XYLO-BOT:

A INTERACTIVE MUSIC PLATFORM FOR CHILDREN WITH AUTISM

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OUTLINE:

- Social Behaviors & Autism Spectrum Disorders
- Objectives of Our Study
- Socially Assistive Robotics & Music Therapy
- Literature Review
- Platform & Experiment Design
- Experimental Results
- New Instrument Design
- Contributions and Future Works

Non-Verbal Cues

Facial Expression

Emotion Engagement

Gaze Regulation

Body Language

Motor Control

Verbal Cues

Tone of Voice

Turn Taking

Deficits of ASD VS. Typically Developing Children (TD)

Difficulty in showing Facial expression

@gavinthomas

VS

Eye contact and Joint Attention Problems

http://www.dana.org/Publications/Brainwork/Details.aspx

Objectives of Our Study

- Eye contact Joint attention hand-eye collaboration
- Motor control training
- Event based emotion engagement
- Music emotion understanding

Eye Gaze & Joint Attention

- Eye contact during music interaction
- Joint attention during music play

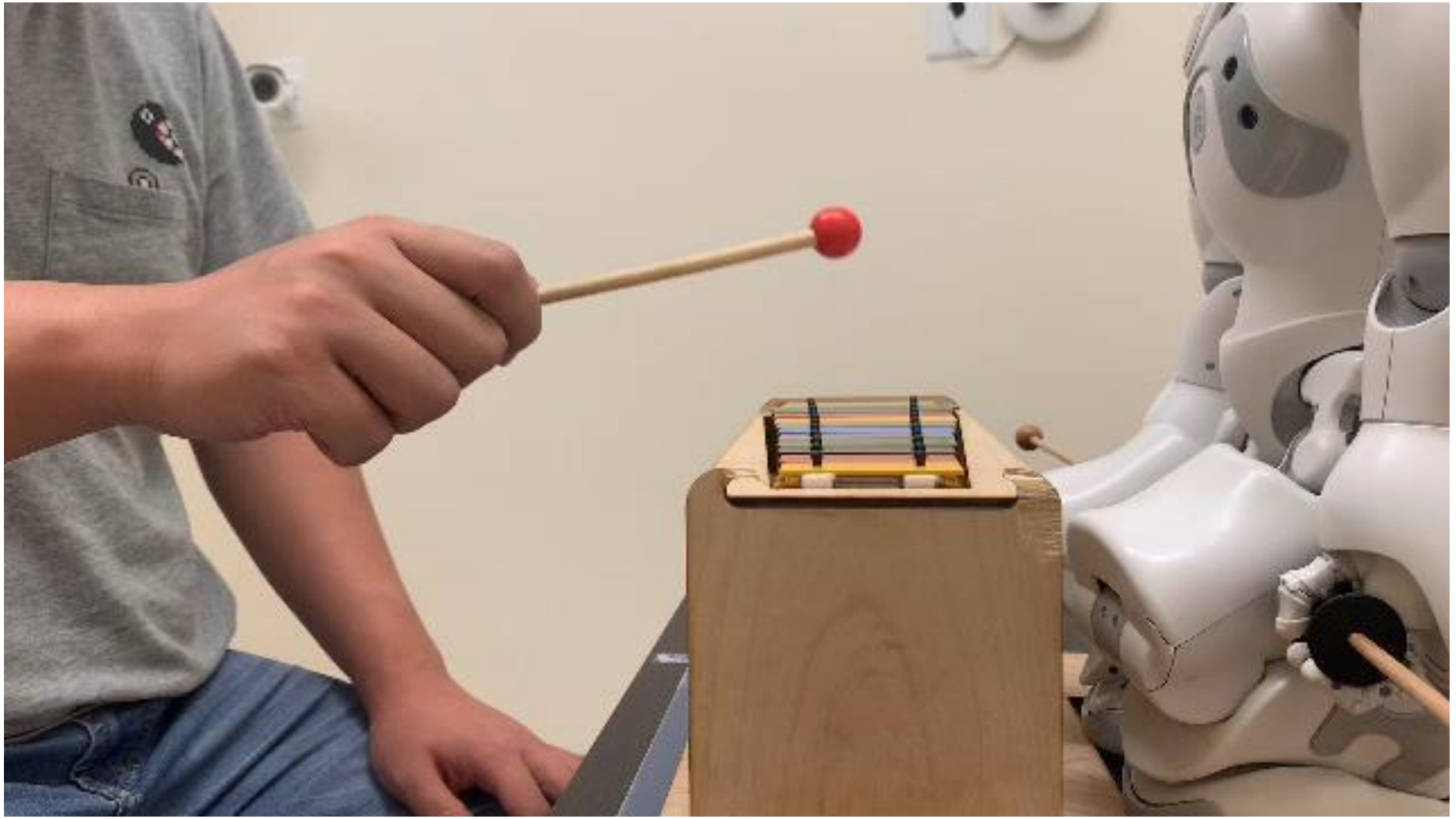
Motor Control: How to play Music Properly

