ASLBoT

Assisted Sign Language Bot Translator

Group #14

Gustavo Camero - CpE

Luis Hurtado - EE

Michael Loyd - EE

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Assigned Professor

Dr. Samuel Richie

Advisor/Client

Dr. Chung Yong Chan

Motivation

- Member works at clinic
  - Noticed a lack of efficient translation
  - Looking for standardized language interpretation
  - No support for sign language

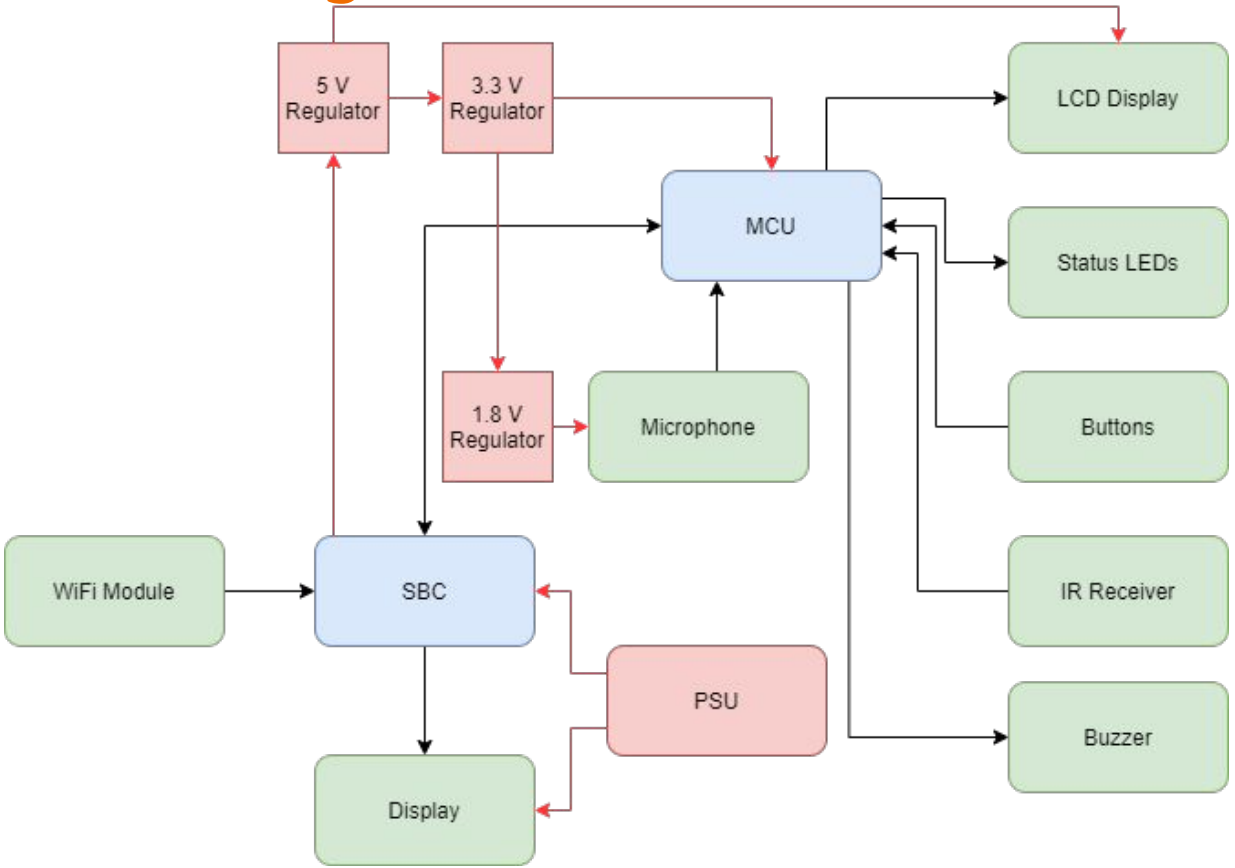
Goals & Objectives

- Translate English speech into American Sign Language.
- Connect wirelessly for cloud-based service access.
- Perform speech-to-text and speech-to-ASL language translations.
- Indicate various statuses of the device via LEDs.
- Capture audio at frequencies around natural human pitches that can be translated into text via speech-to-text algorithms.
- Stand upright in a custom-designed housing, which accommodates the SBC, MCU, Wi-Fi module, buzzer, and microphone.
- Display real-time, high-quality animations of sign language gestures.
- Receive manual inputs from the user, including start/stop recording and mode selection.

