LOCKHEED MARTIN

EML4551-2

Virtual Reality Tracking and Realistic Haptic Feedback Gloves

Team Introductions

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Project Background

- Sponsor: Lockheed Martin
- The purpose of this project is to improve current virtual training systems at Lockheed Martin through the design of Virtual Reality gloves that will reduce the cost and size of current simulation systems while still providing realistic feedback to the user

Figure 1: (a) A Lockheed Martin F-35 Flight Simulator

Figure 1: (b) Same simulator at a different angle

Jonathan Roberts

Important Terms and Acronyms

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- Haptic feedback: Feedback provided by the gloves in response to interaction with the virtual environment
- Tactile feedback: Feedback provided by interaction with the real world environment
- IMU: Inertial measurement unit
- LRA: Linear resonant actuators

Jonathan Roberts

Targets

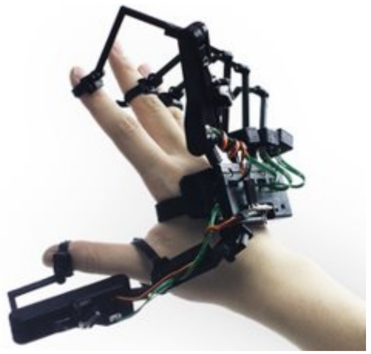
Metric	Target
System latency	20 milliseconds
Tactile feedback	Sensation of touch retained
Haptic feedback	Physical response to interaction with virtual environment

Figure 2: Most Important Targets and Metrics

- From the customer needs the following targets were determined
- These were then used to determine the engineering characteristics

Jake Kennedy

Concept Generation: Haptic Feedback



Concept 1: Force Feedback

- Consists of a series of motors and mechanical arms
- Provides feedback by applying resistance to fingers

Concept 2: Microfluids

- Consists of microfluidic chambers connected to pneumatic actuators
- Actuators apply pressure to the hand to simulate touch

Concept 3: LRA

- Consists of a series of vibration motors at specific parts of the hand
- Provides feedback using vibrations on the fingers and palms

Jake Kennedy

Concept Selection: Haptic Feedback

Table 1: House of Quality for Haptic Feedback

Customer Requirements	Importance Weight Factor	Engineering Characteristic: Size	Effectiveness of feedback	interference with tactile feedback	Durability
Weight	7.4	5		5	
Effectiveness	17		9		
Cost	6.51		1		5
Durability	20.2	1		5	9
Size	3.4	9			
Raw Score (600.15)		87.80	159.5	138.0	214.4
Relative Weight %		14.63	26.58	22.99	35.72
Rank Order		4	2	3	1

Table 2: Pugh Chart for Haptic Feedback

Criteria	Baseline: Datum: LRA	Alternative Solution: Concept 1: Force feedback	Concept 2: Microfluids
Size	DATUM	-	-
Effectiveness of Feedback		+	+
Interruption of Tactile Feedback		-	-
Durability		-	-
Sum of Positives		1	1
Sum of Negatives		3	3

- Engineering characteristics were compared to customer requirements
- These characteristics were then given weights to determine importance
- All characteristics continued through since all were relatively important

- Each concept was weighted against the LRAs in a Pugh matrix
- The LRAs were determined to be the best concept

Jake Kennedy

Concept Generation: Gloves

Concept 1: Golf Glove

- Leather palm for grip
- Spandex on back of hand
- Weather resistant
- Lightweight, thin, and form fitting

Concept 2: Partial Fingerless Pilot's Gloves

- Leather palm for grip
- Wool on back of hand
- Index, thumb, and middle finger are fingerless
- Durable but thick

Concept 3: Batting Gloves

- Leather palm for grip
- Form fitting nylon on back of hand
- Lightweight and thin

Concept 4: Fingerless Tactical Gloves

- Durable Nylon and Kevlar weave
- Reinforced plastic knuckles
- Completely fingerless

Jake Kennedy

Concept Selection: Gloves

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Table 3: House of Quality for Gloves

		Engineering Characteristic			
Improvement Direction		↓	↑	↓	↑
Customer Requirements	Importance Weight Factor	Size	Effectiveness of feedback	interference with tactile feedback	Durability
Weight	7.4	5		5	
Effectiveness	17		9		
Cost	6.51		1		5
Durability	20.2	1		5	9
Size	3.4	9			
Raw Score (600.15)		87.80	159.5	138.0	214.4
Relative Weight %		14.63	26.58	22.99	35.72
Rank Order		4	2	3	1

- A house of quality was used to determine the most important engineering characteristic
- Durability was most important with 35.72% relative weight

