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Robots for Disabilities

Leapmotion Testing for Accuracy as an Input Method for Robotic Surgery

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Robotic Surgery

- Developed to address issues with traditional surgery techniques
  - increase dexterity/precision
  - reduce recovery time
  - reduce physiologic tremors
- Ability to perform surgery remotely
  - battlefield for wounded soldiers
  - transcontinental for specialized surgery reaching more patients
- Limited long-term studies to truly understand benefits/disadvantages

TABLE 1. Advantages and Disadvantages of Conventional Laparoscopic Surgery Versus Robot-Assisted Surgery

	Conventional Laparoscopic surgery	Robot-assisted surgery
Advantages	Well-developed technology	3-D visualization
	Affordable and ubiquitous	Improved dexterity
	Proven efficacy	Seven degrees of freedom
		Elimination of fulcrum effect
		Elimination of physiologic tremors
		Ability to scale motions
		Micro-anastomoses possible
		Tele-surgery
		Ergonomic position
Disadvantages	Loss of touch sensation	Absence of touch sensation
	Loss of 3-D visualization	Very expensive
	Compromised dexterity	High start-up cost
	Limited degrees of motion	May require extra staff to operate
	The fulcrum effect	New technology
	Amplification of physiologic tremors	Unproven benefit

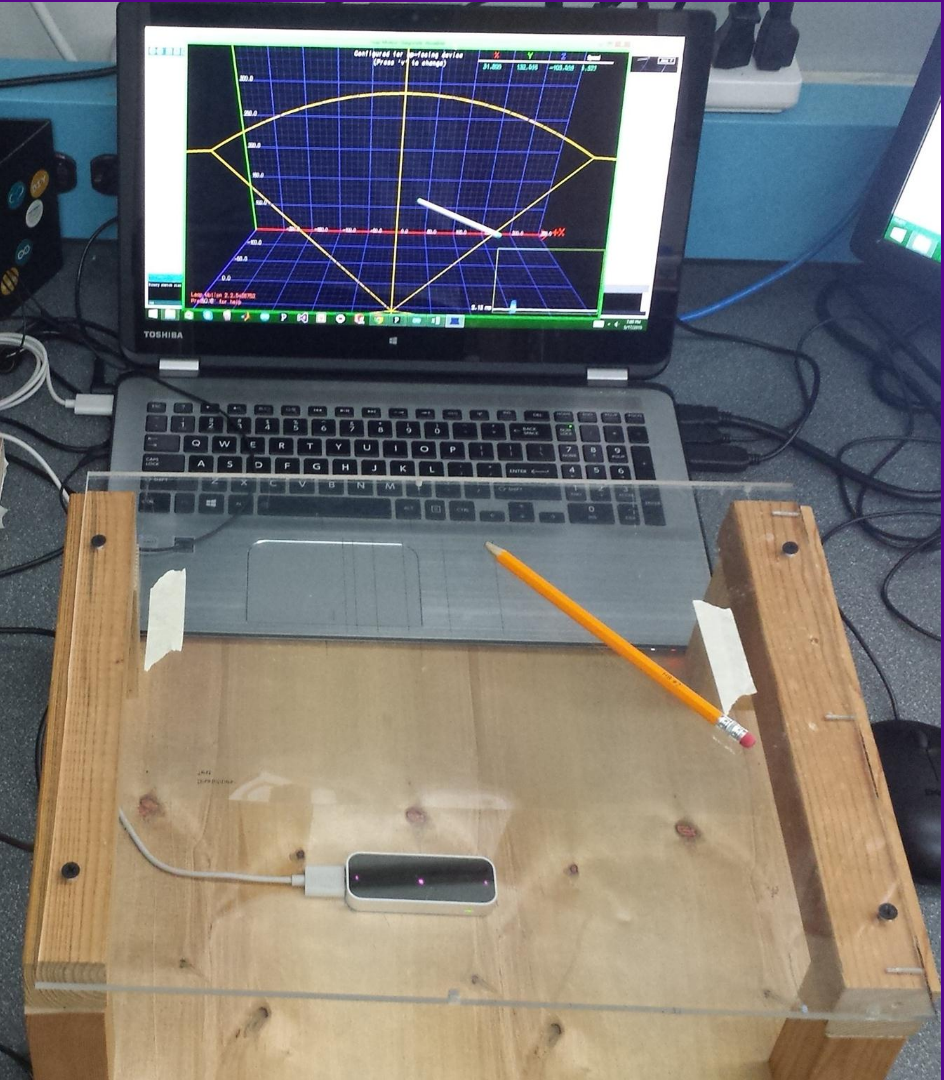
Surgical Robots

- Current end effector manipulation accomplished by use of a joystick-like controller

- A more intuitive, hands-free method has potential for ease-of-use

Project Goals

- Examine the accuracy of position measurements made by the Leapmotion sensor
- Control a robotic arm utilizing the Leapmotion sensor as the input



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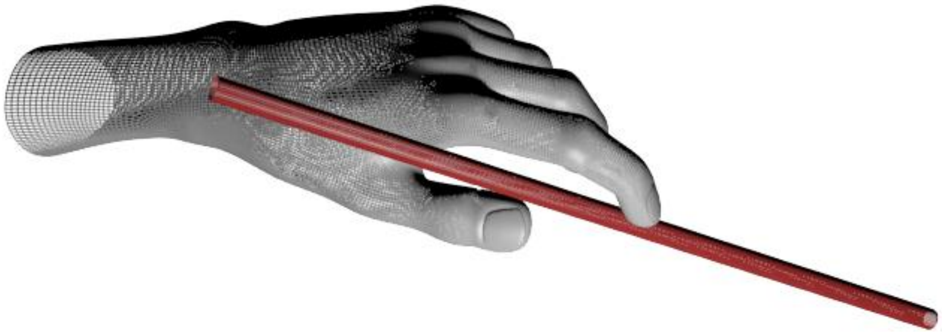
Leapmotion

Leap Motion

- Two monochromatic IR cameras
- Tracks infrared light (850 nm) projected onto hands
- 8 ft^3 of interaction space
- Image processing
- Tracking algorithm infers hand position and orientation

Tool tracking

- Tracks the tip of a "tool"
- A pencil is used in this study
- Data is only used once the z-component reaches the threshold
- Tool requirements:
  - longer, thinner, and straighter than a finger
  - Cylindrical