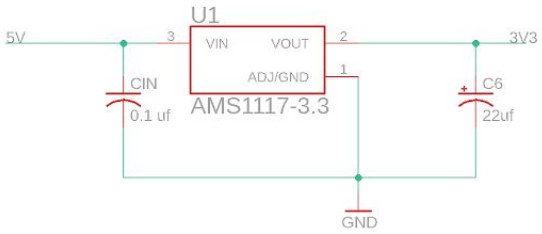
Requirement Specifications

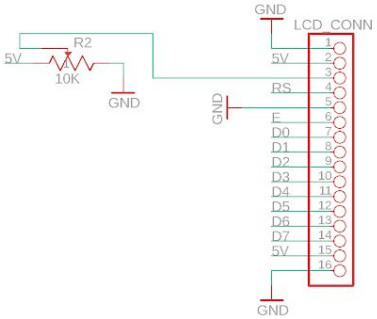
Component	Parameter	Design Specification
Microphone	Signal Production	100 mV at 1m
Microphone	Frequency Response Gain	-3 dB for 80 Hz to 260 Hz
Speaker	Sound Production	50-70 dB at 1m
Memory	Size	32 GB
Power Supply	Power	32 W (12V @ 3A)
System	Translation Accuracy	20% (BLEU Average)
System	Dimensions	6” x 6” x 3”
System	Cost	$500

