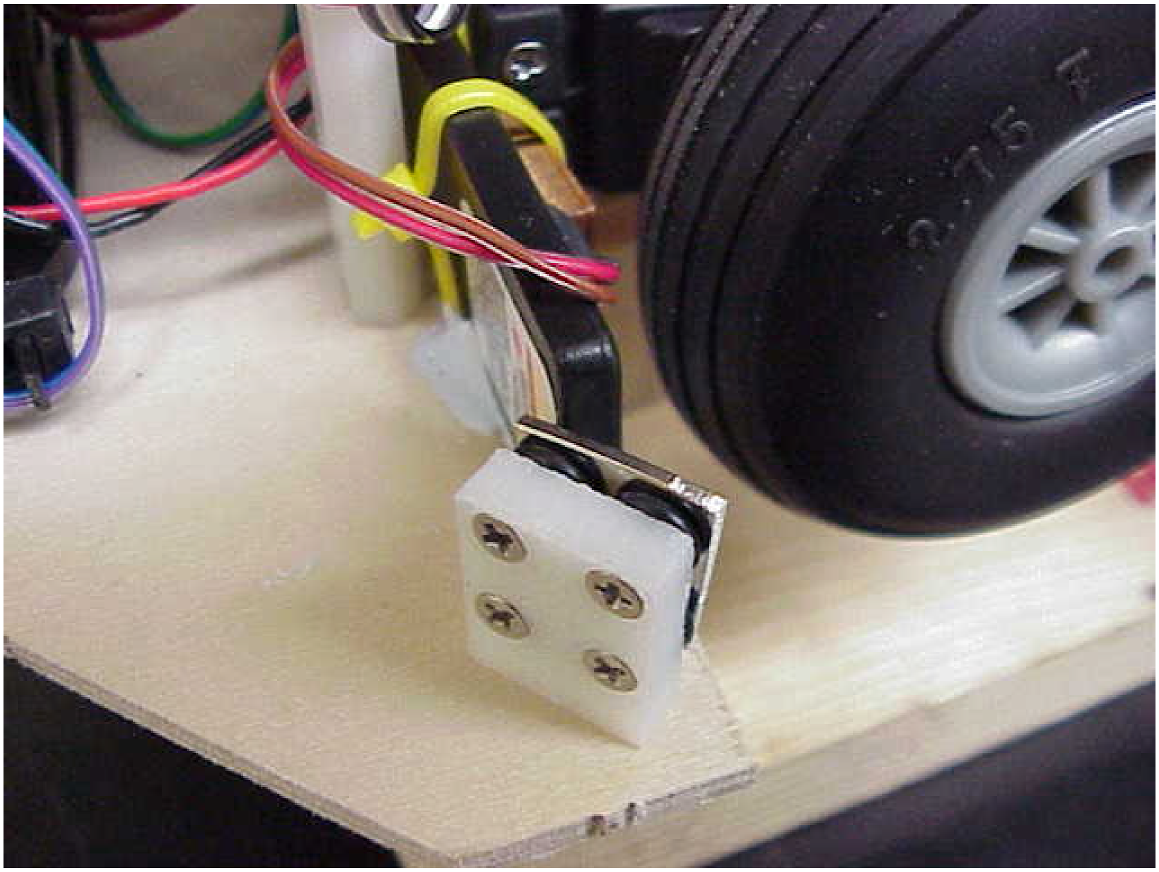

Figure 8. #1 Mirror at Laser Head.

Actuation

Two “hacked” servomotors as described in the TJ_PRO manual are used to drive Gopher. Two additional stock servos are used to actuate the gripper. One servo opens and closes the jaw, and the other raises or lowers the gripping unit.