Table 4: Pugh Chart for Gloves

	Baseline	Alternative Solution		
Criteria	Datum: Fingerless Gloves	Concept 1: Golf Gloves	Concept 2: Partial fingerless pilots gloves	Concept 3: Batting Gloves
Max glove thickness	DATUM	+	S	+
Tactile Feedback		-	-	-
Haptic feedback		+	+	+
Durability		-	+	-
Sum of Positives		2	2	2
Sum of Negatives		2	1	2

- All concepts were carried on to the Pugh chart
- The fingerless gloves were chosen as the datum
- The partial fingerless pilot's gloves were selected as the best concept

Jake Kennedy

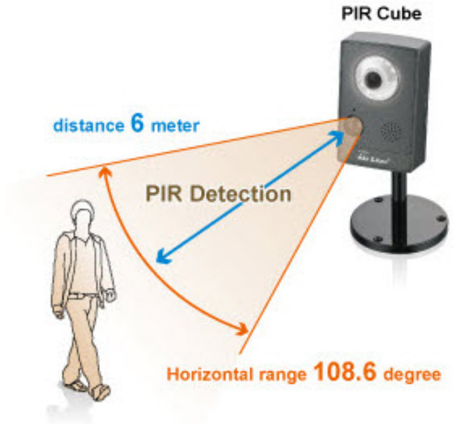
Concept Generation: Tracking

Concept 1: Machine Learning with Motion Tracking Cameras

- Optical markers are placed on the tracked surface
- The camera uses the difference in the markers to calculate the position
- Machine learning is used to gain higher resolution

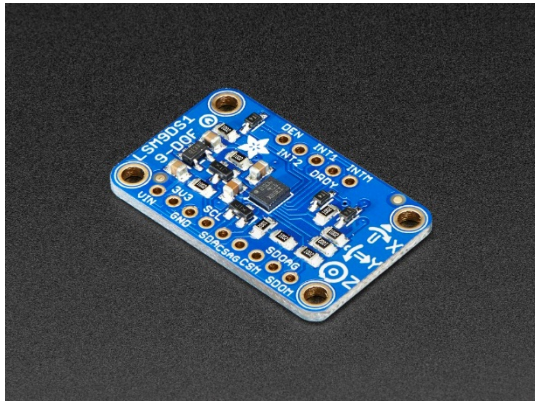
Concept 2: Photo Sensors

- Uses pulsing light, lasers, and photo sensors to track objects in the virtual environment
- Photo sensors spread over the tracked surface to detect light from the box while counting until the laser hits the surface



Concept 3: Infrared Sensors

- Passive sensors that use emanating infrared radiation to estimate depth
- The system would use these depth readings to map an object in 3D



Concept 4: IMUs

- Consists of an accelerometer, gyroscope, and magnetometer
- Sensors are oriented on each axis of 3D plane to position the object

Alex Erven

Concept Selection: Tracking

Table 5: House of Quality for Tracking

		Engineering Characteristics		
Improvement Direction		↓	↓	↑
Units		ms	in	n/a
Customer Requirements	Importance Weight Factor	Latency	Size	complexity
Size	15.2		9	
Accuracy	10.4	9		9
Time	20.0			9
Cost	1.33	5	5	5
Raw Score (524.1)		100.3	143.5	280.3
Relative Weight %		19.13	27.38	53.49
Rank Order		3	2	1

- Table 5 was used to determine the most important engineering characteristic
- Complexity of the subsystem was most important with a relative weight of 53.49%

Table 6: Pugh Chart for Tracking

	Baseline	Alternative Solution		
Criteria	Datum: IMU	Concept 1: Machine Learning	Concept 2: Photo Sensors	Concept 3: Infared Sensors
Latency	DATUM	-	S	S
Size		S	-	-
Complexity		-	-	-
Sum of Positives		0	0	0
Sum of Negatives		2	1	2

- IMUs were selected as the Pugh chart datum
- Opposing concepts only had comparative minuses
- IMUs were selected as best concept

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Concept Generation: Microcontroller

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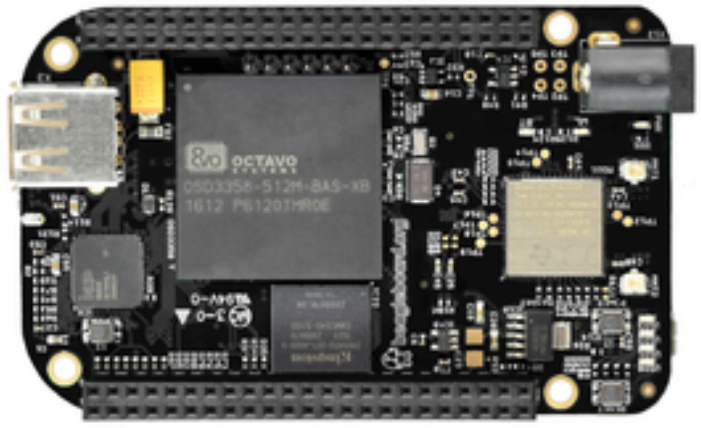

