# Mechatronics Project Report

## Introduction

Robotic fish are utilized in the Dynamic Systems Laboratory in order to study and model schooling in fish populations, with the goal of being able to manage aquatic ecosystems. Such a tool could be beneficial in mitigating the ecological damage in industrial disasters. Currently, lab members must immerse their hands into tanks in order to retrieve the robotic fish (shown in figure 1) in the course of an experiment. Performing this task while manipulating electronics is a hazardous combination. Our goal is to design an autonomous robotic arm to retrieve and place robotic fish, thereby relieving the scientist of an unpleasant and potentially unsafe task.

**Figure 1 The robotic fish**

## Design Overview

### Arm Design

The fishing arm is composed with two servos providing articulation in two directions (see Figure 2). A rigid arm is equipped with a net that can be lowered and raised into and out of the tank. The presence of an incoming fish can be detected with an infrared probe. A fish passing between the emitter and sensor triggers the microcontroller to prepare to capture the fish.

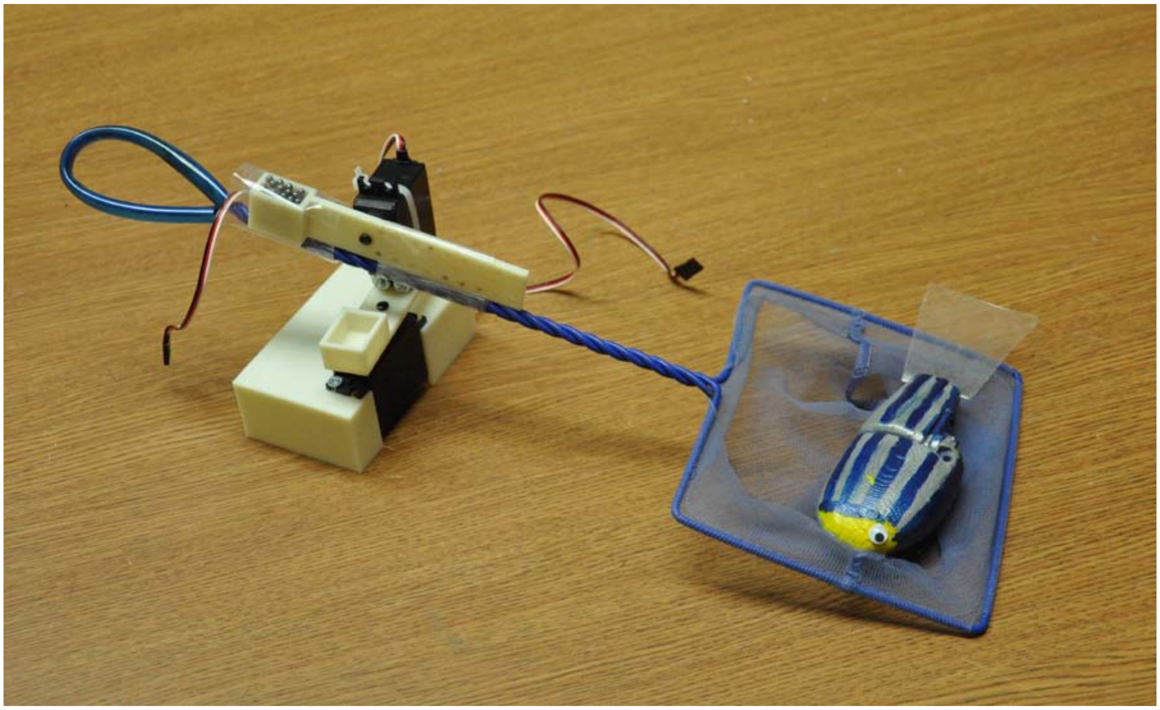
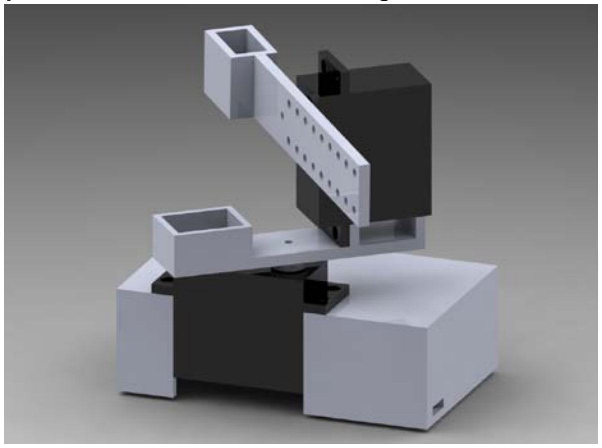