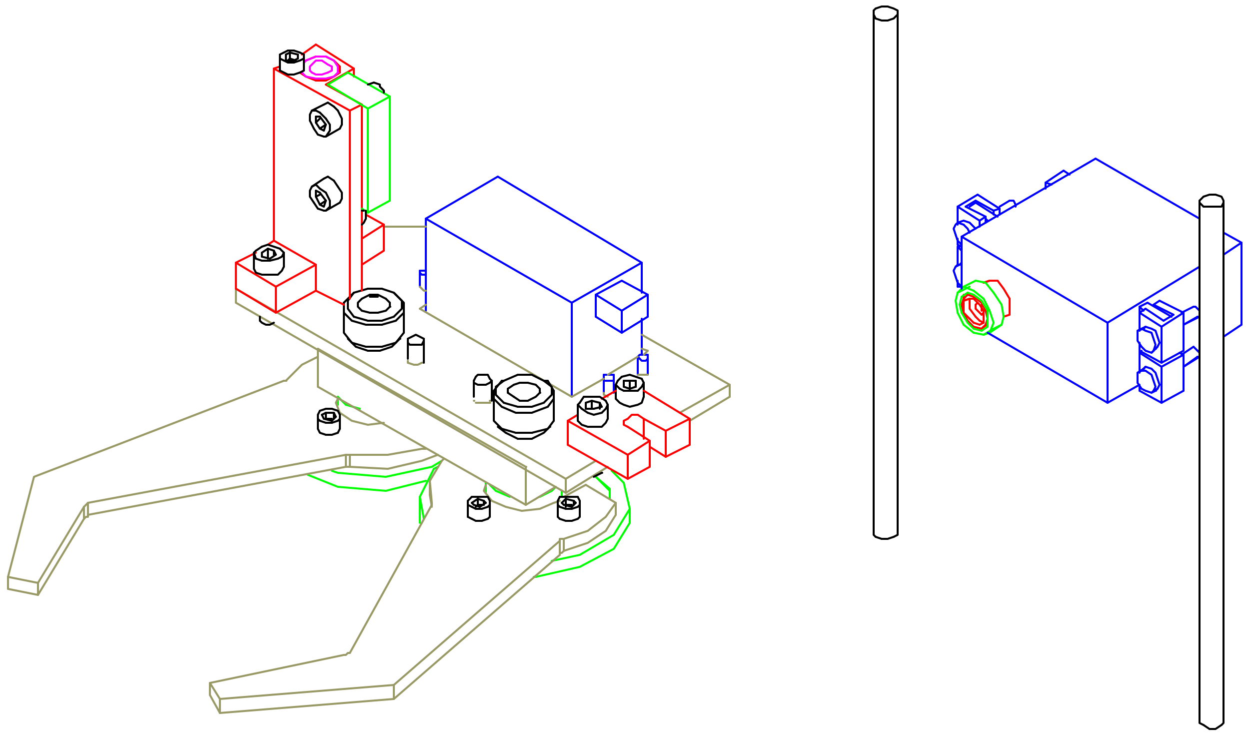

Figure 9. The gripper jaw and the rail mechanism on which it is raised and lowered.

Qty	Type	Function	Implementation
2	Servos (Modified)	Locomotion	Open Loop
1	Servo	Gripper	Open Loop
1	Servo	Lift	Open Loop

Table 4. Actuators.

All the actuators are driven open loop. For the drive mechanism, it means that there was no expectation that the robot would go straight. It wanders the table anyway, so that was not a concern. For the jaw, it means that when the command is given to close, it is assumed a puck is captured. The lift mechanism need only not drive past it mechanical constraints, so open loop was acceptable.

Behavior

Gopher wanders the table essentially at random, turning way from the table edges, and gripping pucks when ecountered. The pucks are collected one at a time. After the third puck is collected and deposited near the beacon, the robot stops.

In order to accomplish this, the robot must be calibrated to the enviornment just prior to running his code. Gopher does not self-calibrate, so this is done manually and source code is modified accordingly. The beacon is the first item which is calibrated. Gopher is placed about 1' from the beacon to determine the threshold at which Gopher will drop pucks (eye_test.s19 is downloaded.) Next the CDS cell circuit is calibrated. The mirrors are easily adjusted to get a good red spot on each cell, so these thresholds rarely required modification (CDS_test.s19 was used for this.)

Conclusion

The photo of the final assembled Gopher shows the laser hitting a pink foam-rubber puck (2.6" diameter). The diameter was chosen to be the same as a soda can. Although the robot can collect cans this was not implemented. (The height of the cans blocks the view of the beacon, and would be a difficult behavior to implement, despite the alure that the robot can distinguish cans from pucks due to the blocked view.)