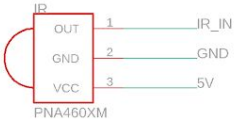
Overall Block Diagram

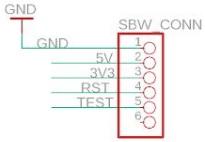


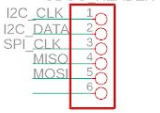
Hardware Schematic

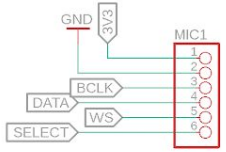


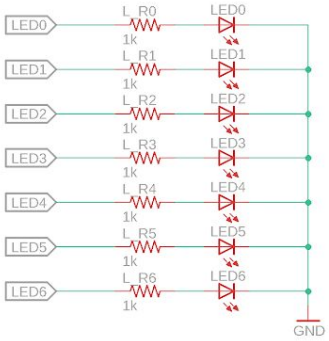


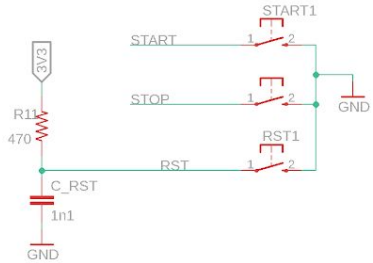


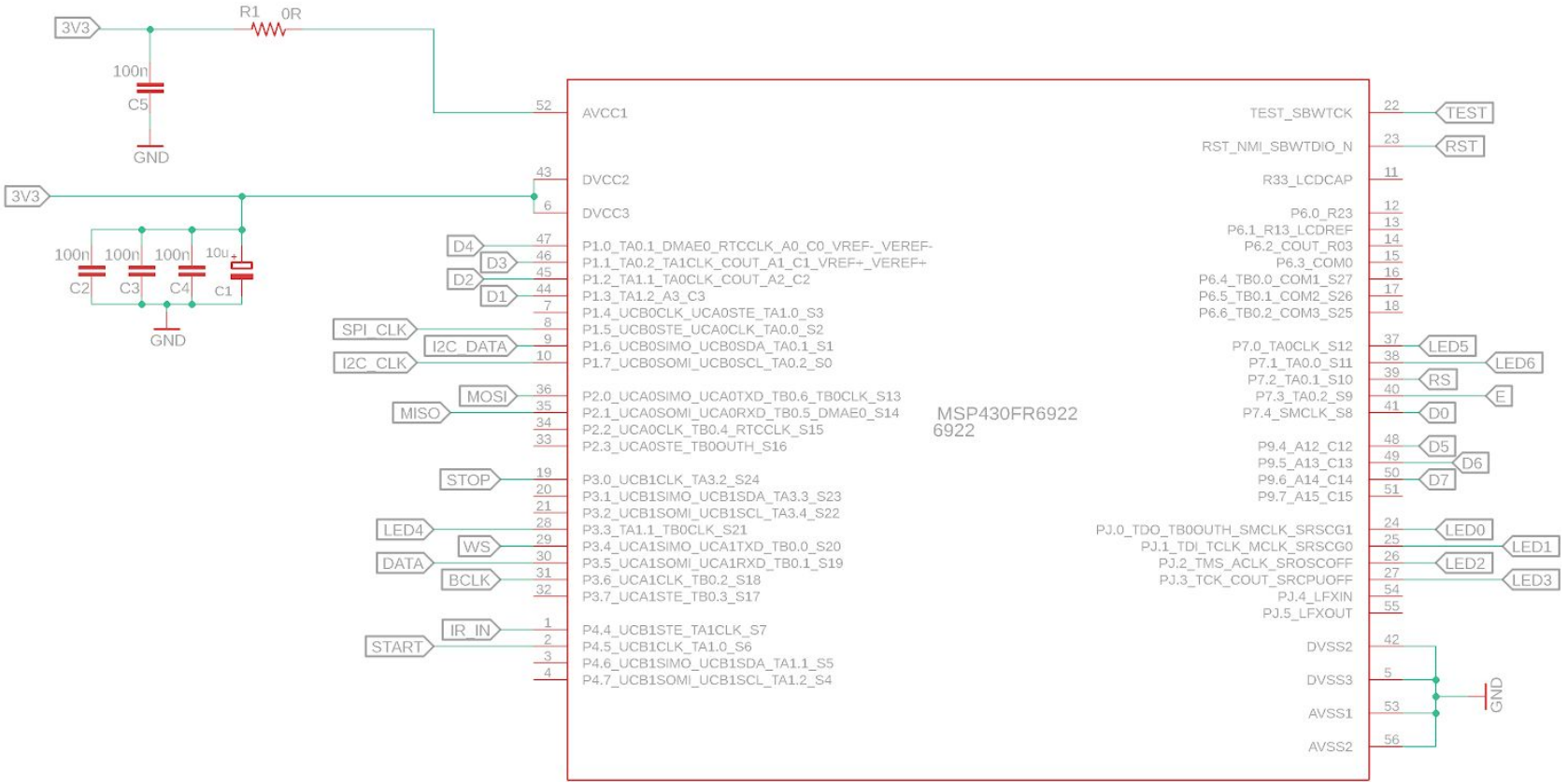










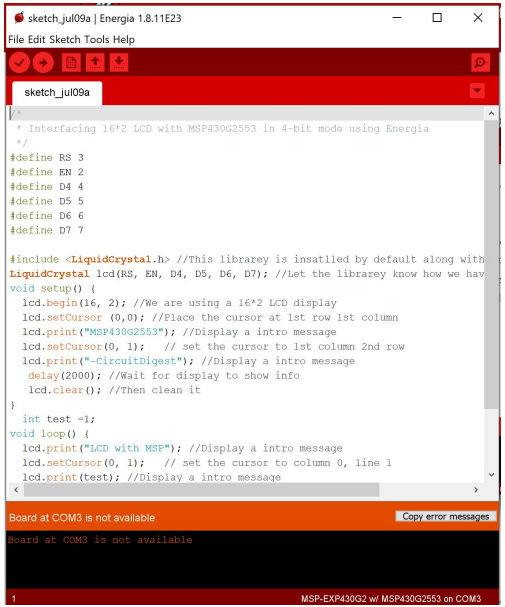

3V3
R1
0R
100n
C5
GND
3V3
100n
C2
100n
C3
100n
C4
10u
C1
GND
MSP430FR6922
6922
52 AVCC1
43 DVCC2
6 DVCC3
47 P1.0_TA0.1_DMAE0_RTCCLK_A0_C0_VREF-_VEREF-
46 P1.1_TA0.2_TA1CLK_COUT_A1_C1_VREF+_VEREF+
45 P1.2_TA1.1_TA0CLK_COUT_A2_C2
44 P1.3_TA1.2_A3_C3
7 P1.4_UCB0CLK_UCA0STE_TA1.0_S3
8 P1.5_UCB0STE_UCA0CLK_TA0.0_S2
9 P1.6_UCB0SIMO_UCB0SDA_TA0.1_S1
10 P1.7_UCB0SOMI_UCB0SCL_TA0.2_S0
36 P2.0_UCA0SIMO_UCA0TXD_TB0.6_TB0CLK_S13
35 P2.1_UCA0SOMI_UCA0RXD_TB0.5_DMAE0_S14
34 P2.2_UCA0CLK_TB0.4_RTCCLK_S15
33 P2.3_UCA0STE_TB0OUTH_S16
19 P3.0_UCB1CLK_TA3.2_S24
20 P3.1_UCB1SIMO_UCB1SDA_TA3.3_S23
21 P3.2_UCB1SOMI_UCB1SCL_TA3.4_S22
28 P3.3_TA1.1_TB0CLK_S21
29 P3.4_UCA1SIMO_UCA1TXD_TB0.0_S20
30 P3.5_UCA1SOMI_UCA1RXD_TB0.1_S19
31 P3.6_UCA1CLK_TB0.2_S18
32 P3.7_UCA1STE_TB0.3_S17
1 P4.4_UCB1STE_TA1CLK_S7
2 P4.5_UCB1CLK_TA1.0_S6
3 P4.6_UCB1SIMO_UCB1SDA_TA1.1_S5
4 P4.7_UCB1SOMI_UCB1SCL_TA1.2_S4
22 TEST_SBWTCK
23 RST_NMI_SBWTDIO_N
11 R33_LCDCAP
12 P6.0_R23
13 P6.1_R13_LCDREF
14 P6.2_COUT_R03
15 P6.3_COM0
16 P6.4_TB0.0_COM1_S27
17 P6.5_TB0.1_COM2_S26
18 P6.6_TB0.2_COM3_S25
37 P7.0_TA0CLK_S12
38 P7.1_TA0.0_S11
39 P7.2_TA0.1_S10
40 P7.3_TA0.2_S9
41 P7.4_SMCLK_S8
48 P9.4_A12_C12
49 P9.5_A13_C13
50 P9.6_A14_C14
51 P9.7_A15_C15
24 PJ.0_TDO_TB0OUTH_SMCLK_SRSCG1
25 PJ.1_TDI_TCLK_MCLK_SRSCG0
26 PJ.2_TMS_ACLK_SROSCOFF
27 PJ.3_TCK_COUT_SRCPUOFF
54 PJ.4_LFXIN
55 PJ.5_LFXOUT
42 DVSS2
5 DVSS3
53 AVSS1
56 AVSS2
GND
D4
D3
D2
D1
SPI_CLK
I2C_DATA
I2C_CLK
MOSI
MISO
STOP
LED4
WS
DATA
BCLK
IR_IN
START
TEST
RST
LED5
LED6
RS
E
D0
D5
D6
D7
LED0
LED1
LED2
LED3