- Motion 1

VS

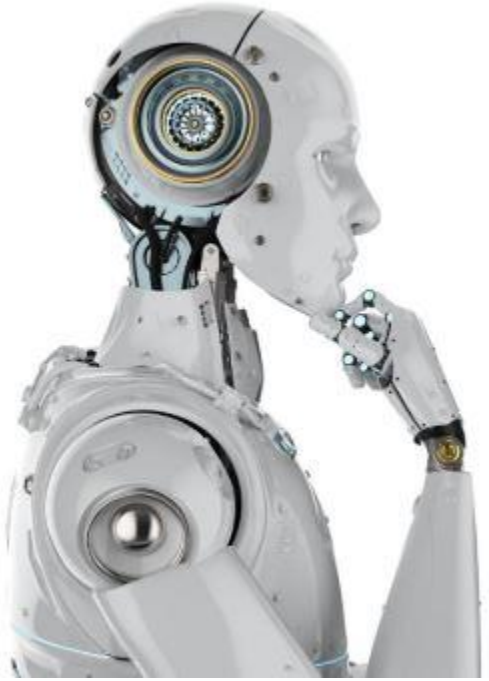
- Motion 2

Motor Control: How to play Music Properly



Why Robot?

- Complex human-human interaction
- ASD kids avert from human
- More interest in mechanical objects and robots



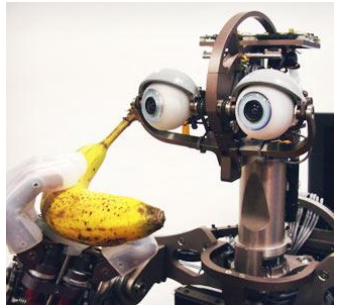
T. Fong, I. Nourbakhsh, and K. Dautenhahn. A survey of socially interactive robots. *Robotics and Autonomous Systems*, 42(3-4):143-166, 2003

Socially Assistive Robotics (SAR)

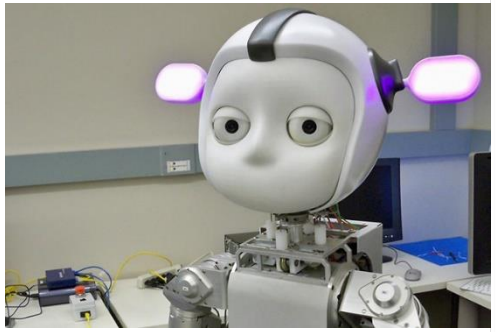
- Objectives for using SARs
  - Defining socially assistive robotics
  - Assisting human with physical deficits
  - Provide social interaction
  - Tutoring
- Different types of robots
  - Non-Humanoid Robot
  - Humanoid Robot

Social Robots

Non-Humanoid Robots



Humanoid Robots



Music Therapy

- Spontaneous self-expression
- Emotional communication
- Social engagement

Kim J, Wigram T, Gold C. Emotional, motivational and interpersonal responsiveness of children with autism in improvisational music therapy. Autism. 2009 Jul;13(4):389-409.