Concept 1: BeagleBone Black Wireless

- ➢ 5 V Operating Voltage
- ➢ Size: 3.4” by 2.1”
- ➢ 4 GB On-Board Memory Storage
- ➢ 1 GHz ARM Cortex-A8 Processor
- ➢ 2.4 GHz WIFI and Bluetooth 4.1 with BLE
- ➢ Cost: $75

Concept 2: Arduino MKR1000 WIFI

- ➢ 5 V Operating Voltage
- ➢ Size: 2.4” by 1”
- ➢ 256 KB On-Board Memory Storage
- ➢ 48 MHz ARM Cortex-M0+ Processor
- ➢ 2.4 GHz WIFI
- ➢ Cost: $35

Concept 3: Raspberry Pi 3 Model B+

- ➢ 5 V Operating Voltage
- ➢ Size: 3.35” by 2.2”
- ➢ 1 GB On-Board Memory Storage plus micro SD card slot
- ➢ 1.4 GHz ARM Cortex-A8 Processor
- ➢ 2.4/5 GHz WIFI and Bluetooth 4.2 with BLE
- ➢ Cost: $35

Alex Erven

Concept Selection: Microcontroller

Table 7: House of Quality for Microcontroller

		Engineering Characteristics			
Improvement Direction		↓	↓	↑	↑
Units		W	in	bytes	Hertz
Customer Requirements	Importance Weight Factor	Power Consumption	Size	Memory	Processing Power
Size	5.5		9	1	5
Cost	2.33		5		9
Processor	7	1	1		9
Memory	4.5	1	9	9	
Raw Score	(277.6)	11.50	108.7	46.00	111.5
Relative Weight %		4.10	39.1	16.6	40.2
Rank Order		4	2	3	1

- Determined that size and processing power were the most important characteristics
- Needs to be powerful enough to run the gloves, but small enough to not impede mobility

Table 8: Pugh Chart for Microcontroller

	Baseline	Alternative Solution	
Criteria	Datum: Raspberry Pi 3 Model B+	Concept 1: BeagleBone Black Wireless	Concept 2: Arduino MKR1000 WiFi
Size	DATUM	S	+
Cost		-	S
Processor		-	-
Memory		+	-
Sum of Positives		2	2
Sum of Negatives		2	1

- Raspberry Pi 3 Model B+ was selected as the benchmark comparison
- Raspberry Pi 3 Model B+ was selected as the best concept

Alex Erven

Concept Generation: Power Supply

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Concept 1: Wired Connection

Concept 2: Rechargeable Removable Batteries

Concept 3: Disposable Batteries

Concept 4: Encased Rechargeable Pack

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Concept Selection: Power Supply

Table 9: House of Quality for Power Supply

		Engineering characteristic		
Customer Requirements	Importance Weight Factor	Battery life	Power delivered	Size
Weight	6.20	5	5	9
Range of Motion	10.2	1	1	5
Efficiency	6.11	5	5	5
	Raw Score (280.9)	71.75	71.75	137.4
	Relative Weight %	25.55	25.55	48.91
	Rank Order	3	3	1

- ➢ Engineering characteristics were compared to customer requirements
- ➢ These characteristics were then given weights to determine importance
- ➢ All characteristics continued through since there were so few characteristics

Table 10: Pugh Chart for Power Supply

	Baseline	Alternative Solution		
Criteria	Datum: Encased Rechargable	Concept 1: Wired Connection	Concept 2: Removable Rechargable	Concept 3: Disposable Batteries
Weight	DATUM	+	-	-
Battery Life		+	+	+
Power Delivered		S	S	S
Size		+	-	-
Sum of Positives		3	1	1
Sum of Negatives		0	2	2

- ➢ Each concept was weighted against the Encased Rechargeable in a Pugh matrix
- ➢ The removable rechargeable batteries were determined to be the best concept

Alex Erven

Final Design Concept

- Partial fingerless pilot's gloves
- 12 LRAs, 1 on each palm and front of each finger
- Removable rechargeable battery on back of each hand
- Raspberry Pi 3 B+ on the back of each hand
- 12 9-axis IMUs, 1 on the back of each finger and hand

Moving Forward

- Purchase Materials
- Risk Assessment

Figure 3: Final concept components

Alex Erven

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Alex Erven

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