**Figure 2 Servos in housing with base, arm, and net attached.**

## Arm fabrication

The robotic arm was created in SolidWorks, (see Figure 3), with two degrees of freedom. Starting at its base, the robotic arm was designed with a roll joint followed by a pitch joint. The end effector was a fish net to catch the robotic fish. Counter weight slots were included in each linkage of the robotic arm to balance the weight of the servo or fish net. The prototype parts fabricated from ABS plastic for the robotic arm were printed on the Dimension 3D printer. The printed parts were assembled with aluminum nut and bolts and attached to the servos. Note, the robotic arm originally had holes in the last linkage for the fish net but was not used.



## Servos and Control

The fishing sequence begins at a ready state, during which a servo holds the arm steady above the water. When the operator is ready to begin fish retrieval, he can push the tact switch to engage the waiting state, during which the net is lowered into the water. In order to prevent the net mesh billowing up from the flux of water, the arm first overshoots the target position by a few degrees. Then the arm raises the net back up to target position, thereby causing the reverse flux of water to help push the net mesh back into place. At a trigger induced by optical sensing of the fish, the arm then raises the net back out of the water. In the final stage of the sequence, the arm is rotated at its base perpendicular to the water, bringing the captured fish to the operator.

Clearly two servos are employed to move the arm in the parallel and perpendicular planes with respect to the surface of the water. The rotation of the arm perpendicular to the water's surface is controlled by a standard type servo. With this type of servo, the different positions of the fishing sequence are encoded with pulse width modulation, using pulse width durations in the range of 1000 to 2200 microseconds. The standard servo is optimum for controlling the levering of the arm, since the sequence of positions in fishing mode require fine precision.

A continuous rotation servo is used at the base of the arm assembly to move the arm from its ready position to a position more convenient for removing the fish. Motion in the continuous rotation type servo is also coded by pulse width modulation, but only in such a way that direction and speed can be controlled. This property makes for less precision in positioning the arm, but such precision was deemed acceptable for bringing the retrieved fish to the operator.

## Digital and Analog Sensing

Unlike sport fishing, which may seem to require a sixth sense, the sensing problem in the fishing arm system is simplified by having direct control over the target robotic fish. The fish can be steered by the operator towards the net, thus the sensing problem is essentially reduced to object detection.

Objective simplicity notwithstanding, underwater object detection presented a challenge. Range sensing by ultrasonic echo was predicted to be the easiest way to determine the presence of a fish. However, the surface of the water proved to return an echo, rendering the PING sensor blind to anything beneath the surface. Attempts to sequence the operation of the PING sensor in such a way as to detect an echo from a previous pulse (i.e., an echo from beneath the surface) were complicated by the relatively long 750 microsecond insensitive period of the device, combined with the fact that water carries a sound wave more than four times faster than air.

Optical sensing was determined to provide the ultimate solution. However, detecting the reflection or shadow of visible light was ruled out due to the high power required either to sense light across the width of the tank, or to sense reflected light from a small object an unknown distance within the tank.

### Digital IR detection

In the final design, an infrared (IR) emitter-detector pair is used in a shadow detecting configuration. The IR emitter's beam is directed at the detector such that there is normally a TTL low signal on the output pin of the detector, indicating the presence of IR light. Whenever an object occludes the IR beam, the detector signals TTL high. The shadow detecting configuration was chosen over reflection to prevent spurious reflections from the opposite wall of the tank. Despite the electromagnetic wave absorption properties of water for light outside of the visible spectrum, this IR detection scheme proves to operate reliably across a tank with 45 cm width. It is unclear how well this particular solution would scale to larger tanks, but in the case that two walls of the tank are out of range for the emitter-detector pair, then presumably operation can be extended by switching to an IR reflection scheme.