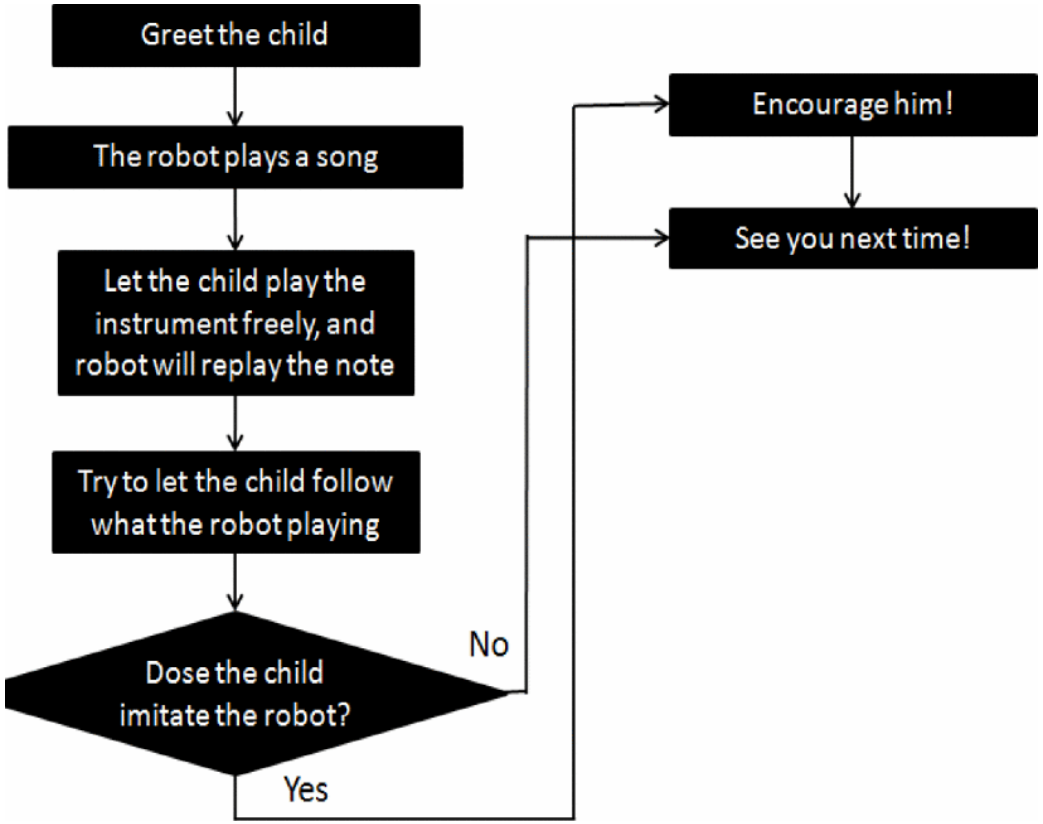
Music Emotion Understanding

- Music as the Language of Emotion
  - Music clip for Feeling 1:
  - Music clip for Feeling 2:

Pratt CC. Music as the language of emotion. The Library of Congress.