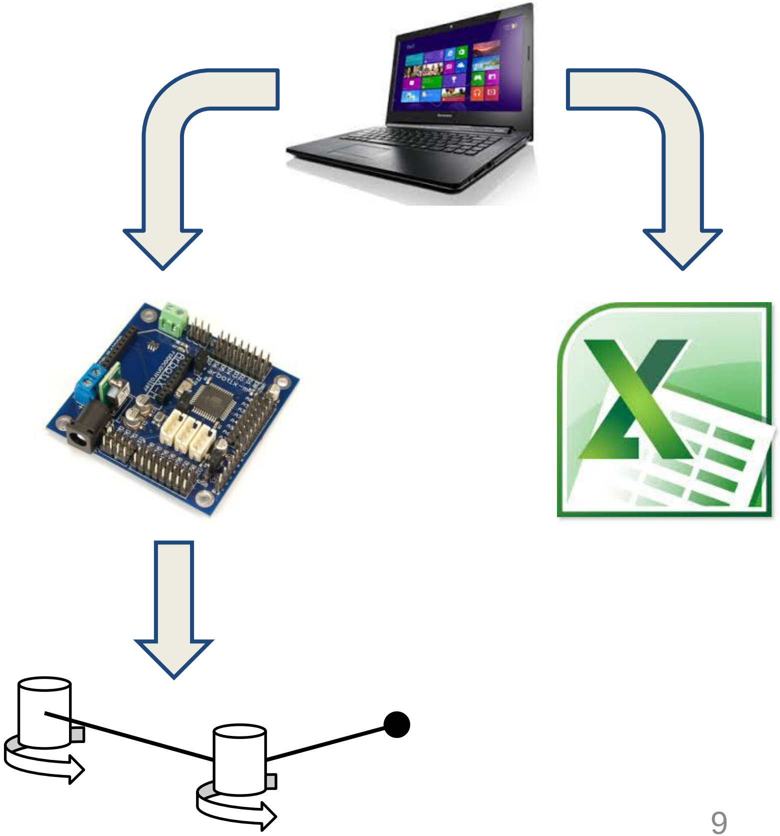


A tool is longer, thinner, and straighter than a finger.

Only thin, cylindrical objects are tracked as tools.

Hardware Communication

- **Leap Motion data is accessed through processing**
- **Robotic Arm**
  - **Tip position is sent to the arbotiX-M Robocontroller through Serial Com.**
- **Data Collection**
  - **Text-files created are exported for analysis in excel**



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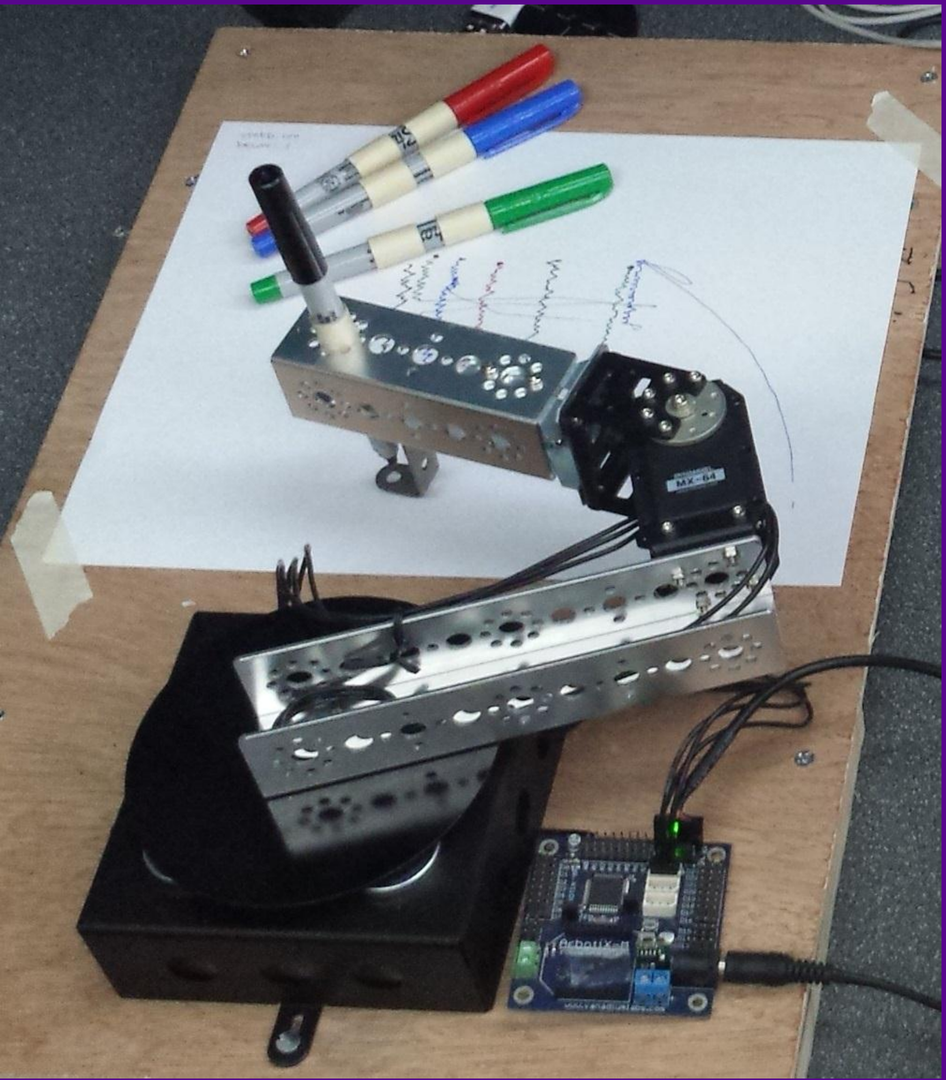
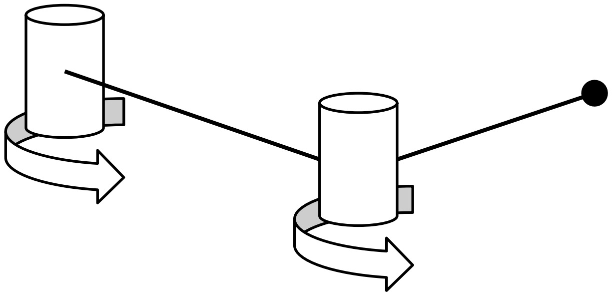


