Robotic Headlamp Manufacturing

Manufacturing

ENGR 480

Allan Sierra □ Gurkarn Gill □ David Garcia □ Theodore Zirkle

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Machine Instructions

Loading the machine:

One of our main goals when designing this machine was to ensure that it would be easy for the technician to load it, even when the machine was running. We met this goal with the use of three feeders, one for each part that makes up the Headlamp.

The steps to load the machine will be presented next, using Figures 1 and 2 as a guide. Feeder 1 will be the one to the right of the picture, Feeder 2 the one in the middle, and Feeder 3 the one to the left. Upwards orientation is considered to be when the Headlamp is resting on the bottom of the bottom piece.

1) Place the bottom piece of the Headlamp into Feeder 1, oriented so that it is faced upwards.
2) Place the Battery packs into Feeder 2, oriented so the lamp is facing upwards.
3) Place top piece of the Headlamp into Feeder 3, oriented so that the extrusion with a hole for light to shine through is facing upwards.
4) Make sure that the Bed is clear.

Starting the machine:

Starting the MOTOMAN robot to begin manufacturing the headlamps is a simple process if using the pendant controller to control the robot. Note you must have associated files to begin with the robot arm.

1) Turn on the main power of the MOTOMAN robot and wait for the pendant to boot up
2) Select the job named 2016HEADLAMP by selecting job from the left side of the main menu
3) When the job is selected make sure you move the cursor to the top of the code (where the lefthand column on the screen shows 0000)
4) Turn the key found on the top to play mode
5) Press the Servo on Ready button on the pendant to unlock servos
6) Press the large green button labeled start to begin manufacturing

Once the start button is pressed the robot will continue until either you manually pause the robot manually by either pressing the grey hold button beside the halt button, or turning the key to switch the pendant to another mode other than play mode. Another condition that the robot stops is when it reaches one of two empty or jammed conditions.

Error Management

There are two types of errors that one can go through when the robot is running automatically. One of the first error states one can run into is the **empty error** which is only possible when the optical sensor doesn't sense that a back panel wasn't picked and placed on the assembly bed.

The second error type that is possible is when the sensors detect that there is still something inside the assembly bed after completing an entire cycle. This is known as **incompletion error** when the robot has gone through the entire cycle successfully, however the senses discover that there is still an object on the assembly bed after the intended removal phase. This occurs when the robot's gripper doesn't manage to pull out the final product, or the final product wasn't snapped shut and the robot only picks up partial pieces of the headlamp assembly. For both cases the robot resets to home position and an error light on the right side of the table activates indicating that a failure or jam has just occurred.

Clearing jams:

As a group we first thought about "jam scenarios" that might pop up when running the robot. Then we came up with solutions that might prevent these scenarios. These scenarios are presented below:

Scenarios:

1) When the robot doesn't pick up the entire assembly or the partial assembly.
2) If the something gets jammed in the air tubes.
3) Make sure there is no junk in the way the robot.

Solutions:

1) We have sensors that sense error when the robot does not pick up the entire assembly, when this occurs the robot stops working until we clear the "jam" and then tell robot to continue its functions.

2) If something gets caught in the air pressure tubes, replace the tubes altogether because if you clear the jam in the tubes there might be some other smaller pieces left behind and we don't want to break our pneumatic.

3) Clean your workstation and make sure no junk is in the way of the robot.

Process Diagrams

Machine layout:

The overall machine layout form a top down view is most easily described with the picture below. The four main components: the robot, feeders, bed and sensor were arranged as the diagram and picture below illustrates:

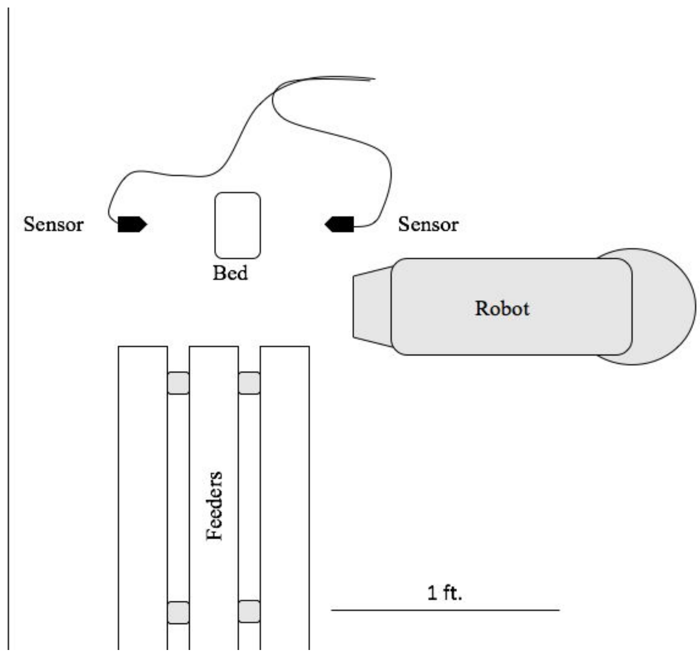


Figure 1: Overall Manufacturing Setup Diagram

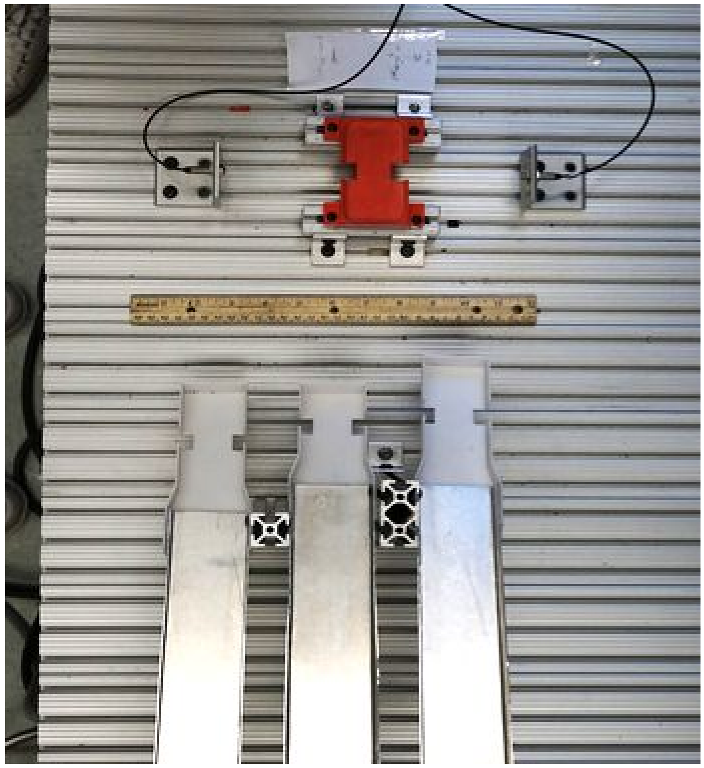


Figure 2: Actual manufacturing Setup

CAD drawings:

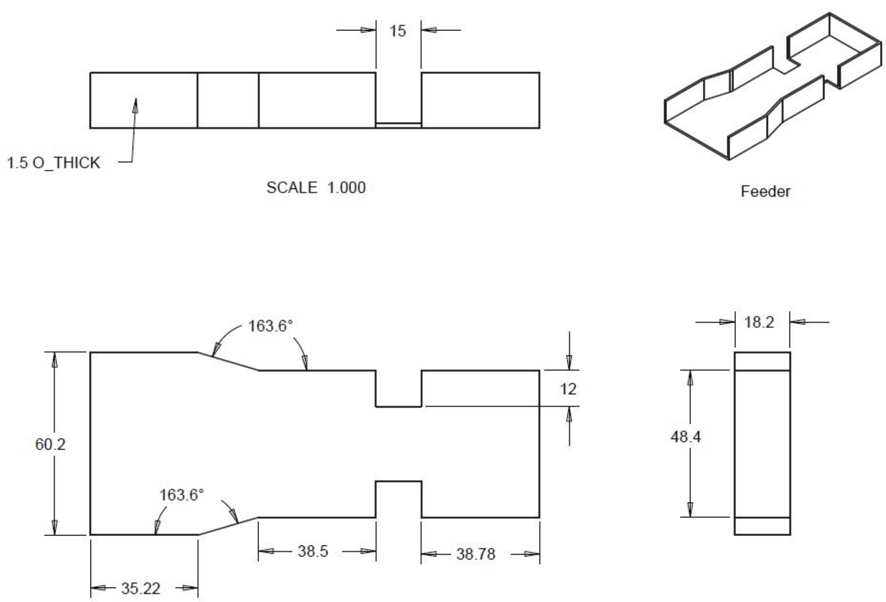


Figure 3: Feeder CAD Drawing

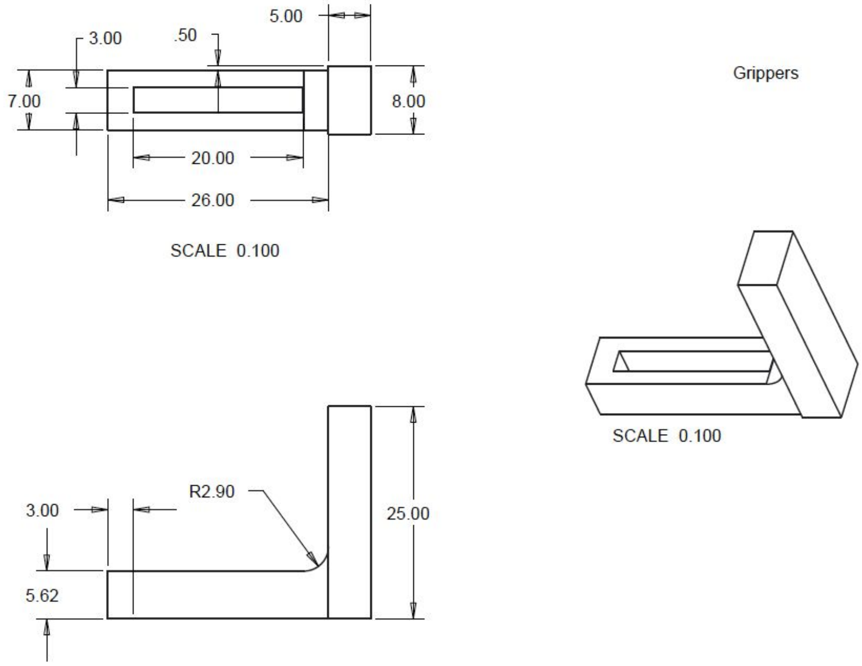


Figure 4: Gripper CAD Drawing

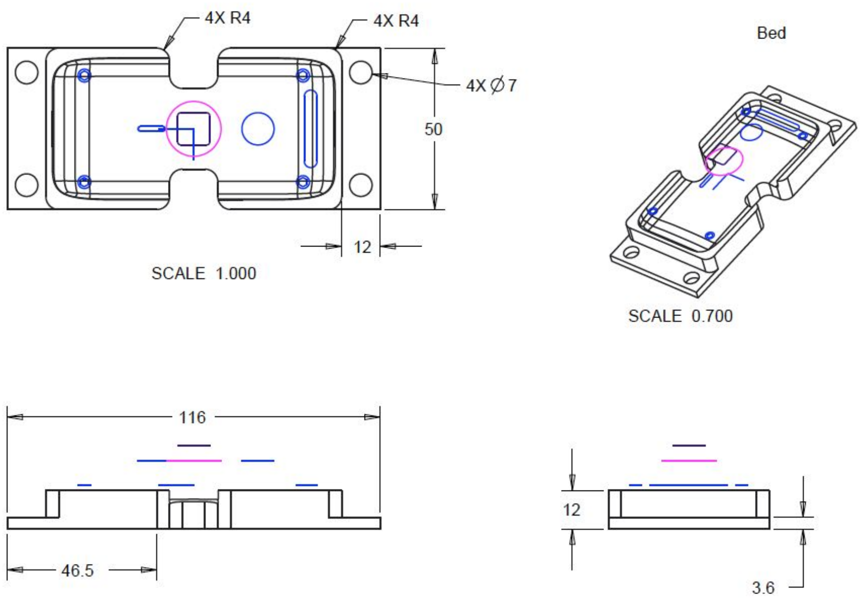


Figure 5: Construction Bed CAD Drawing

MOTOMAN Programming Job:

/JOB

//NAME 2016HEADLAMP

%% Start Code

NOP

%% Initializes the outputs of the robot

-Provides power to sensor

-Resets gripper to open position no matter the starting position

```
DOUT OT#(7) ON
*AGAIN
DOUT OT#(1) OFF
DOUT OT#(2) ON
TIMER T=0.25
DOUT OT#(2) OFF
MOVJ
MOVL   //MOVE
```

%% Moves into position to pick up bottom headlamp piece and activates gripper

```
MOVL  //Picks up piece
TIMER T=1.00
DOUT OT#(1) ON
DOUT OT#(2) OFF
TIMER T=1.00
```

%% Moves to the assembly bed to place bottom piece

```
MOVJ  VJ=1.00
MOVL
MOVC
MOVC
MOVC   //DROP PIECE
MOVL
TIMER T=1.00
DOUT OT#(2) ON
DOUT OT#(1) OFF
TIMER T=1.00
MOVL
```

%% Checks to see if a bottom piece is present in the assembly bed

%% If present then it continues

%% If not then it relays an error light to the user

- It moves to home position to turn on light

- Waits for the button press showing the all clear signal

- Jumps to the line labeled AGAIN

```
TIMER T=0.50
IFTHEN IN#(2)=OFF
        MOVJ VJ=10.00
        DOUT OT#(5) ON
        WAIT IN#(1)=ON
```

```
        DOUT OT#(5) OFF
        JUMP *AGAIN
ENDIF
MOVC
MOVC
MOVC
```

%% Moves to grip the battery from the rack

```
MOVL   //GRAB PIECE
TIMER T=1.00
DOUT OT#(1) ON
DOUT OT#(2) OFF
TIMER T=1.00
MOVL
MOVC
MOVC
MOVC
MOVL
```

%% Drops battery into bottom piece

```
MOVJ VJ=1.00  //DROP BATTERY
TIMER T=1.00
DOUT OT#(2) ON
DOUT OT#(1) OFF
TIMER T=1.00
```

%% Nudges battery for extra precision and predictablity

```
MOVL  V=1.0 //Nudges
MOVL
MOVL
MOVC
MOVC
MOVC
```