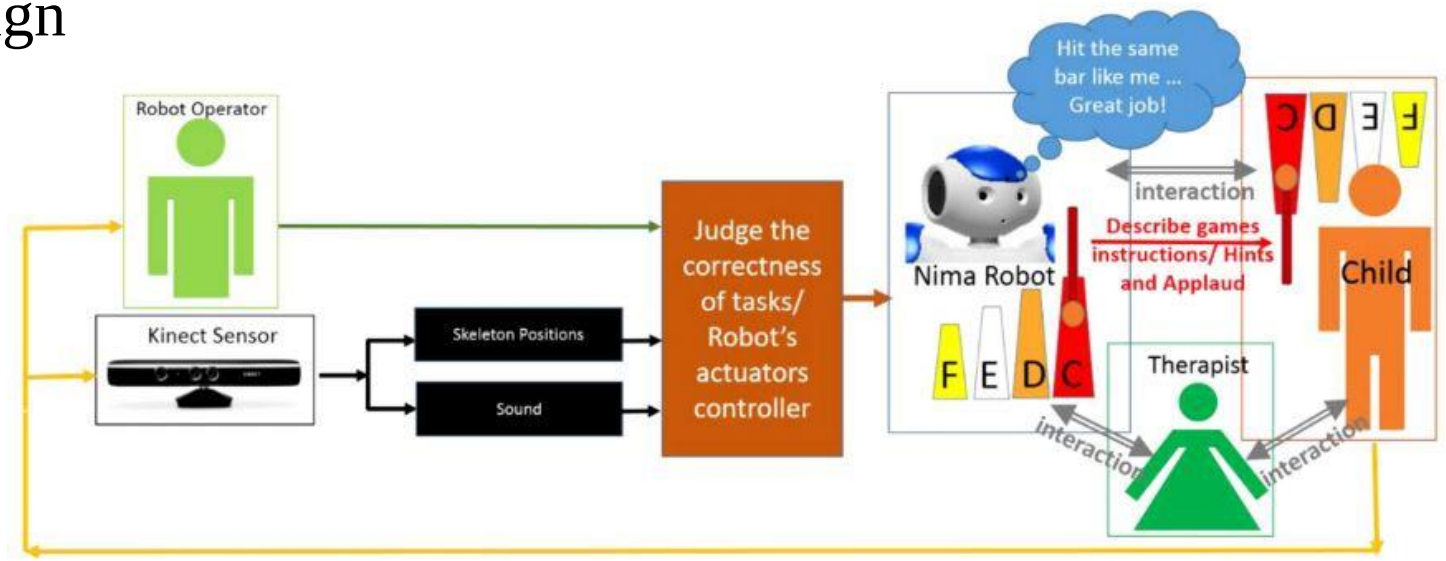
Literature Review

- Peng, Ying-Hua, Cheng-Wei Lin, N. Michael Mayer, and Min-Liang Wang. "Using a humanoid robot for music therapy with autistic children." In 2014 CACS International Automatic Control Conference (CACS 2014), pp. 156-160. IEEE, 2014.



Literature Review

- Taheri, Alireza, Ali Meghdari, Minoo Alemi, and Hamidreza Pouretemad. "Teaching music to children with autism: a social robotics challenge." *Scientia Iranica* 26, no. 1 (2019): 40-58.
  - Very detailed experiment design
  - Lack of technical design of the robot play system
  - Lack of autonomous design