MCU Selection

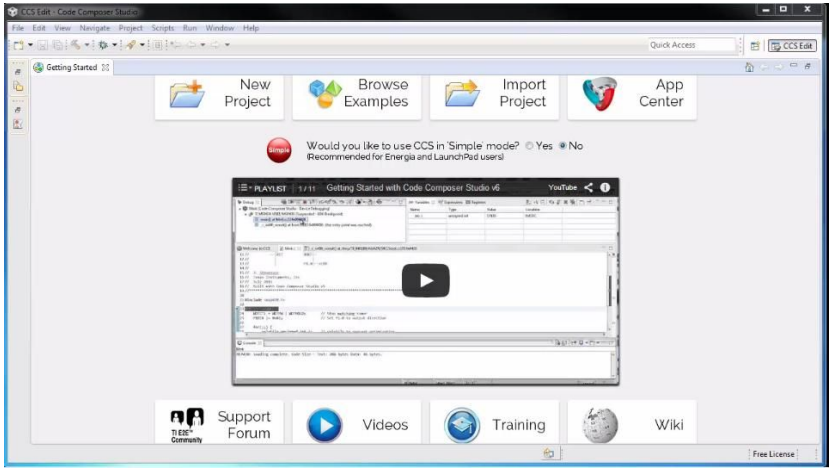
	GPIO Pins	ADCs	Communication Protocols	Cost
STM32L162ZDT6	115	12-bit/ 40 Channels	I^2C, I^2S, SPI, USART, USB	$9.80
STM32L151RDT6TR	51	12-bit/ 40 channels	I^2C, I^2S, SPI, USART, USB	$6.85
MSP430FR6989	**83**	**12-bit/ 16 channels**	**I^2C, I^2S, SPI, UART**	**$7.86**

MCU Development Environment

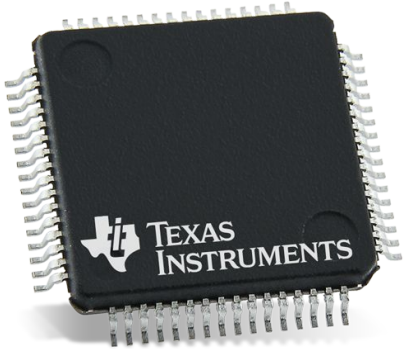
Energia



Code Composer Studio



MCU Functionality



- Takes in raw data from microphone
- Uses LEDs to indicate overall status of system
- Utilizes LCD to indicate recording status and incoming text stream
- Communicates with SBC to send raw audio data and receive updates
- IR sensor for wake functionality
- On-board buttons to start and stop recording and reset