### Analog Detection: Operator Instruction

A tactile button is used to provide simple analog interface to the operator. As described above, the button is available to prepare the arm for the fishing sequence.

## Circuits

### Servo Modules

Both servos are connected via servo extension cables to the servo ports on the Board of Education.

### Sensor Circuits

As described previously, the sensing requirements of the fishing arm are light and only call for simple circuits.

### IR Emitter-Detector

The infrared emitter is connected through PIN 5 with a 1KΩ resistor, limiting the current sink on the pin to less than 4 mA (assuming at least a 1.5 V drop in practice across the IR LED). For the 45 cm tank tested, a 220Ω resistor was used, keeping the source on the pin still under 16 mA. The IR detector is powered across $V_{DD}$ and $V_{SS}$, and the TTL pin is connected straight to PIN 6. The detector itself is extended remotely through a link of servo extension cables. *Note that the pin map for the IR detector has high and low in the place of black and red cables on the servo cables.*

In addition to the detection unit, a red indicator LED is sourced by PIN 0 across another 220Ω resistor for visual feedback regarding object detection. When both LED are sourced simultaneously, the total current on the lower bank of pins is under 32 mA.

### Tact Button

The normally open tact button is wired to connect a voltage divider to PIN 8 when the switch is closed, at which point voltage on the pin goes high.