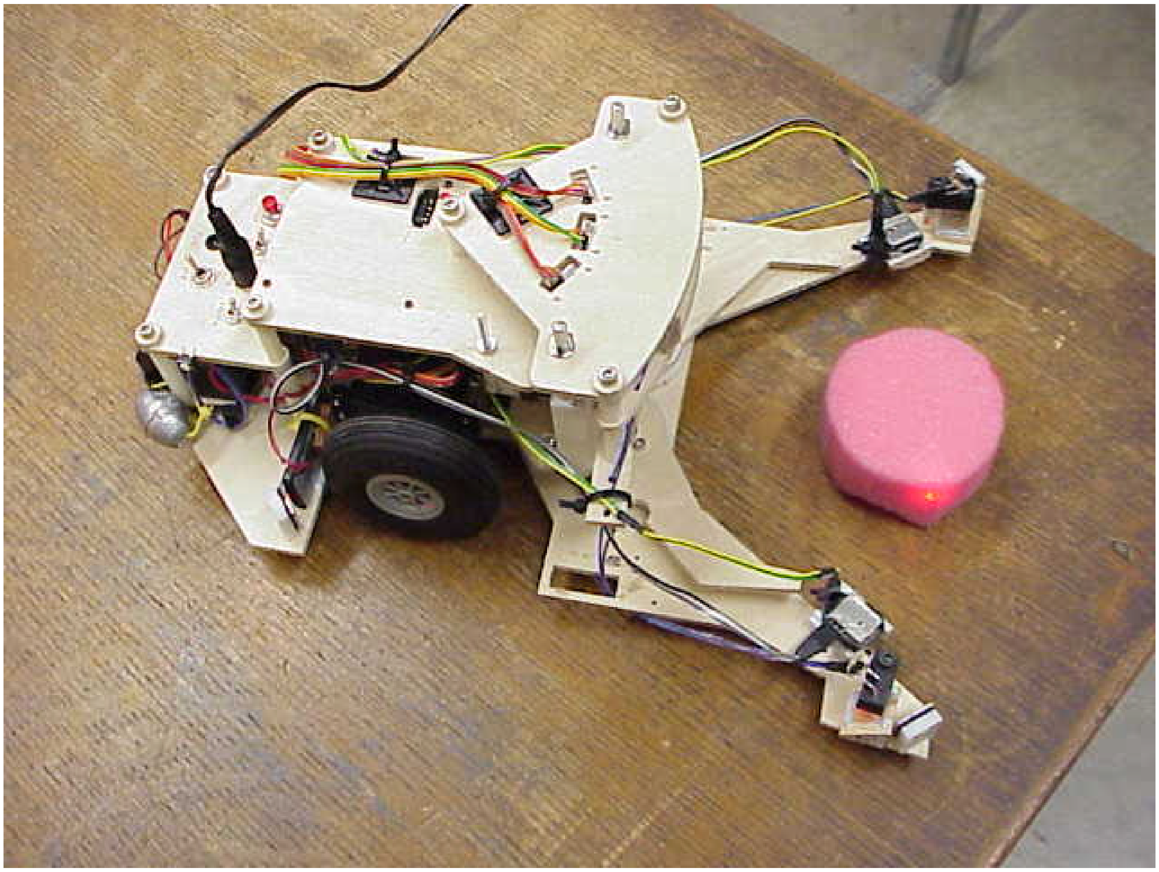

Figure 10. Final Gopher.

Also note that the edge detectors have been moved forward – they are glued to the chassis out near the mirrors.

On a very good day, Gopher can find and collect three pucks. But the table edges are difficult to avoid and he accasionally drops a wheel off the side.

The beacon is sometimes difficult to detect when the robot gets in cool or hot spots in the IR field. This causes problems in the behavior because the assumption was made that since there is no straight line across a table from the robot to the beacon that leaves the table, the edges are ignored during the beacon seeking beahvior. This was not a good idea, because, if he goes to the wrong “beacon”, he will go off the table.

Other problems seem to come from the fact that the performance of the drive mechanism seems to deteriorate as more behaviors are added to the source code. Originally, the robot was expected to move slowly, and this was possible on the test-mule. Once the final robot was built, the drive motors did not respond well to commands that were less than "full speed". This resulted in relocation of the edge detectors late in the project (farther ahead of the drive wheels). The robot never hit the floor, only because I got good at catching him. Two edge detectors were not enough to resolve the table navigation to the point where I would let him wander "unsupervised".

Future Work

Should Gophers development continue here are some things which will improve his behavior:

1. Make a new base pan in order to relocate the edge detectors out farther from the drive wheels.
2. Add at least one more edge detector.
3. Improve IR beacon to clean up hot an cool spots in the IR field.
4. Diagnose drive motor problem in order to get consistent lower speeds.
5. Implement Interupts or software to prioritize edge detection.
6. Add sensors to prevent inadvertant contact with pucks (at the forward mirror locations) – IR emitter detectors are my first choice.

7. Add another skid, so the robot sits on four points at all times – to take some weight off the drive wheels.
8. Add limit switches to the grip and lift mechanisms to prevent damaging the gears.

Credits

Thanks go to the IMDL staff, Dr. Antonio Arroyo, Rand Chandler, Scott Norman, and Dr. Eric Schwartz for their input and instruction.

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