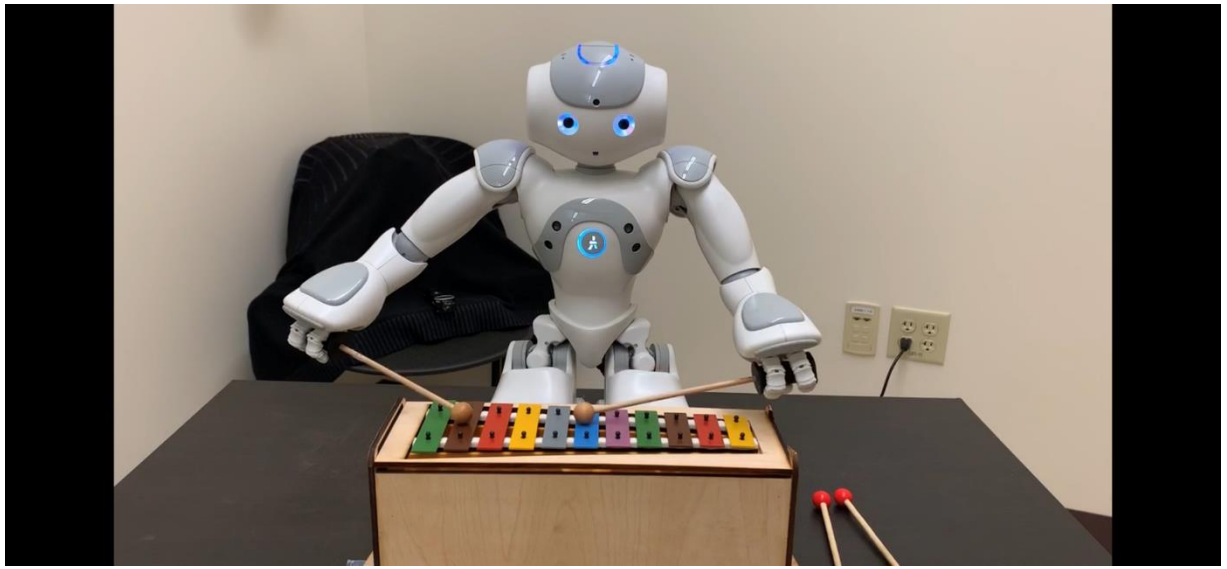


Literature Review

- Suzuki, Ryo, and Jaeryoung Lee. "Robot-play therapy for improving prosocial behaviours in children with Autism Spectrum Disorders." In 2016 International Symposium on Micro-NanoMechatronics and Human Science (MHS), pp. 1-5. IEEE, 2016.

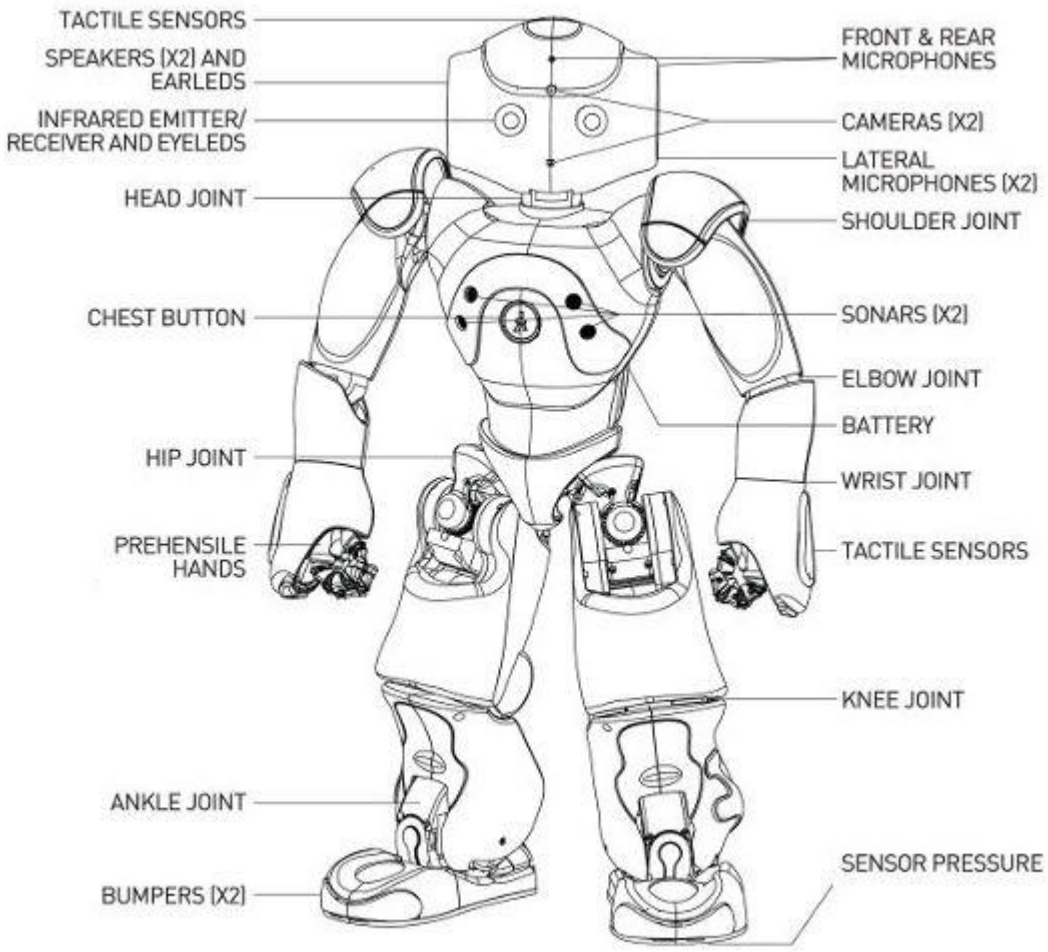
- Beer, Jenay M., Michelle Boren, and Karina R. Liles. "Robot Assisted Music Therapy: A Case Study with Children Diagnosed with Autism." In The Eleventh ACM/IEEE International Conference on Human Robot Interaction, pp. 419-420. IEEE Press, 2016.