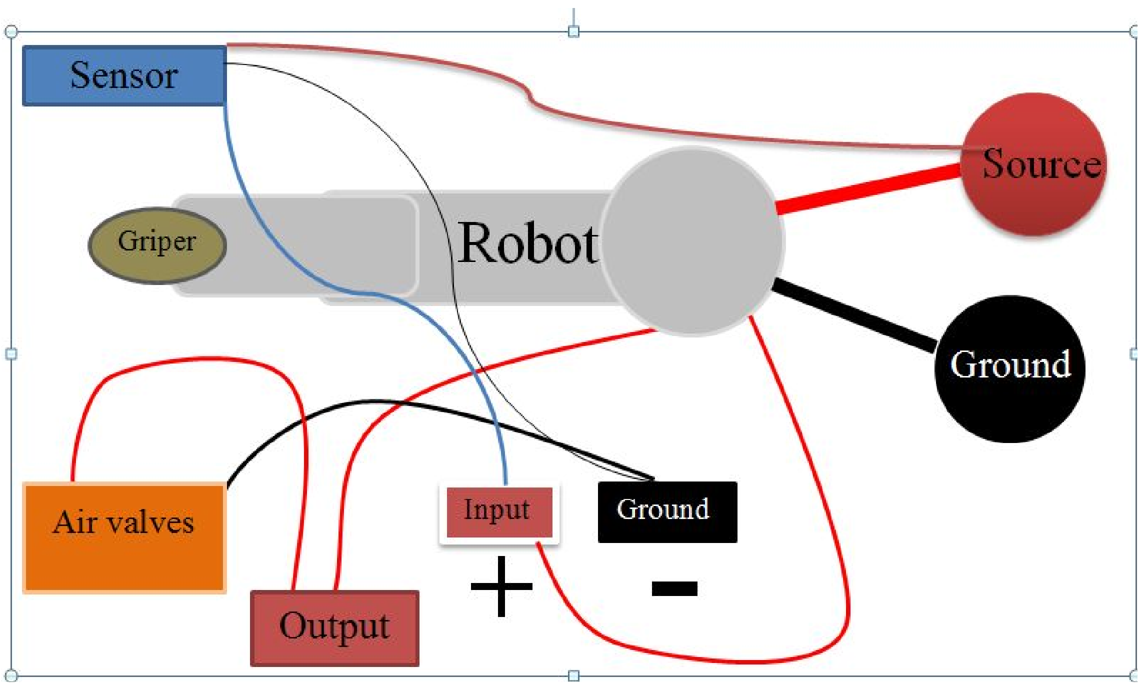
%% Grabs top piece of headlamp

```
MOVL //GRAB PIECE
TIMER T=1.00
DOUT OT#(1) ON
DOUT OT#(2) OFF
TIMER T=1.00
MOVL
MOVL
MOVC
```

MOVC
MOVC
%% Slowly drops top for extra care
MOVL V=3.0 //DROP TOP
TIMER T=1.00
DOUT OT#(2) ON
DOUT OT#(1) OFF
TIMER T=1.00
%% Nudges top piece for precision
MOVL V=2.0 //Nudges
%% Reorients the gripper to push the top to snap both halves together
MOVL
MOVL
MOVJ
MOVL
%% Slowly pushes the halves together
MOVL V=1.0
MOVL V=1.0
MOVL V=1.0
MOVL
MOVJ
MOVJ
%% Grabs final assembly from assembly bed
MOVL   //GRAB WHOLE
TIMER T=1.00
DOUT OT#(1) ON
DOUT OT#(2) OFF
TIMER T=1.00
MOVL
MOVC
MOVC
MOVC
MOVL //DROP WHOLE
TIMER T=1.00
DOUT OT#(2) ON
DOUT OT#(1) OFF
TIMER T=1.00
%% Drops assembly into finishing box
%% Checks for anything left in the assembly bed and gives user the error light

```
%% Error state is same as above
IFTHEN IN#(2)=ON
        MOVJ C00051 VJ=10.00
        DOUT OT#(5) ON
        WAIT IN#(1)=ON
        DOUT OT#(5) OFF
        JUMP *AGAIN
ENDIF
%% Clears robot arm away from assembly bed and jumps to reinitialize once more
MOVJ   //MOVE CLEAR
JUMP *AGAIN
END
```

Wiring diagrams:



Procedure Descriptions

Machine operations:

The machine had four major components: the robot, feeders, construction bed, and sensor. Due to the simplicity of the design the machine operations are relatively easy to describe.

The purpose of the robot was to pick up parts from the feeders, deliver them to the construction bed, and apply a pressure in order to successfully snap the part shut. The robot was also responsible for delivering the completed part to the correct box. The robot had to be programmed meticulously to ensure that each step of the process worked, from picking up the parts to snapping the case shut. It was an iterative process, with the coding becoming more and more specific as the project drew to a close.

The feeders were designed to continuously place the headlamp components in the same location every time. It was vital that the feeders supply the parts in the same spot every time so the robot could return to the same position each time. Additionally the angle of the feeders had to be chosen correctly so no shingling occurred when the parts slid down the ramp.

The construction bed was used to correctly align the parts so the robot could successfully return to the same position to push down on the case and snap it shut. The construction bed was created by 3D printing a "mold" of the bottom piece. This was done so the bottom piece theoretically only had one position it could lie in when it landed in the bed.

The purpose of the sensor was to make sure certain key processes were successfully completed. The sensor sensed whether the bottom piece was in the construction bed or not. This was used to check whether parts were loaded in the feeders as well as to ensure that the case was successfully created and removed from the construction bed.

The overall process integrating all of the components is as follows: The robot picks up each part individually and deposits them onto the construction bed while the sensor ensures the bottom piece has been placed appropriately. Next, the robot changes orientation so the "pusher" attachment is directed downwards and the robot moves slowly downward to snap the case shut. Finally, the robot attempts to pick up the completed part and remove it to the appropriate location. At this point, the sensor once again checks to see if the bottom piece has been successfully removed or not.

Maintenance instructions:

These instructions are for the anything that breaks or needs replacements. Most of the setup needs very little replacement. If the "assembly manufacturing process" were to run 24/7 then the replacements would need to be done more often. When our team was using the equipment for about 6 weeks, we needed very few replacements because we crashed the robot in places where it did not belong. The components that we used in order to construct our project and might need replacements for are aluminum metal beds, grippers, tubes, wires, plastic bed attachments, pneumatic gripper, and robot part replacements.