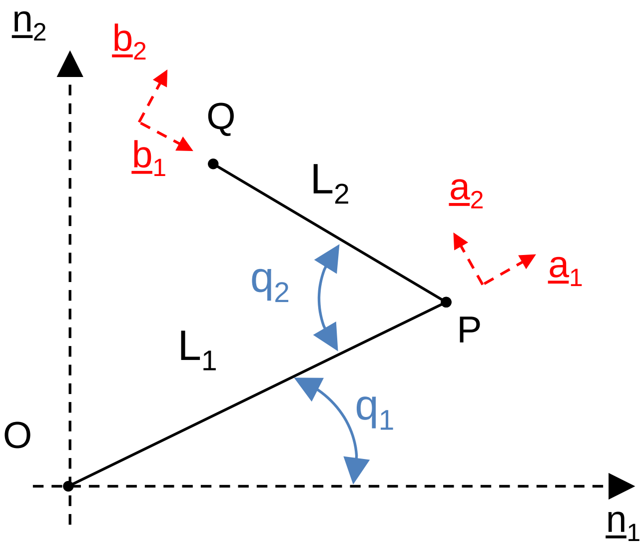
Robotic Arm

Forward Kinematics

- Diagram
- Transformation matrices
- End effector equation

Inverse Kinematics

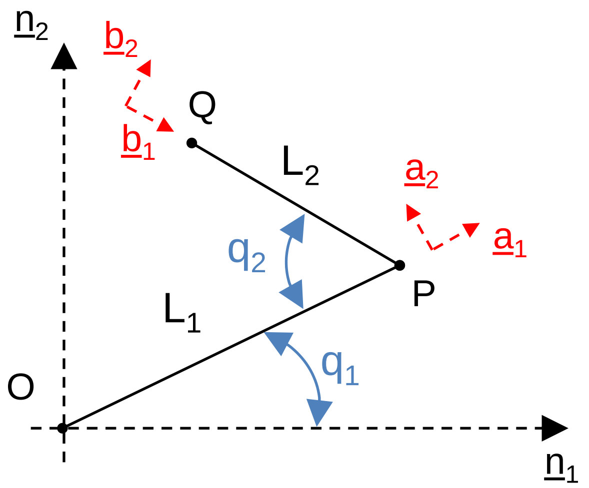




Rotation matrices:

${}^{N}R^{A}$	$\underline{a}_1$	$\underline{a}_2$
$\underline{n}_1$	c_1	$-s_1$
$\underline{n}_2$	s_1	c_1

${}^{A}R^{B}$	$\underline{b}_1$	$\underline{b}_2$
$\underline{a}_1$	c_2	s_2
$\underline{a}_2$	$-s_2$	c_2



$${}^{N}R^{B} = {}^{N}R^{A} \cdot {}^{A}R^{B}$$

${}^{N}R^{B}$	$\underline{b}_1$	$\underline{b}_2$
$\underline{n}_1$	$c_1c_2 + s_1s_2$	$c_1s_2 - c_2s_1$
$\underline{n}_2$	$c_2s_1 - c_1s_2$	$s_1s_2 + c_1c_2$

=

${}^{N}R^{B}$	$\underline{b}_1$	$\underline{b}_2$
$\underline{n}_1$	$c_{1\text{-}2}$	$s_{2\text{-}1}$
$\underline{n}_2$	$s_{1\text{-}2}$	c_{12}

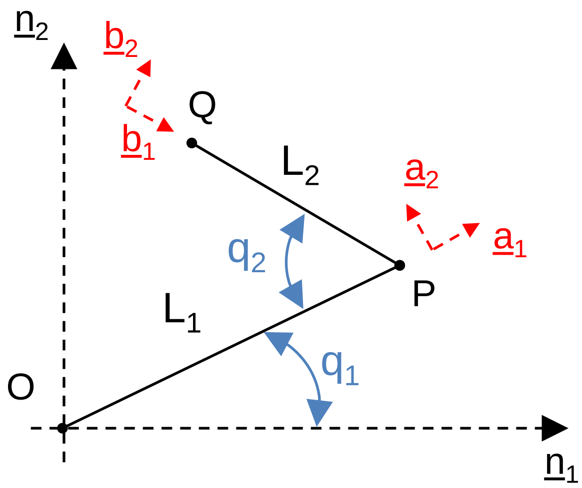
End effector:

$$\underline{r}^{Q/O} = \underline{r}^{P/O} + \underline{r}^{Q/P} = L_1\underline{a}_1 - L_2\underline{b}_1$$

$$= L_1c_1\underline{n}_1 + L_1s_1\underline{n}_2 - L_2c_{1\text{-}2}\underline{n}_1 - L_2s_{1\text{-}2}\underline{n}_2$$

$$x = L_1c_1 - L_2c_{1\text{-}2}$$

$$y = L_1s_1 - L_2s_{1\text{-}2}$$



${}^{N}R^{A}$	$\underline{a}_1$	$\underline{a}_2$
$\underline{n}_1$	c_1	$-s_1$
$\underline{n}_2$	s_1	c_1

${}^{N}R^{B}$	$\underline{b}_1$	$\underline{b}_2$
$\underline{n}_1$	$c_{1\text{-}2}$	$s_{2\text{-}1}$
$\underline{n}_2$	$s_{1\text{-}2}$	c_{12}

Inverse Kinematics:

$$\beta = \text{atan2}(x_c, y_c)$$

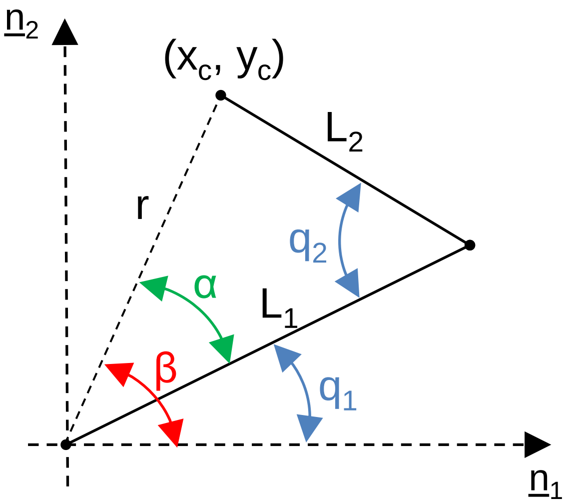
$$q_1 = \beta - \alpha$$

$$\alpha = acos\left(\frac{r^2 + L_1^2 - L_2^2}{2rL_1}\right)$$

$$r^2 = x_c^2 + y_c^2$$

$$q_1 = atan2(x_c, y_c) - acos\left(\frac{x_c^2 + y_c^2 + L_1^2 - L_2^2}{\pm 2L_1\sqrt{x_c^2 + y_c^2}}\right)$$