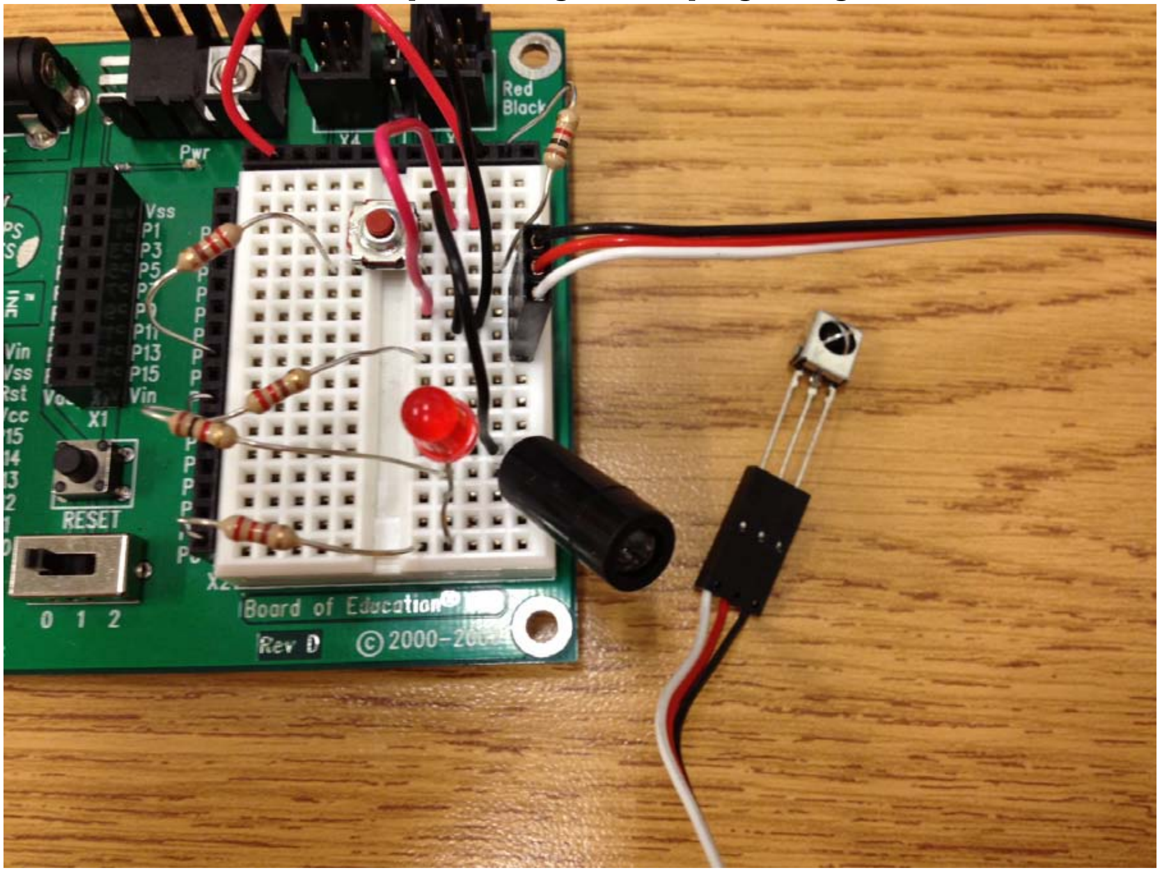


Figure 3 Circuit prototype breadboard

## Conclusion

The prototype performs the task of retrieving the robotic fish from a water tank. In the implementation we followed the guidelines in order to fulfills all the requirements.
The main challenge resulted to be the detection of the object by means of a sensor, whereas we did not encounter particular problem in modeling the mechanical aspect.

## Parts List, Prototype Cost, and Cost Analysis

**Parts Used for Prototype**

- Basic Stamp2 microcontroller ($50) and Board of Education ($70)
- continuous rotation servo ($13)
- standard servo ($13)
- IR LED ($1)

- IR detector ($5)
- fish net ($5)
- assorted discrete components ($5)
- 3D printed servo housing

The total materials cost of constructing the prototype is $162. Clearly the simple control of the arm could ultimately be performed by a low cost chip, bringing the cost down considerably.

## Possible improvements

Starting from this preliminary version, some enhancement can be applied to the prototype. Based on our experience in the implementation of this project, we suggest some possible issues at three different levels.

1) In order to make the structure more ergonomic, the design of the forearm could include directly a support for the net. This can improve the performance of the robot because it would avoid vibration propagation and overloading.
2) In order to reduce the probability of false positive detection, another detecting sensor can be implemented. This new sensor should work in parallel with the main IR sensor.
3) In order to avoid the damaging of the electronic components caused by water splashing a waterproof cover should be installed.