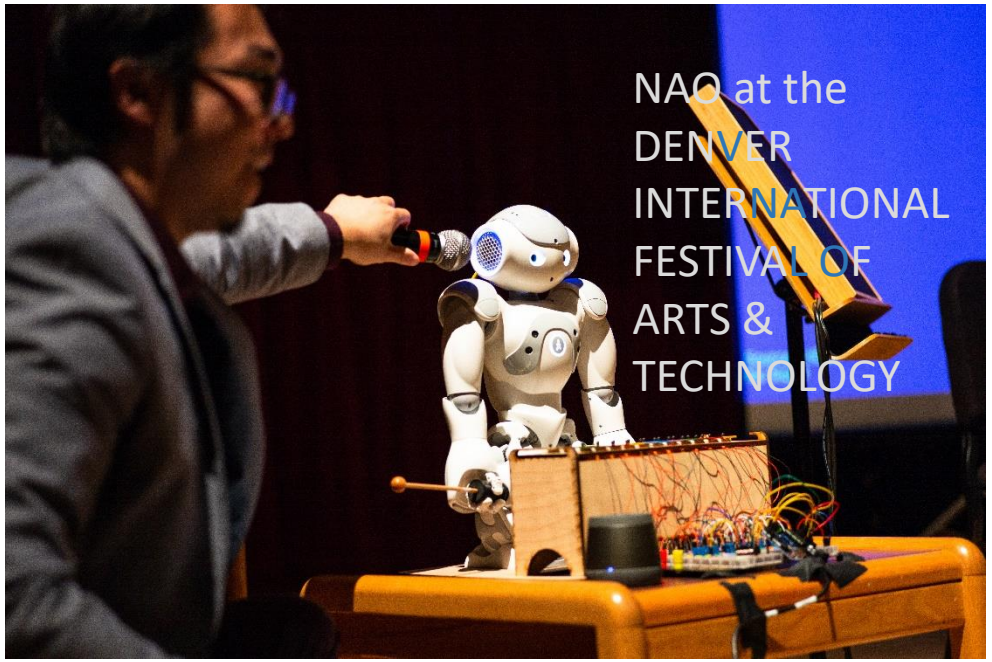
Platform Design



- NAO and Xylophone
- Accessories
- Module-Based Acoustic Music Interactive System

Why NAO?