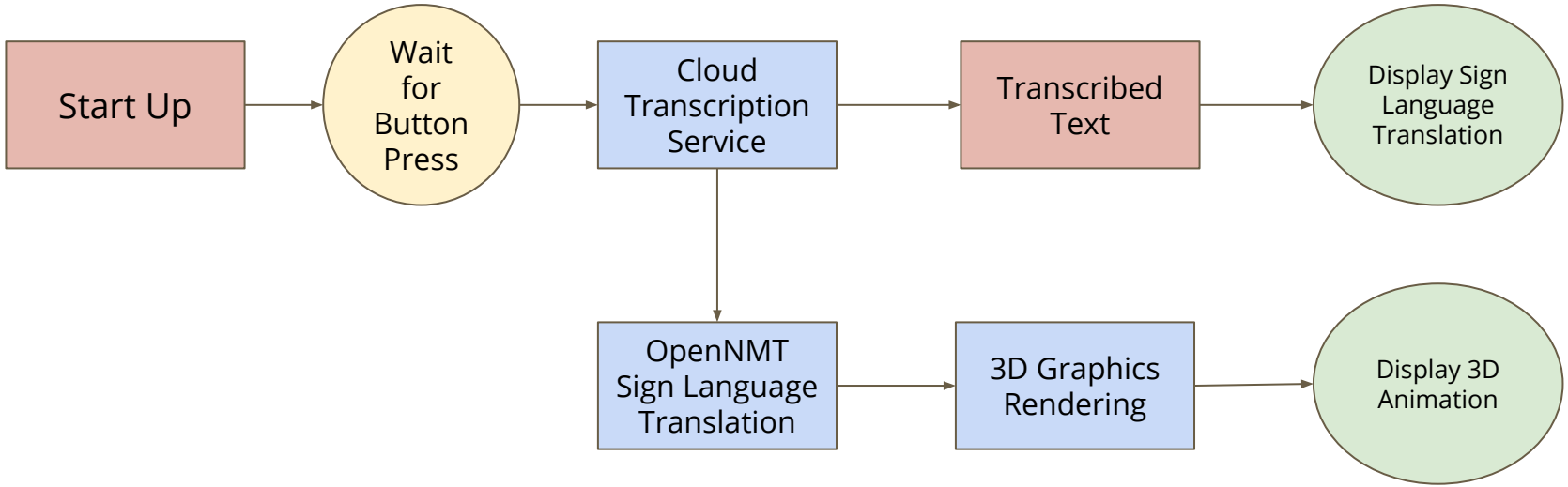
Microphone Selection

	Frequency Range	Output	Interface	Cost
Mini USB Microphone	100 Hz - 10 kHz	Digital	USB	$4.95
SparkFun MEMS Microphone (INMP401/ADMP401)	100Hz - 15 kHz	Analog	ADC	$10.95
MEMS Microphone (SPH0645LM4H)	**50 Hz - 15 kHz**	**Digital**	**I^2S**	**$6.95**

SBC Selection

	Architecture	Communication Protocols	OS	RAM	Memory	Cost
NVIDIA Jetson Nano	ARM64	I^2C, SPI, UART	Linux	4 GB	External Only	$99.00
ASUS TinkerBoard	ARM64	I^2C, SPI, UART, I^2S	Linux	2 GB	External Only	$70.00
UDOO x86 Advanced Plus	x86_64	I^2C, SPI, UART	Linux Windows	4 GB	32 GB	$176.00

Software Diagram



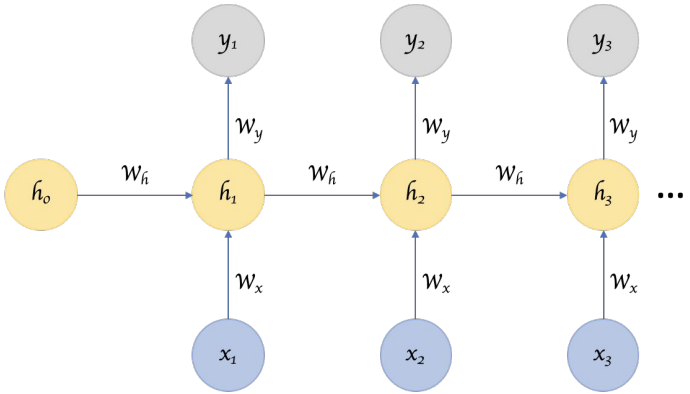
Machine Translation

Rule-Based MT (RBMT)	Statistical MT (SMT)	Neural MT (NMT)
• Large database of linguistic rules and millions of bilingual dictionaries. • For the use of RBMT in text to ASL text translation, a massive database with the rules and resources will need to be created.	• Statistical models that have parameters based on the analysis of monolingual and bilingual corpora. • Relies heavily on existing corpora, minimum of 2 million words. • CPU-intensive	• Uses neural networks with training sets to tune weights. • Examines entire sentence before translating. • Training requires GPU • Large Training sets