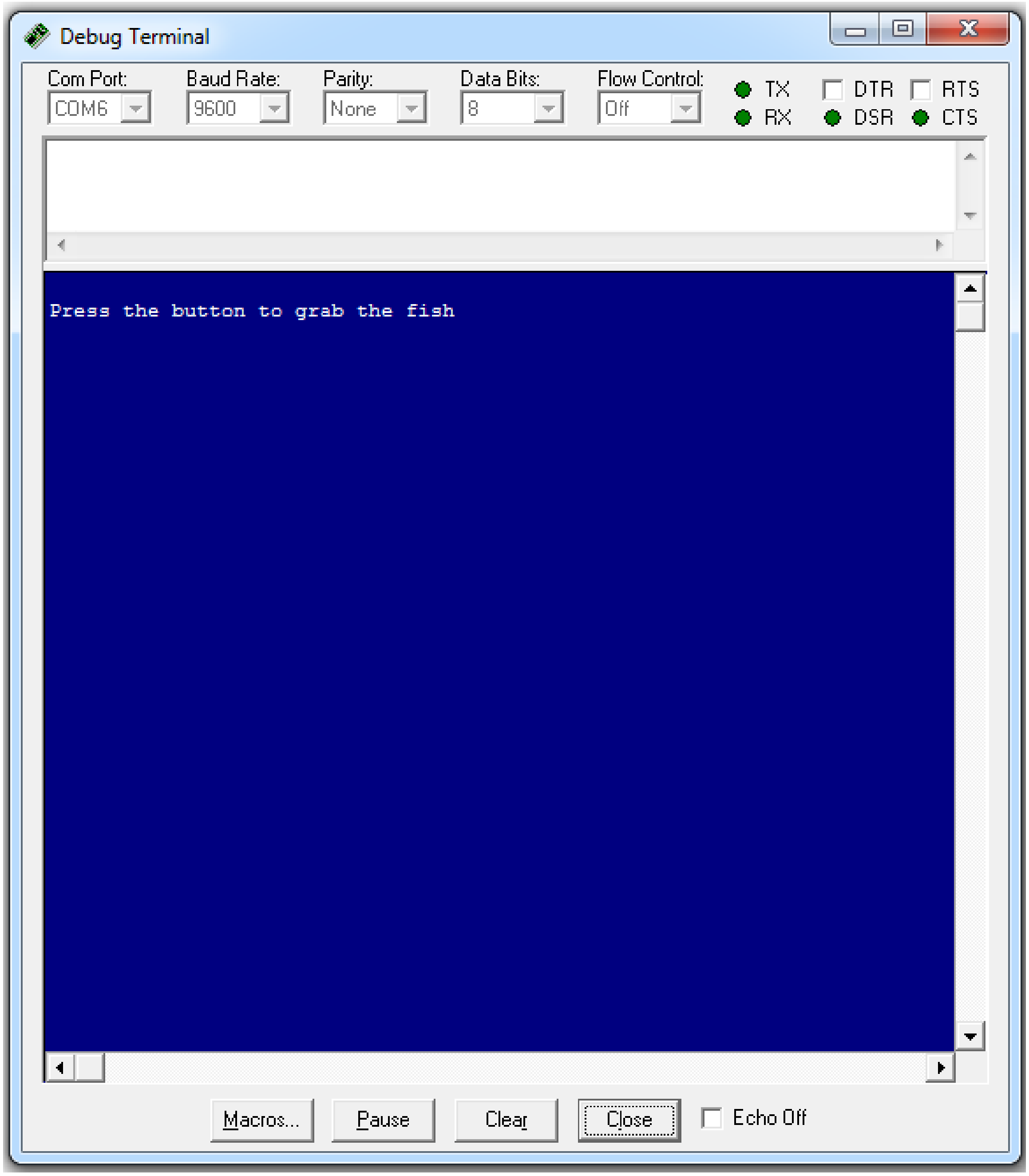
## PBasic Code

1) First variable are declared

```
' {$STAMP BS2}
' {$PBASIC 2.5}


counter  VAR Word
irdetect   VAR Bit
btnWrk   VAR Word
```

2) The code enters a loop and leaves it as soon as the button is pressed

```
DEBUG CR, "Press the button to grab the fish"


DIR8=0
DO
LOW 8
BUTTON 8, 1, 255, 250,btnWrk,1,Grabbing
PULSOUT 14, 1050
PAUSE 20
LOOP
```


Debug Terminal
Com Port:
COM6
Baud Rate:
9600
Parity:
None
Data Bits:
8
Flow Control:
Off
TX
RX
DTR
DSR
RTS
CTS
Press the button to grab the fish
Macros...
Pause
Clear
Close
Echo Off