Sheet metal bed: The aluminum sheets can be remade by first taking a ¼ in thick aluminum metal sheet and cutting a desired length and width. Next step is to bend the metal in order to achieve a comfortable width for the part to slide between comfortably. Drill holes on the edges of the bent sides with a 1/8 in diameter drill bit on the drill press.

Grippers: The grippers were 3-D printed. The grippers are most likely to break because they are small and definitely do the most work in the entire assembly. If they break, then send a CAD file of the part to Dr. Stirling and he will print a new set. Furthermore, a permanent installation would most likely have metal grippers produced.

Tubes: These connect the main airline to the pneumatic and they can last for a long time and do not need replacements for years. If one happens to break or start leaking, then replace them with ¼ in tubes.

Wires: We have wires connecting our PLC to the robot. These wires do not experience high stress situations and therefore do not replacement. If they break by human error, they can be replaced by any size wire that is convenient.

Plastic Feeder Attachments: These white attachments were 3-D printed as well, they can be replaced by again asking Dr. Stirling to reprint them. Lastly they need to have holes as well because they connect to the sheet metal beds. Line the holes on the plastic bed and the sheet metal bed and drill the hole using the same drill bit and press. Again, a more permanent installation would most likely have these made out of metal.

Pneumatic gripper: The gripper itself is meant to last a long time and the gripper used by our group was used prior to us as well. The amount of time used precious to our group is unknown. If the gripper breaks or just needs a replacement, then just call the company and order a new one.

Robot: The robot parts and the robot itself is a mystery to us because the group does not know how it was built. If the robot stops working, then call the Moto robot company and they will come and fix it or tell you how to fix it.

Suggestions for future improvements:

Several improvements on the robot arm's protocols with the present arrangement that may improve the cycle time and optimization. One major improvement would be to increase the robot's motion speed while moving into position to pick up the individual pieces of the headlamp. A drawback of this is the vibrations of a faster motion that may affect the precision of the assembly when snapping the assembly is put together. Another improvement could be to change how the robot attempts to snap the assembly together to improve the reliability of the final push. One method is during the final push is for the robot to "wiggle" the top into place by rotating the head several times while slight pressure is added to allow the pieces to "catch" before the final push to snap them together. A downside would be a longer cycle time or messing up a good setup but that may be minor. Another could be changing the gripper to include a more reliable way to pick up the entire assembly like extra material on the bottom of the gripper to allow lifting from the bottom. The only difficulty with that would mean that it would be slightly more difficult to pick up the individual headlamp pieces because that addition might intersect with the surface the pieces are on.

Performance data:

Due to the behavior of 3D printed material and the variations between each headlamp case, it was difficult to determine exact performance data. However, it was possible to come to several important conclusions regarding the performance of the system. The cycle time was roughly **1 min 30 sec**. This cycle time can be optimized. The robot was not going as fast as it could because this manufacturing system was a proof of concept design. If implemented the robot motions could be sped up much more.

It was challenging to determine the ratio of success parts to failed parts because each case was different. However, by cycling a series of cases we knew worked together yielded the following data:

Cycle	Case 1 Completed	Case 2 Completed	Case 3 Completed
1	Yes	No	No
2	Yes	Yes	No

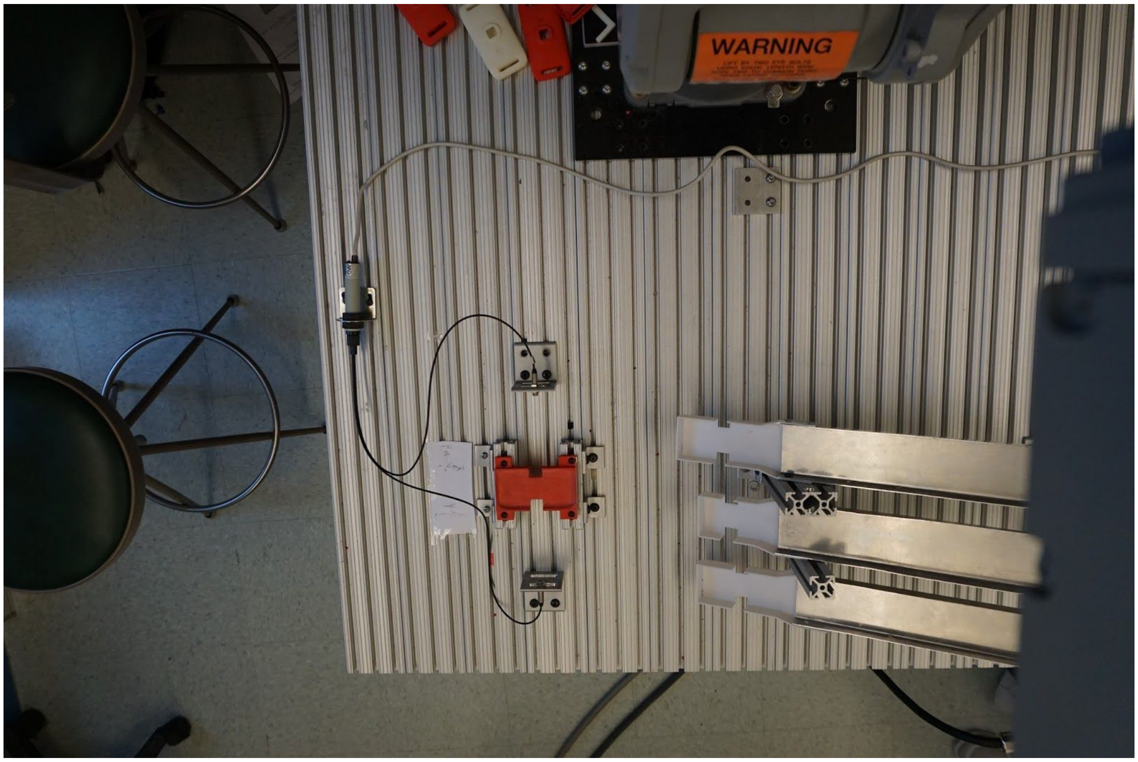
3	Yes	No	Yes
4	No	No	No
5	Yes	Yes	Yes
6	Yes	Yes	No
7	Yes	No	Yes
8	No	Yes	No
9	No	Yes	No
10	Yes	No	No
Success Percent	70%	50%	30%