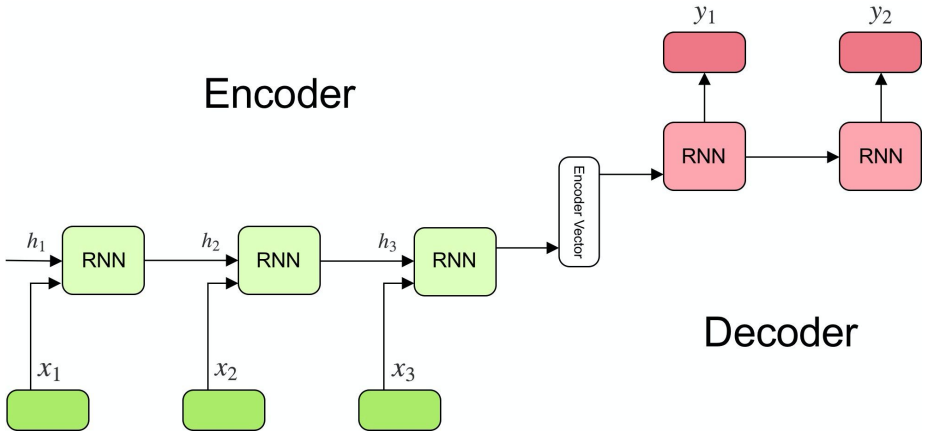
OpenNMT

- Open source
- Can be used with Pytorch
- Based on seq2seq models

Recurrent Neural Network



Sequence-to-sequence



RNNshttps://towardsdatascience.com/recurrent-neural-networks-d4642c9bc7ce
Seq-seq https://towardsdatascience.com/understanding-encoder-decoder-sequence-to-sequence-model-679e04af4346

OpenNMT

colab

- Needs GPU for fast training
- Google Colaboratory
- ~40 minute training time

Training OpenNMT

Requirements:

- Source (English)
- Target (Sign language Gloss)
- Source Validation
- Target Validation

Source	**Target**	**Source Validation**	**Target Validation**
I know sign language	ME KNOW SIGN	I want to know sign language	ME WANT KNOW SIGN LANGUAGE

Training OpenNMT

Approach #1 Specific Domain

- Limits variety of words used
- Corpora based on daily school

hurry we need to go now
on campus
I need to write this paper tonight
this project is due tomorrow
my lecture starts in five minutes
I am going to college this semester
what classes are you taking
I took that class last semester
I wanted to go to the student union
did you finish the paper last night
I was absent from class yesterday
Was the homework supposed to be done individually
I am making new friends in college
I made a friend yesterday
Do you want to be friends
there are a few ways to get to that building
why is the campus so large
the engineering building is very big
I need help because I can not find this classroom
I can't find this classroom
I need help making these signs
How many buildings are there on campus
How much did you write for the paper

Training OpenNMT

Issue - Very Limited Translations

```
SENT 1: ['where', 'can', 'I', 'find', 'the', 'classroom', 'building']
PRED 1: ME NEED HELP MAKE SIGN SIGN
PRED SCORE: -0.0293
```

```
SENT 1: ['I', 'need', 'help', 'finding', 'the', 'classroom']
PRED 1: ME NEED HELP MAKE SIGN SIGN
PRED SCORE: -0.0002
```

Training OpenNMT

Approach #2 Specific Domain + Redundancy

- Continue to limit variety of words used
- Breakdown existing sentences
- Introduce similar sentences

the engineering building is big
the engineering building
engineering building
building is big
engineering building is big

when did you finish your homework
when did you finish
did you finish your homework
finish your homework

Training OpenNMT

```
SENT 1: ['where', 'can', 'I', 'find', 'the', 'classroom', 'building']
PRED 1: ME NEED HELP MAKE SIGN SIGN
PRED SCORE: -0.0293
```

First approach

```
SENT 1: ['where', 'can', 'I', 'find', 'the', 'classroom', 'building']
PRED 1: WHERE ME CAN FIND CLASSROOM
PRED SCORE: -0.0006
```

Second approach

```
SENT 1: ['I', 'do', 'understand', 'the', 'homework']
PRED 1: ME NOT WANT KNOW
PRED SCORE: -0.2670
```

First approach

```
SENT 1: ['I', 'do', 'understand', 'the', 'homework']
PRED 1: ME UNDERSTAND HOMEWORK
PRED SCORE: -0.0006
```

Second approach

Training OpenNMT

Some issues:

```
SENT 1: ['I', 'want', 'to', 'make', 'friends', 'this', 'semester']
PRED 1: ME WANT MAKE FRIEND AT COLLEGE
PRED SCORE: -0.0245
```

Second approach

```
SENT 1: ['I', 'want', 'to', 'make', 'friends']
PRED 1: ME WANT MAKE FRIEND
PRED SCORE: -0.0001
```