3) The forearm goes down

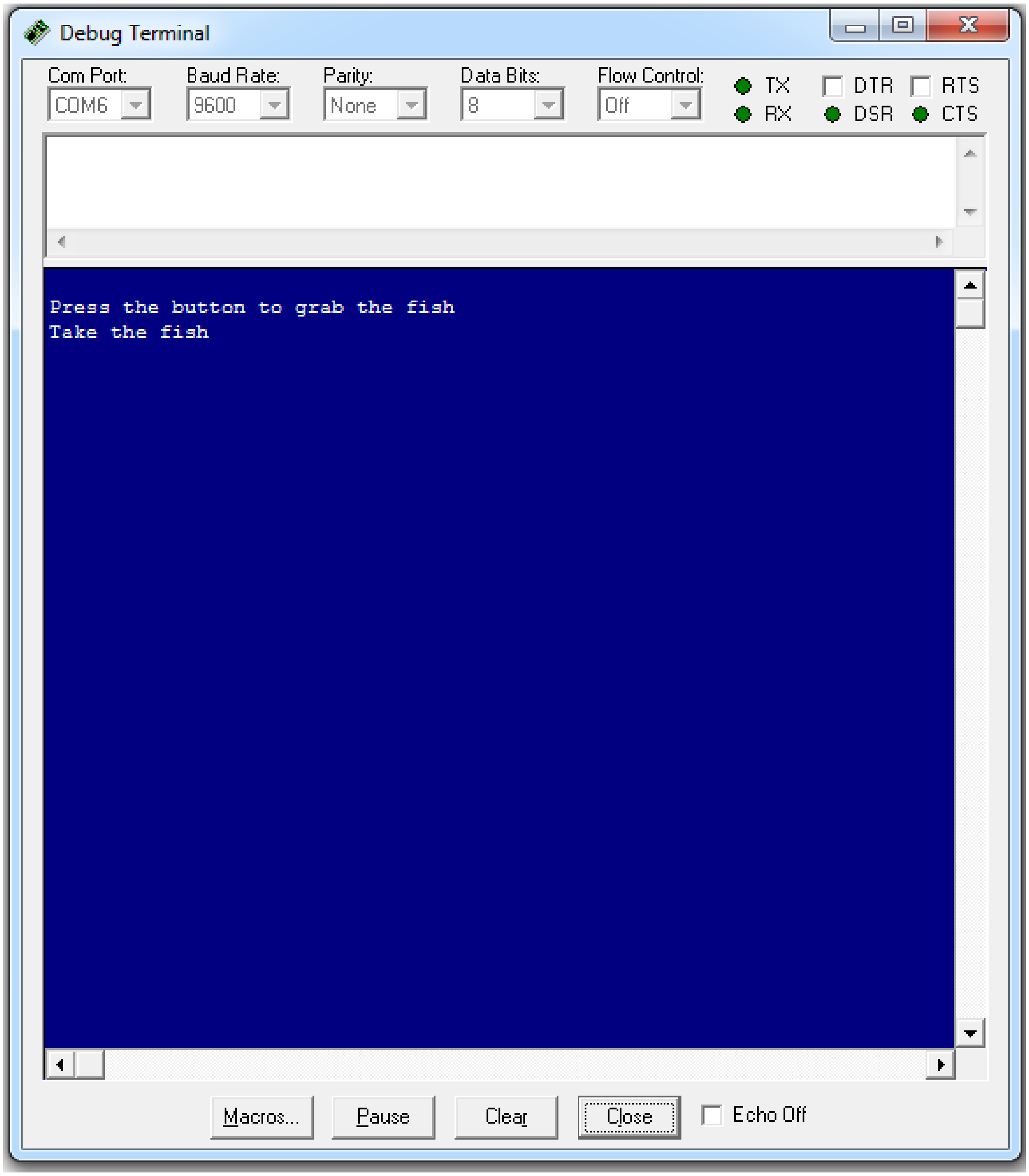
```
Grabbing:

FOR counter=1 TO 70
PULSOUT 14, 775
PAUSE 20
NEXT


PAUSE 1000
```

4) The code enters in a loop and leaves when the detection output is positive

```
Waiting:


FREQOUT 5, 1, 38500
irdetect = IN6



IF irdetect=1  THEN


FOR counter=1 TO 100
PULSOUT 14, 1150
PAUSE 20
NEXT



FOR counter=1 TO 20
PULSOUT 12, 700
PAUSE 20
NEXT
FOR counter=1 TO 3
PULSOUT 12, 800
PAUSE 20
NEXT


GOTO Retrieving


ELSEIF irdetect=0 THEN
GOTO Waiting

ENDIF
```

5) The forearm goes up and the arm rotates out of the tank

```
Retrieving:

PAUSE 2000

FOR counter=1 TO 20
PULSOUT 12, 800
PAUSE 20
NEXT
FOR counter=1 TO 3
PULSOUT 12, 700
PAUSE 20
NEXT
```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