$$q_2 = acos\left(\frac{L_1^2 + L_2^2 - x_c^2 - y_c^2}{2L_1L_2}\right)$$



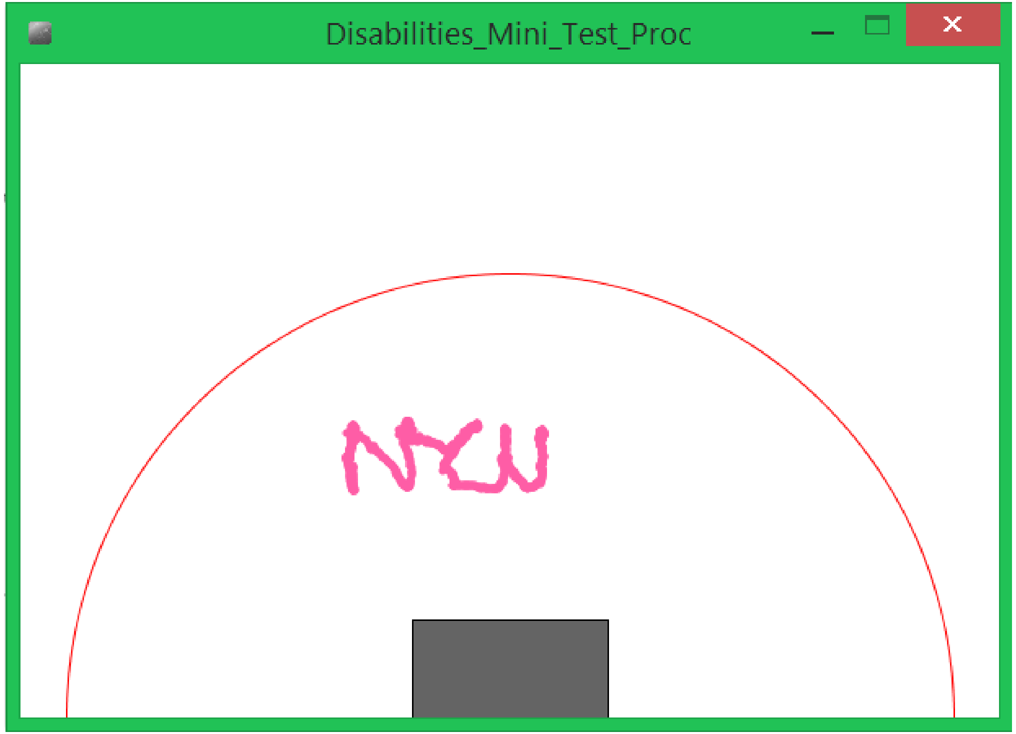
Processing Code:

- **Acquires tip position from Leapmotion**
- **Maps values for graphical interface**
- **Sends position information to Arbotix**

```
for (Map.Entry entry : toolPositions.entrySet())
  {
    Integer toolId = (Integer) entry.getKey();
    Vector position = (Vector) entry.getValue();

    if(position.getY() <= 155.0){
      fill(toolColors.get(toolId));
      noStroke();

      xPos = round(position.getX());
      yPos = (-1)*round(position.getZ());

     //output.println(position.getX() + "\t" + (-1)*position.getZ());    // write coordinates to a file

      if(xPos >= -300 && xPos <= 300){
        xPos = xPos + 300;
      } else{
        if(xPos < -300){
          xPos = 0;
        }
        else{
          if(xPos > 300){
            xPos = 600;
          }
        }
      }

      ellipse((xPos), (400 - yPos), 5.0, 5.0);

      val[0] = byte(xPos/256);
      val[1] = byte(xPos%256);
      val[2] = byte(yPos/256);
      val[3] = byte(yPos%256);
```

Graphical Interface:

- Grey box - motor mount
- Red line - extension limit of arm
- Colored line - tracked tip position



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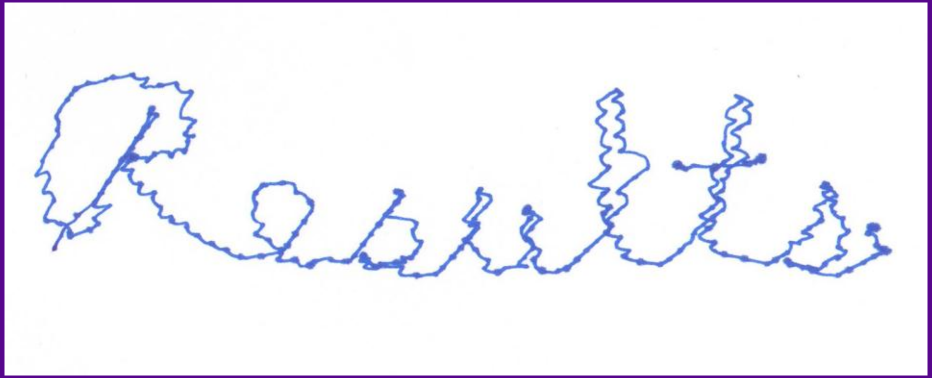
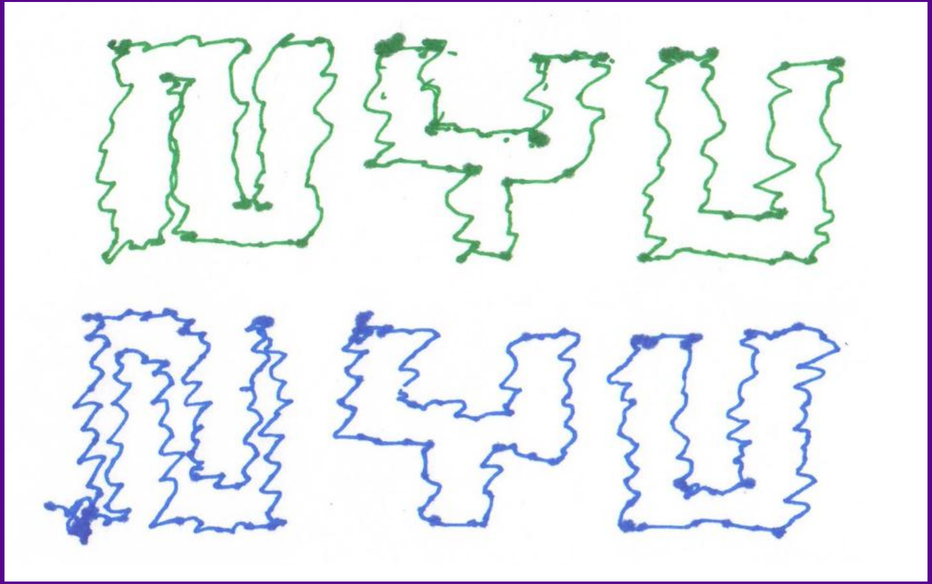
Drawing Results