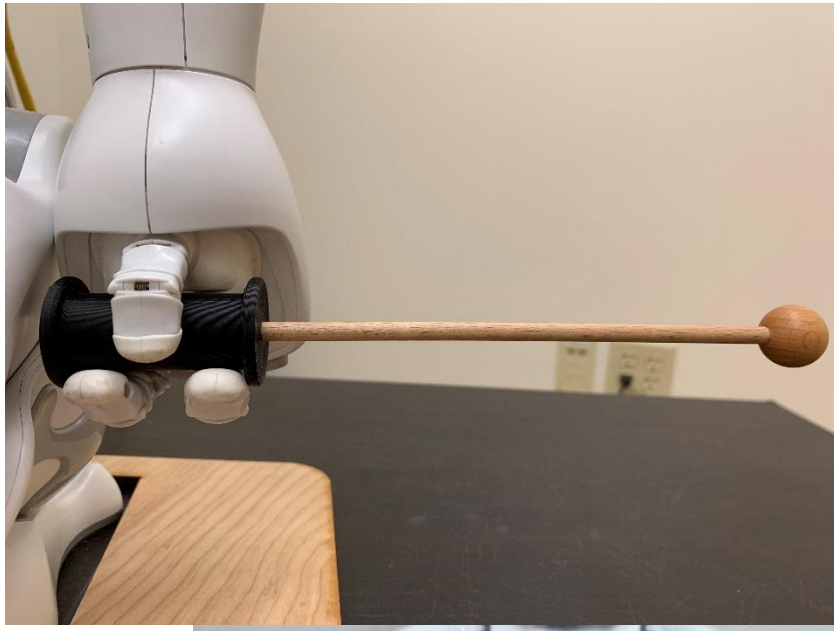




NAO

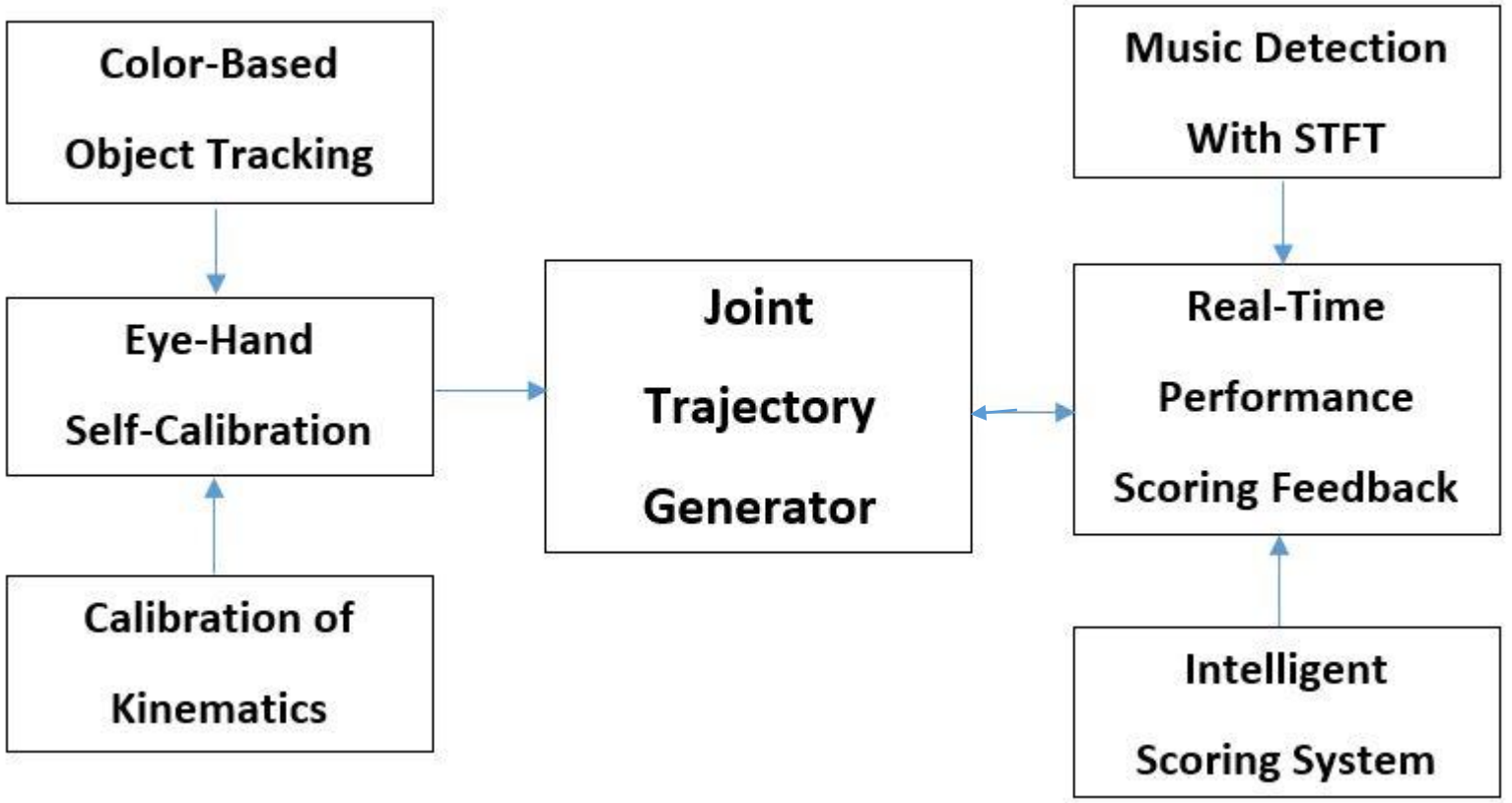
- Motion Control
- Language
- Eye contact
- Speech Recognition