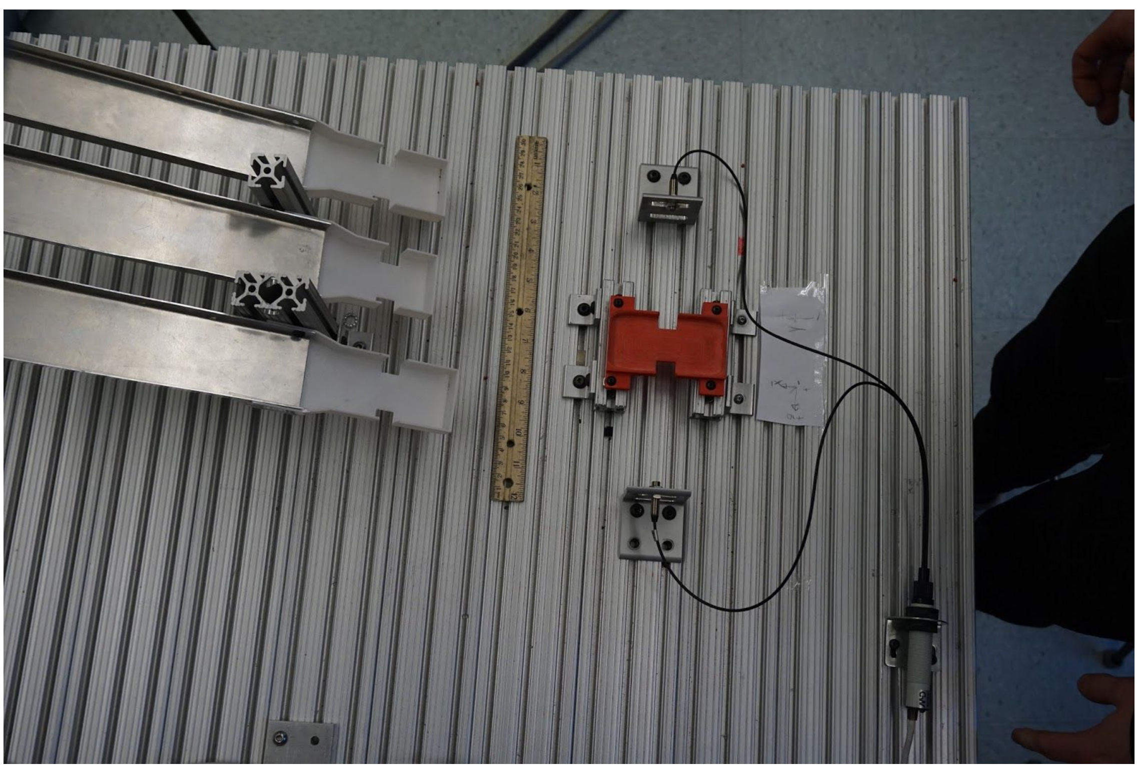
The differences between cases is relatively clear to see from the table above. Case 1 yielded a much higher success rate than either case 2 or case 3. It is interesting to note that case 1 was printed on the STRATASYS while both case 2 and case 3 were printed on hobby printers. It is proposed that more consistent parts would dramatically increase the success rate of complete parts. With an injection molded part paired with the robotic repeatability, a near to perfect success rate could potentially be achieved.