Second approach

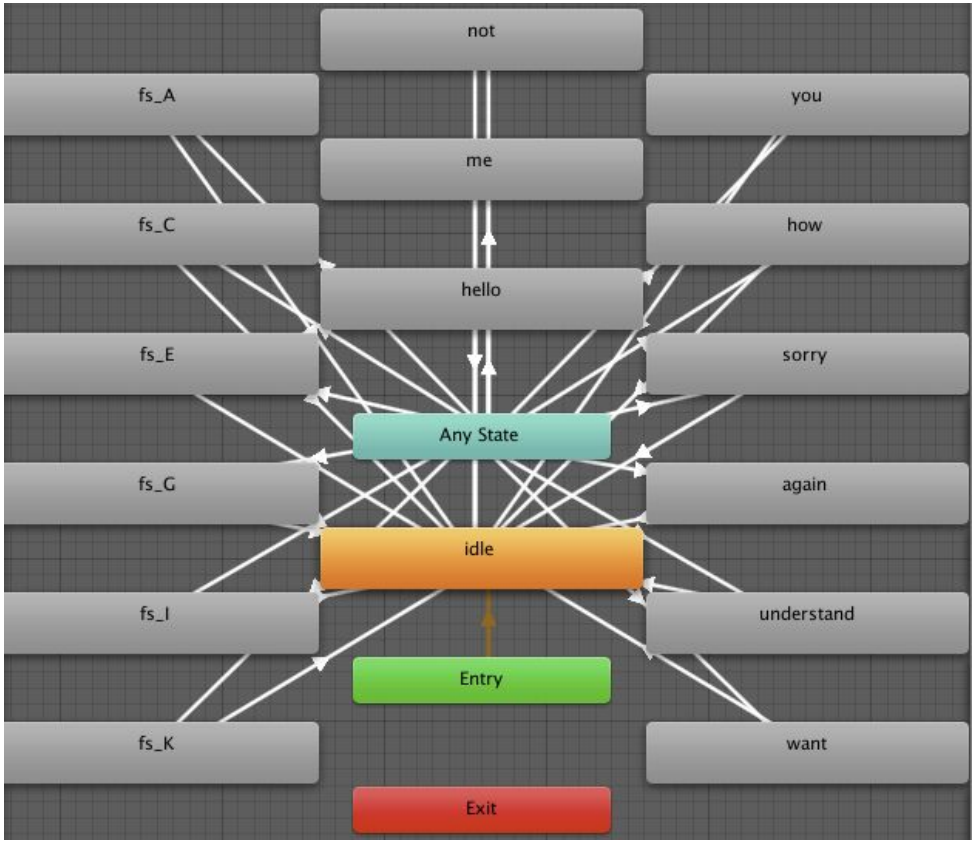
Game Engine

- Functions of the game engine:
  - Display animations
  - Integration of text-to-speech, speech-to-text, and (possible) audio-to-WAV API

	Minimum RAM	Compatible with Linux-based ARM64	Compatible with x86_64	Community Support for SBCs
Unity	**None**	**No**	**Yes**	**Full**
Unreal Engine 4	8 GB	Yes	Yes	Limited
Godot	4 GB	No	Yes	None

Video Rendering

- Dynamic state machine
- Hashmap to map incoming sign language translation from NMT



Video Rendering

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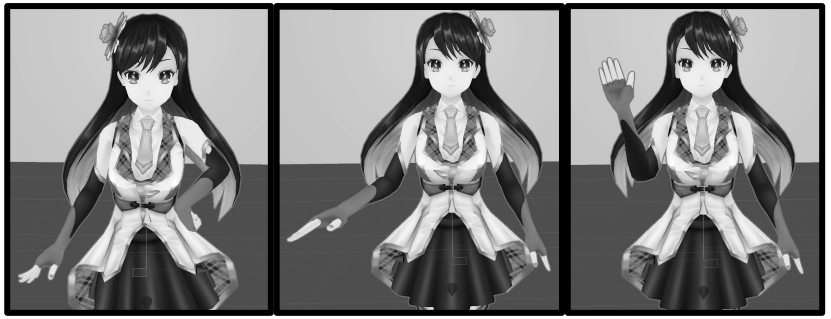
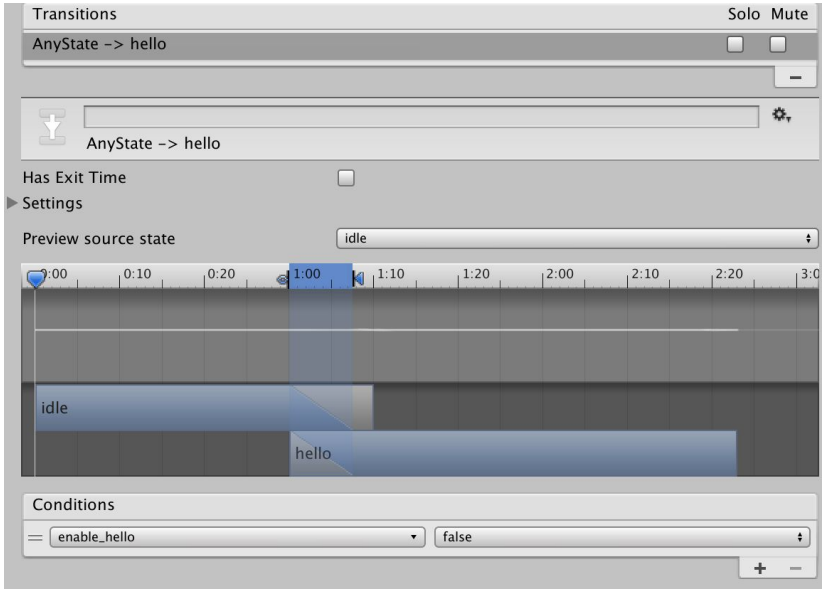