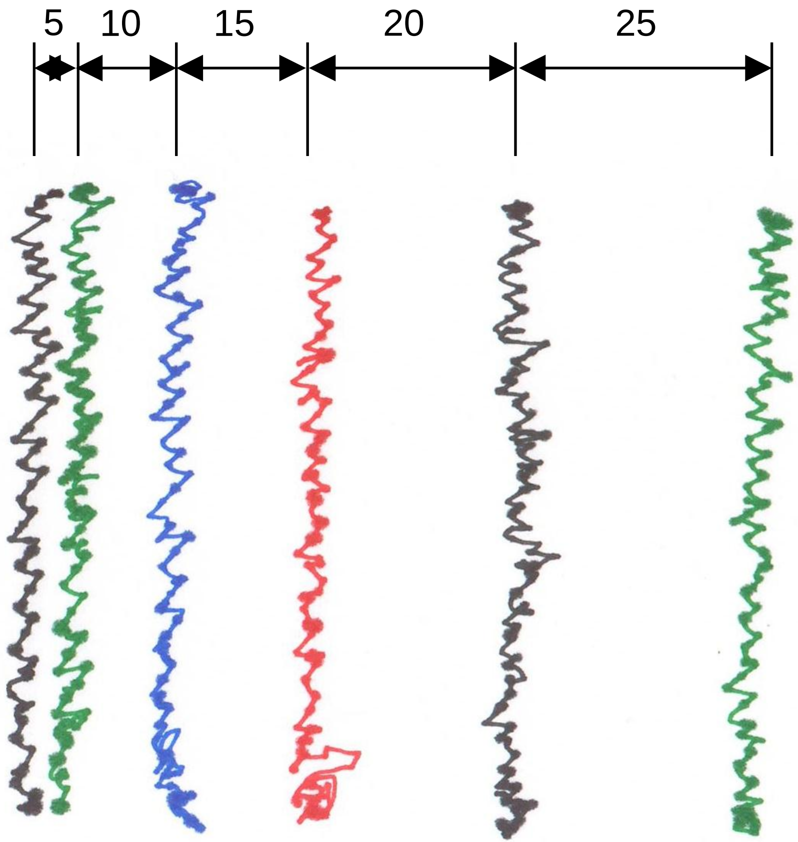
Parameter testing:

Motor Speed: ~2.20rpm

Delay: 10ms

Observation: choppy output

Change: increase motor speed



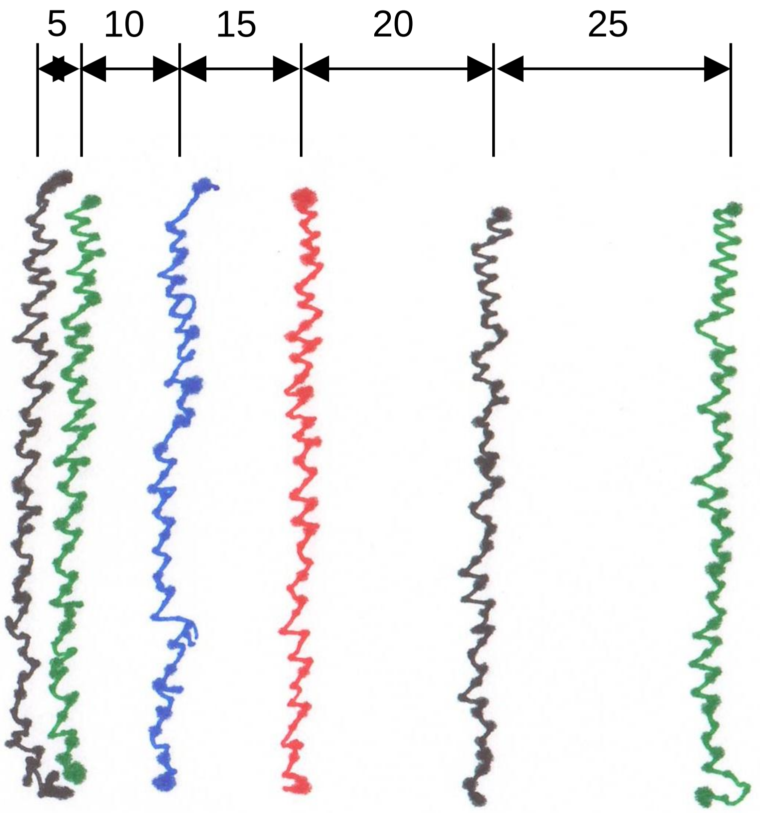
Parameter testing:

Motor Speed: ~8.79rpm

Delay: 10ms

Observation: no noticeable change

Change: reduce delay time



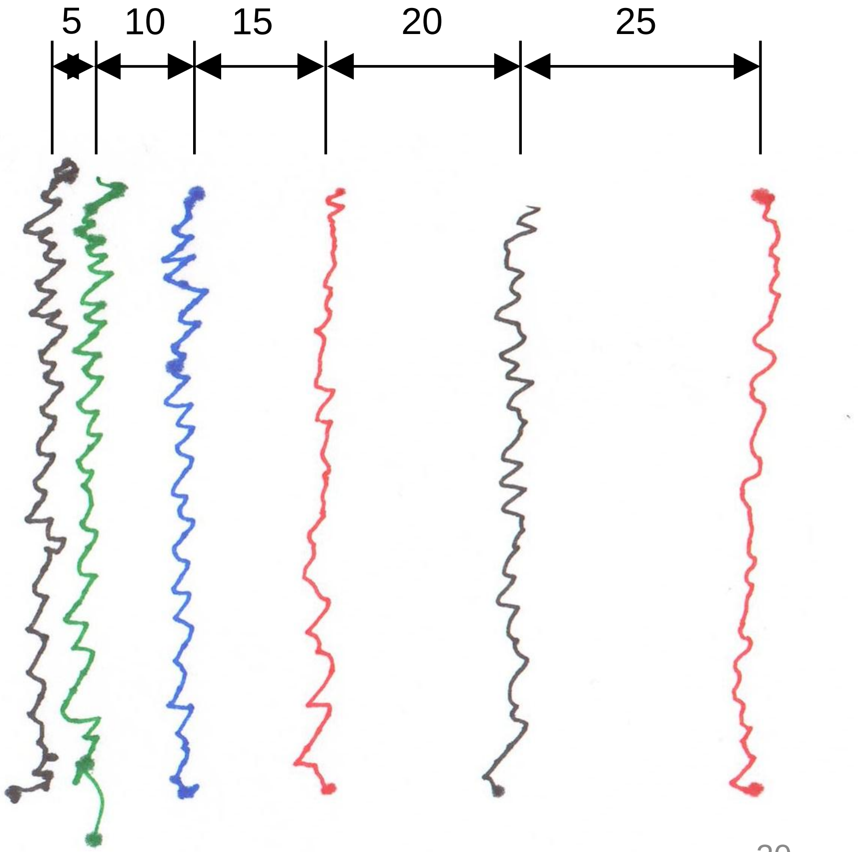
Parameter testing:

Motor Speed: ~4.39rpm

Delay: 5ms

Observation: slightly smoother lines at higher tip speed

Change: increase path accuracy between points (future)