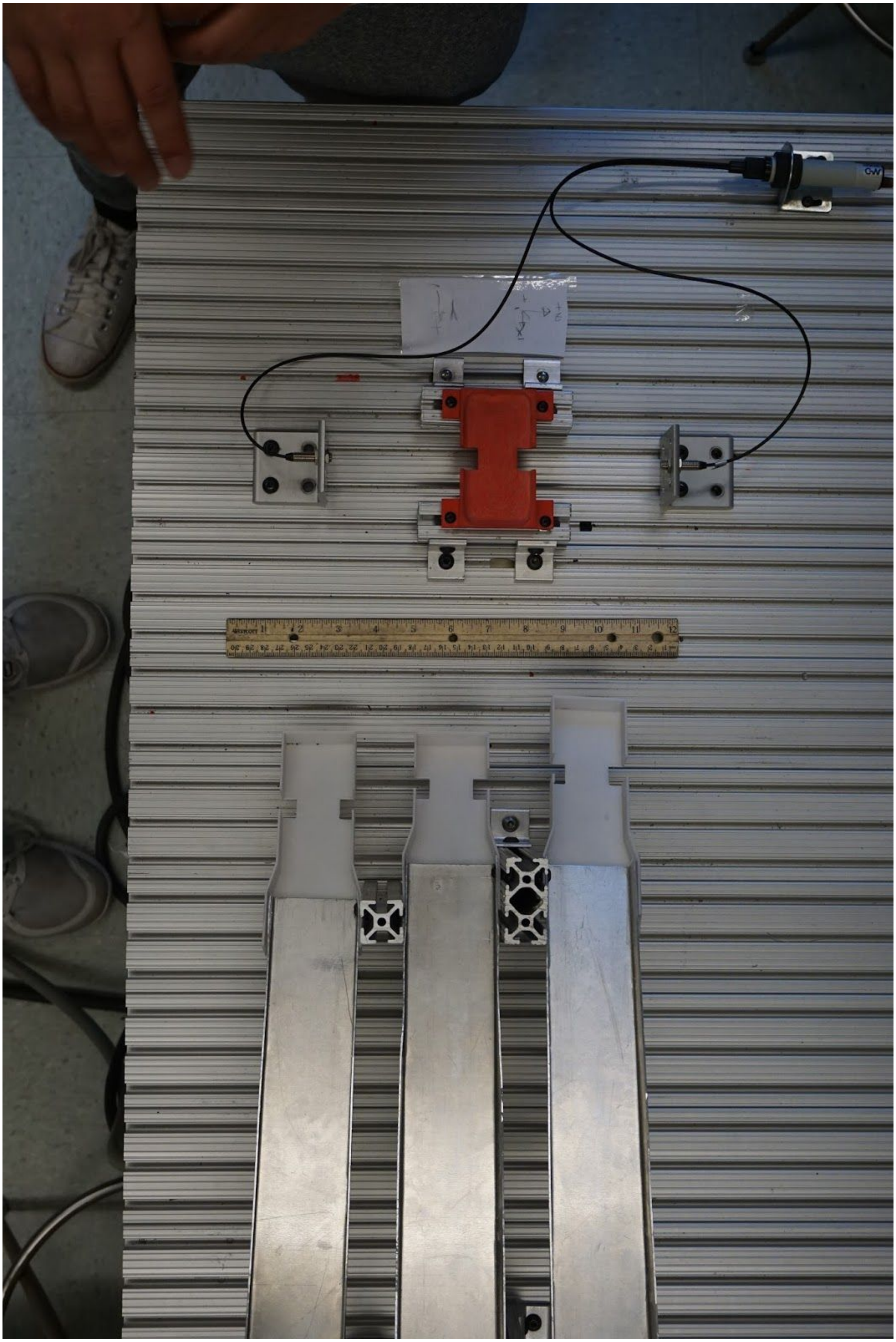
The sensor performance was never seen to have failed. It was consistently able to determine whether the backplate of the headlamp was present on the construction bed. However, with enough cycles, the sensors would potentially have to be realigned due to the vibrations caused by the robot's movements.

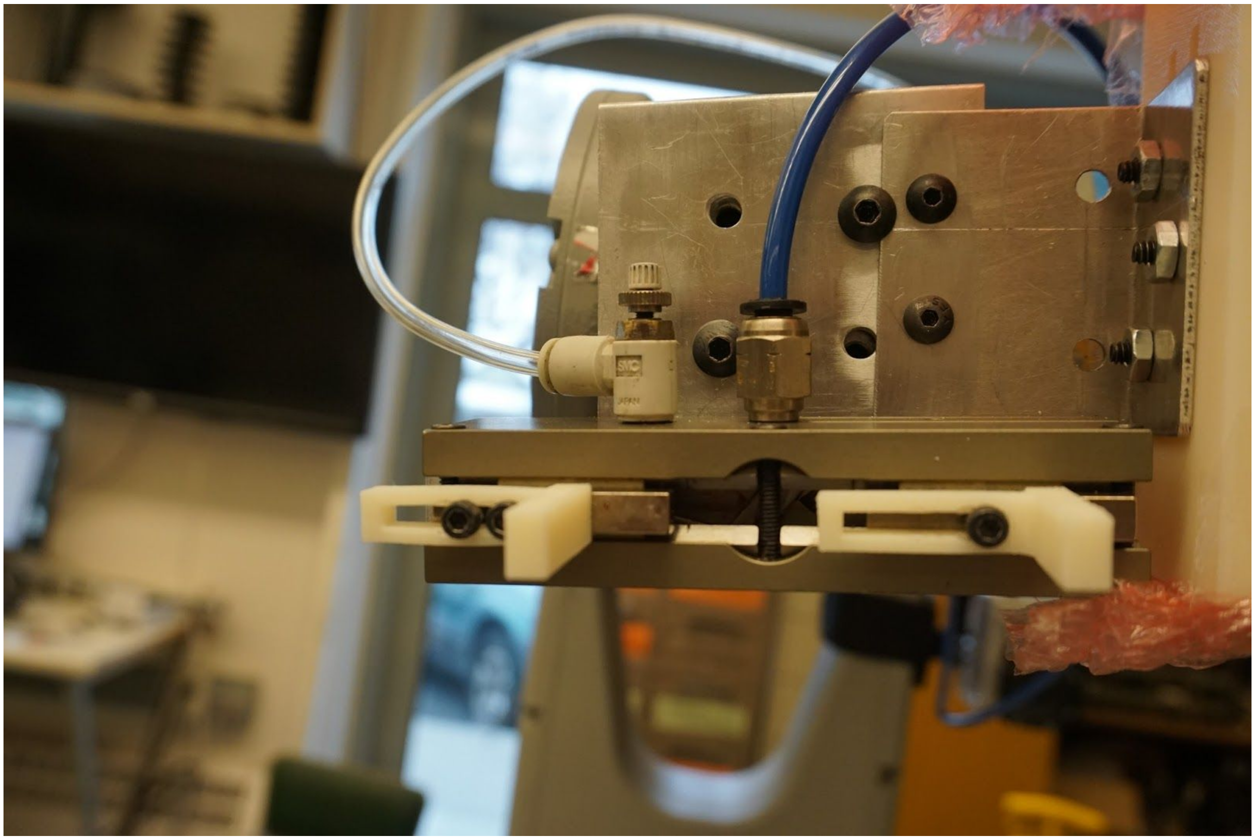
Similar considerations should be made for the bed and feeder performance. During the tests, they worked very consistently with no obvious flaws. However, the vibrations caused by the robot could potentially move the feeders and base, forcing them to be realigned.