“idle” → <transition> → “hello”



Work Distribution

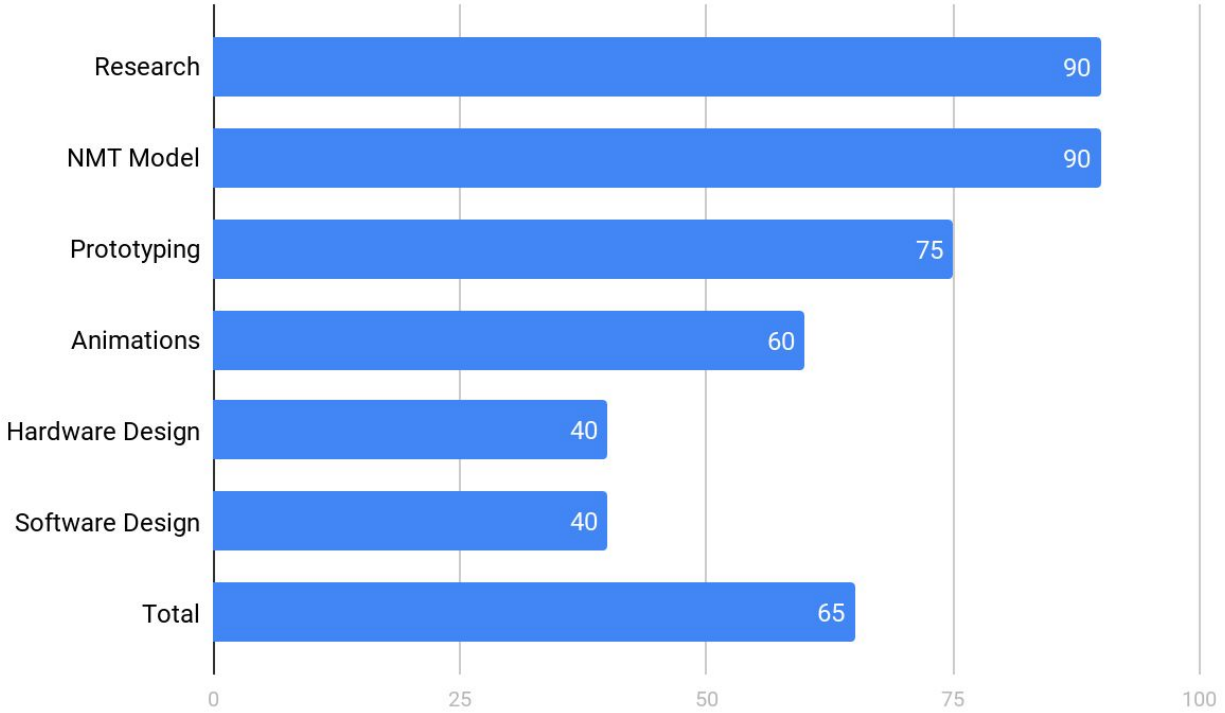
Member	Embedded	Machine Translation	Graphics Rendering	GUI
Gustavo Camero				
Luis Hurtado				
Michael Loyd				
Jared Spinks				

Lead	
Help	

Challenges & Issues

- Hardware Design Challenges:
  - SBC architecture compatibility
  - FPGA - difficulty for soldering and programming given timeframe
- Software Design Challenges:
  - Granularity-based OpenNMT (trial and error)

Progress


Research
90
NMT Model
90
Prototyping
75
Animations
60
Hardware Design
40
Software Design
40
Total
65
0
25
50
75
100

Project Budget

Part	Supplier	Cost
UDOO x86 Advanced Plus	UDOO	$ 176.00
12V-3A Barrel Jack Power Supply	UDOO	$ 8.90
MSP430FR6989	Mouser	$ 7.86
MEMS Microphone SPH0645LM4H	Adafruit	$ 6.95
IR Receiver TSOP38238	Adafruit	$ 1.95
Self-Funded	--	$ --
Total	Supplier	$ 192.76

Questions?