Sensor Results

L	M	N	O	P	Q	R	S
g left			15mm				xavg l
4.9319	170			-32.8063	154.4934		-33.1
4.9319	70			-32.7319	154.4374		-33.1
				-32.6881	154.4478		
d dev left				-32.7167	154.5047		stnd d
13463				-32.7167	154.5047		0.516
4.5184	160			-32.7037	154.3256		-32.
4.5184	80			-32.7134	154.2357		-32.
				-32.6746	154.1254		
5.3453	160			-32.6659	153.9924		-33.6
5.3453	80			-32.7651	154.1272		-33.6
				-32.752	154.1917		
g right				-32.6257	154.0738		xavg r
061166	170			-32.557	153.9339		-17.0
061166	70			-32.5834	153.9753		-17.0
				-32.6673	154.0392		
d dev right				-32.6203	153.9777		stnd d
342119				-32.5885	153.9294		0.859
403284	160			-32.6154	153.77		-16.1
403284	80			-32.5834	153.7028		-16.1
				-32.5496	153.6898		
719047	160			-32.5251	153.6742		-17.8
719047	80			-32.4945	153.6359		-17.8
				-32.4341	153.5462		
tance				-32.3428	153.4329		distan
99303				-32.3256	153.3611		16.11

Experimental set up:

•Coordinate resolution

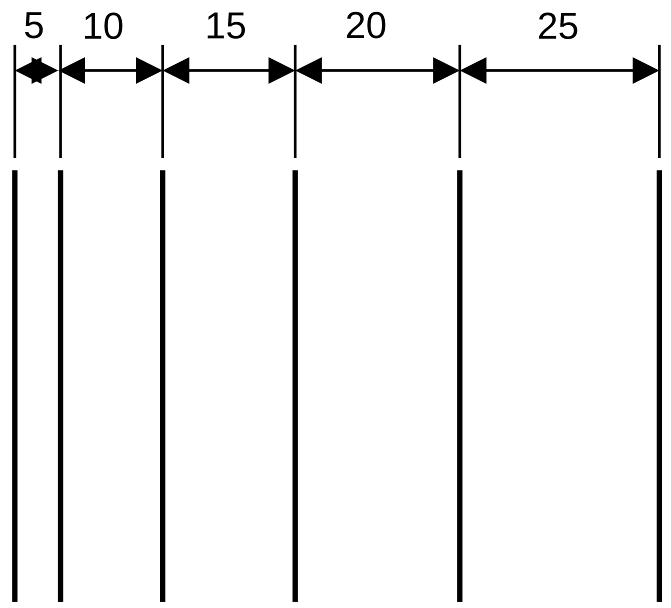
- Coordinates are provided in mm's

•Series of two lines

- 25, 20, 15, 10, and 5mm apart
- Mean of x-position
- Standard deviation of x-position