Appendix A: Pictures





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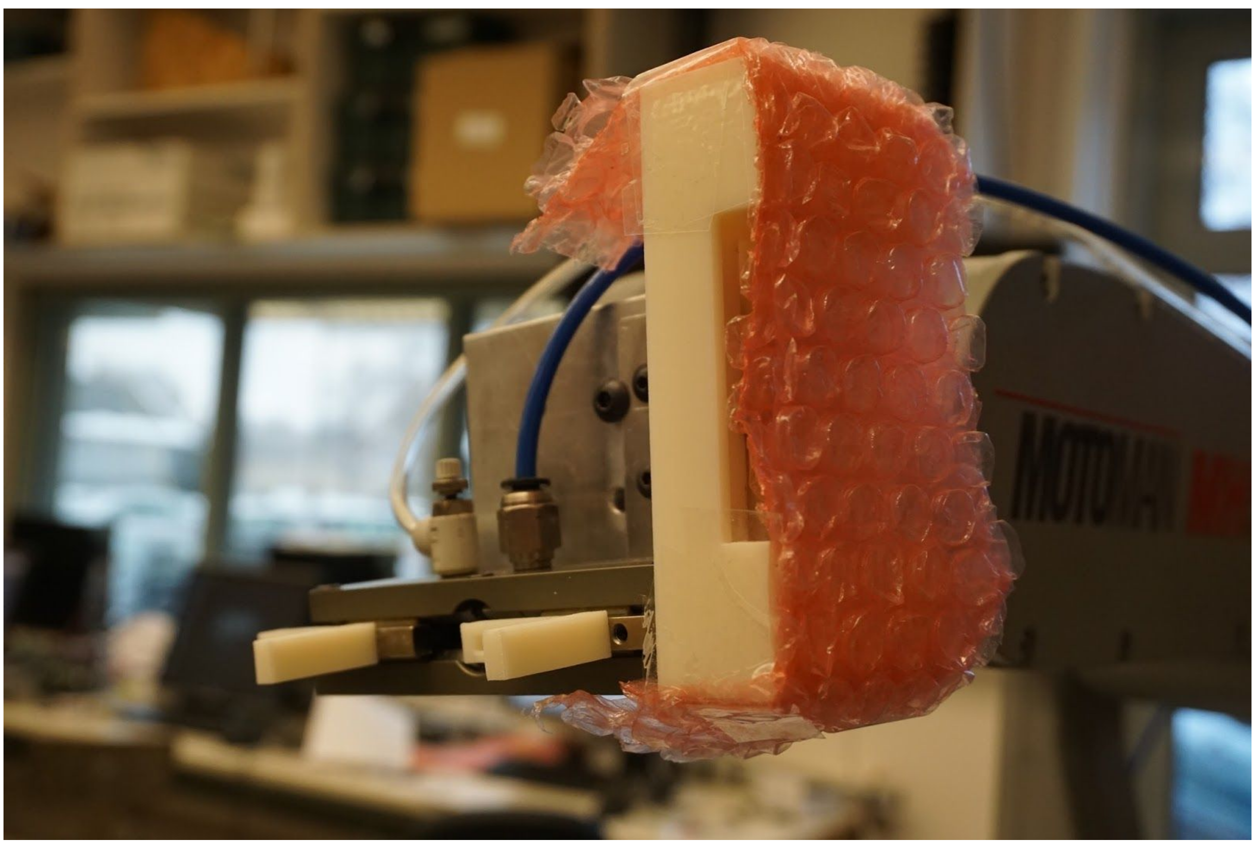
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