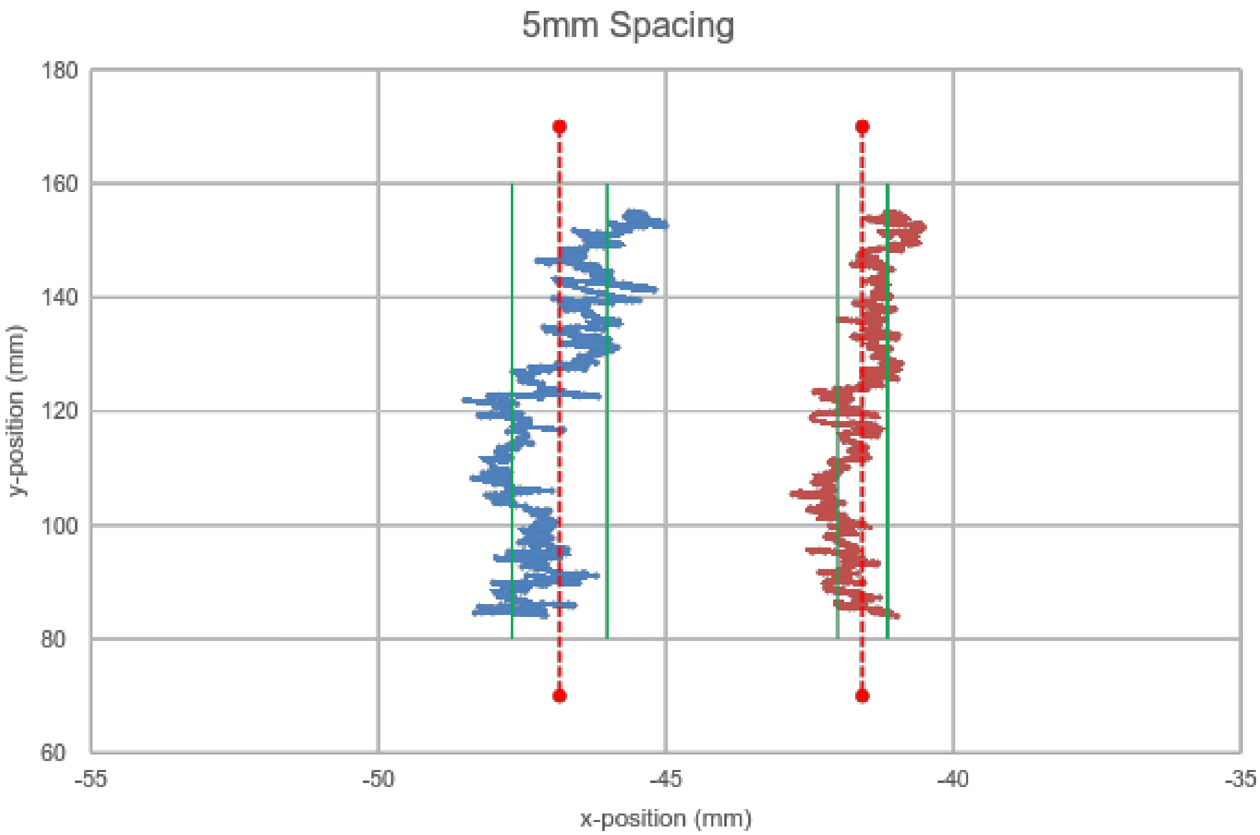
•Comparison

- Comparing the measured distance to average distance from the leap



Distance (mean):
5.26mm

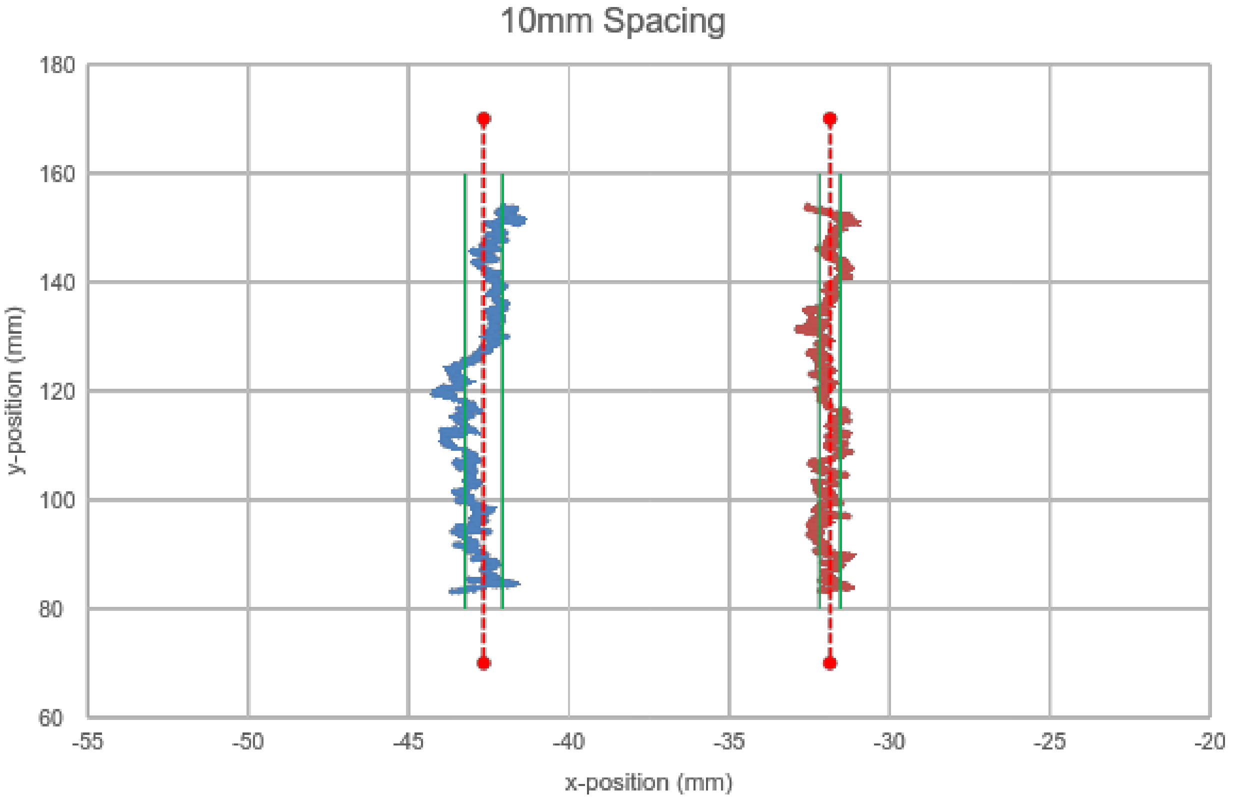
Standard Deviation:
Left: 0.83mm
Right: 0.43mm



Leapmotion Sensor Results

Distance (mean):
10.80mm

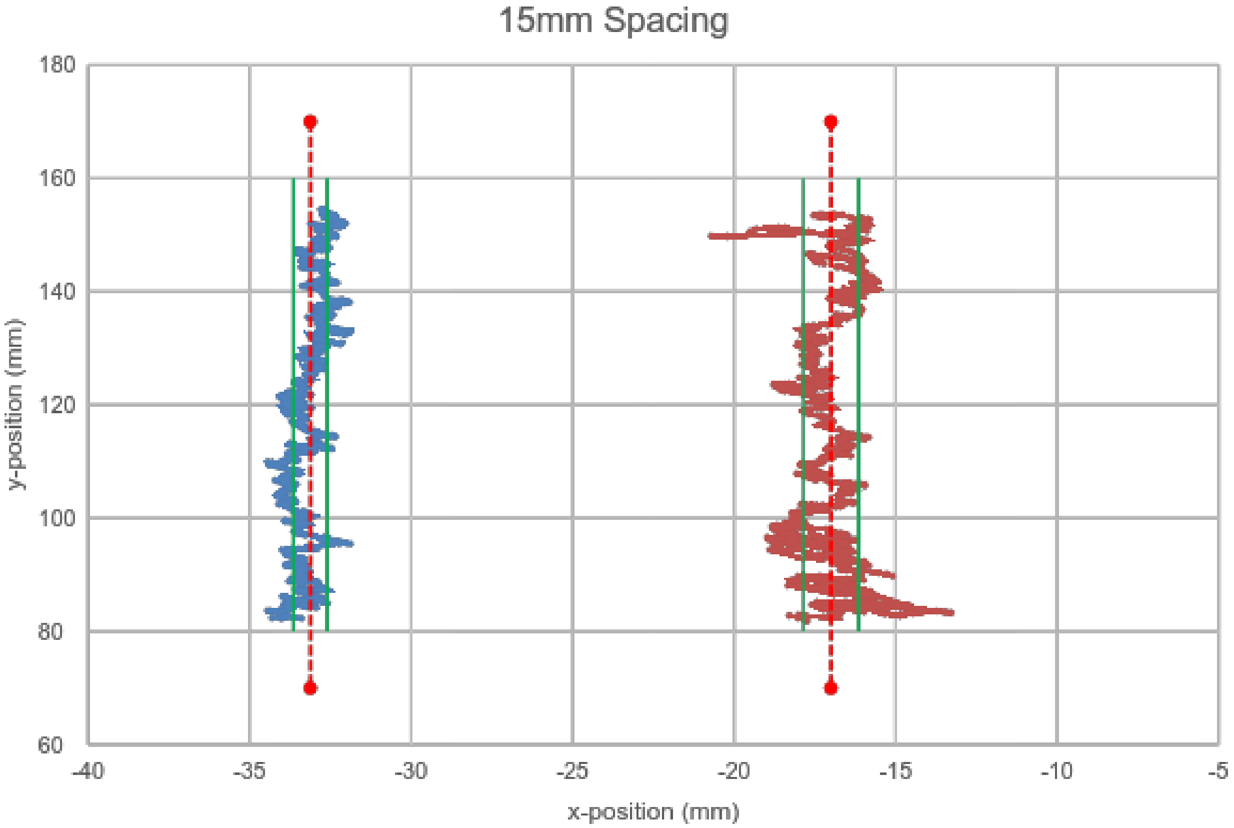
Standard Deviation:
Left: 0.59mm
Right: 0.33mm



Leapmotion Sensor Results

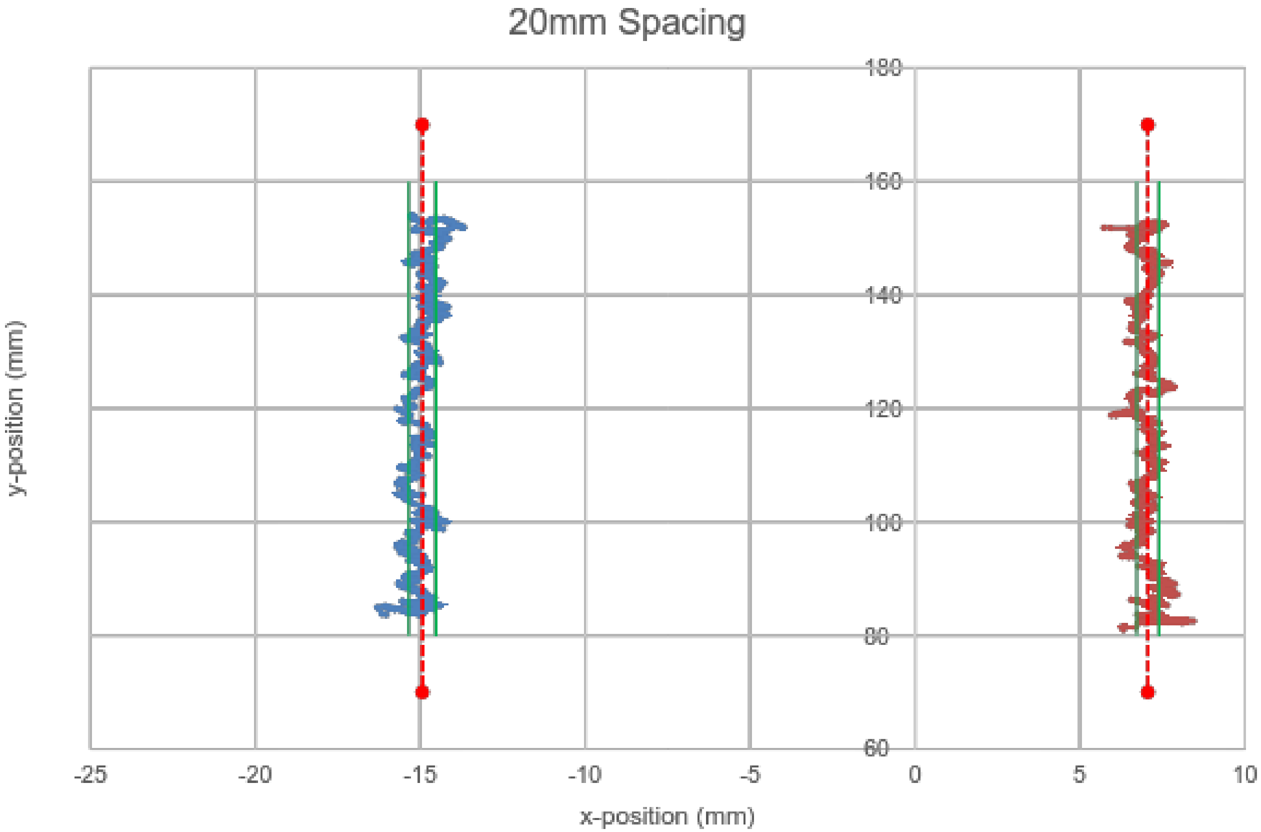
Distance (mean):
16.11mm

Standard Deviation:
Left: 0.52mm
Right: 0.86mm



Distance (mean):
21.99mm

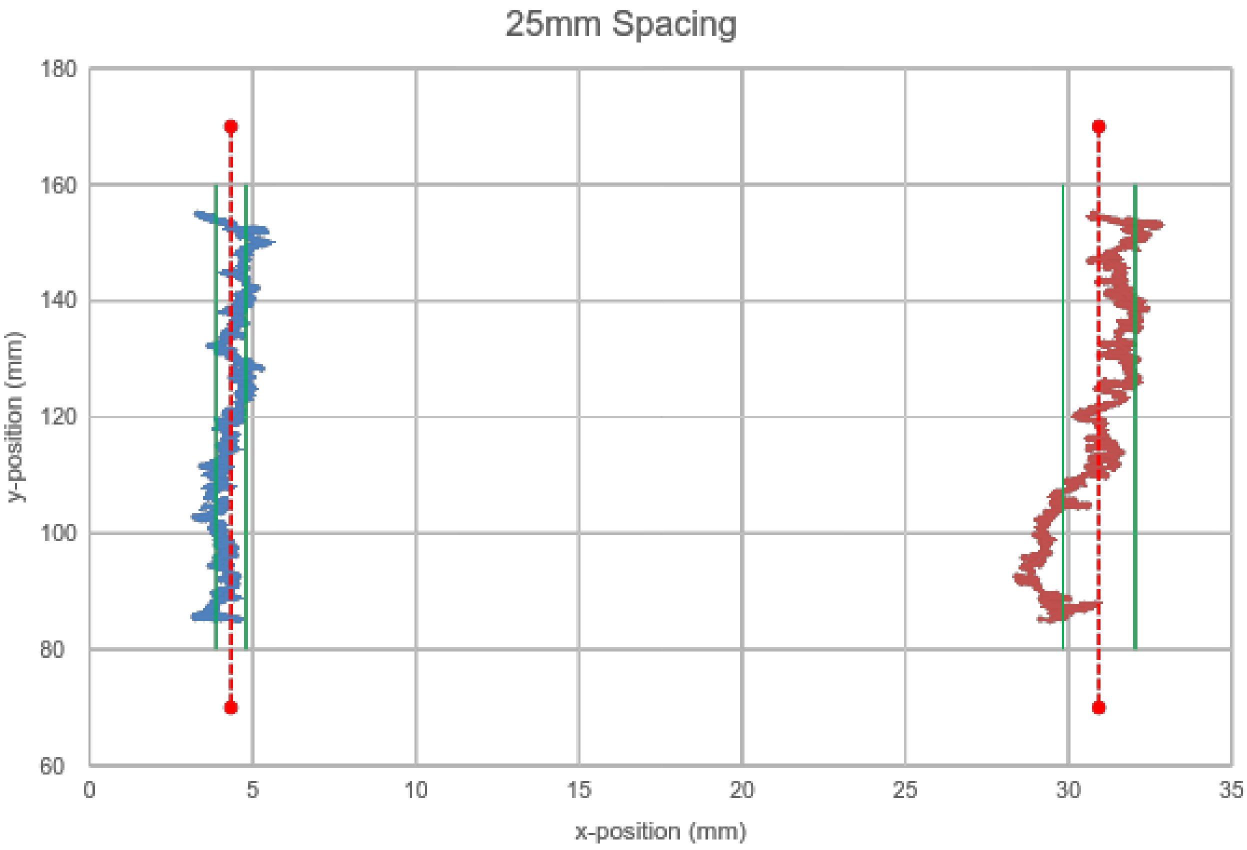
Standard Deviation:
Left: 0.41mm
Right: 0.34mm



Leapmotion Sensor Results

Distance (mean):
26.60mm

Standard Deviation:
Left: 0.46mm
Right: 1.11mm



Problems

- Robotic Arm
  - The path of the end effector between points is random
  - Does not provide smooth transition between data points
  - Tip position data is not smooth
  - Motor resolution provides limited accuracy

- Data Collected
  - Standard deviations are fairly large
  - Human error introduces significant effects on data

Conclusion

- **The Leap Motion successfully controls the robotic arm through tool tracking**
  - **Results show a noisy output, implementing a filter would help**
  - **Implementing a dynamic controller (PD,PID..) would improve performance**
  - **Path planning could decrease error between data points**

- **Data collected from the sensor on average was within 1.5 mm of the actual distance**
  - **Not acceptable for robotic surgery needs**