Accessories



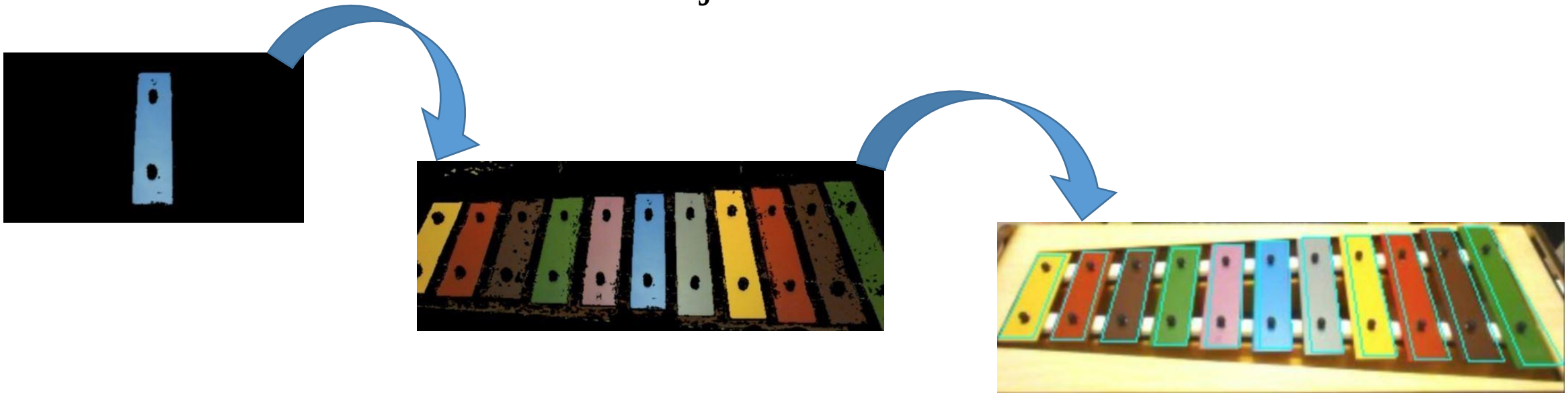
Our design
VS
other's design

Acoustic Music Interactive System

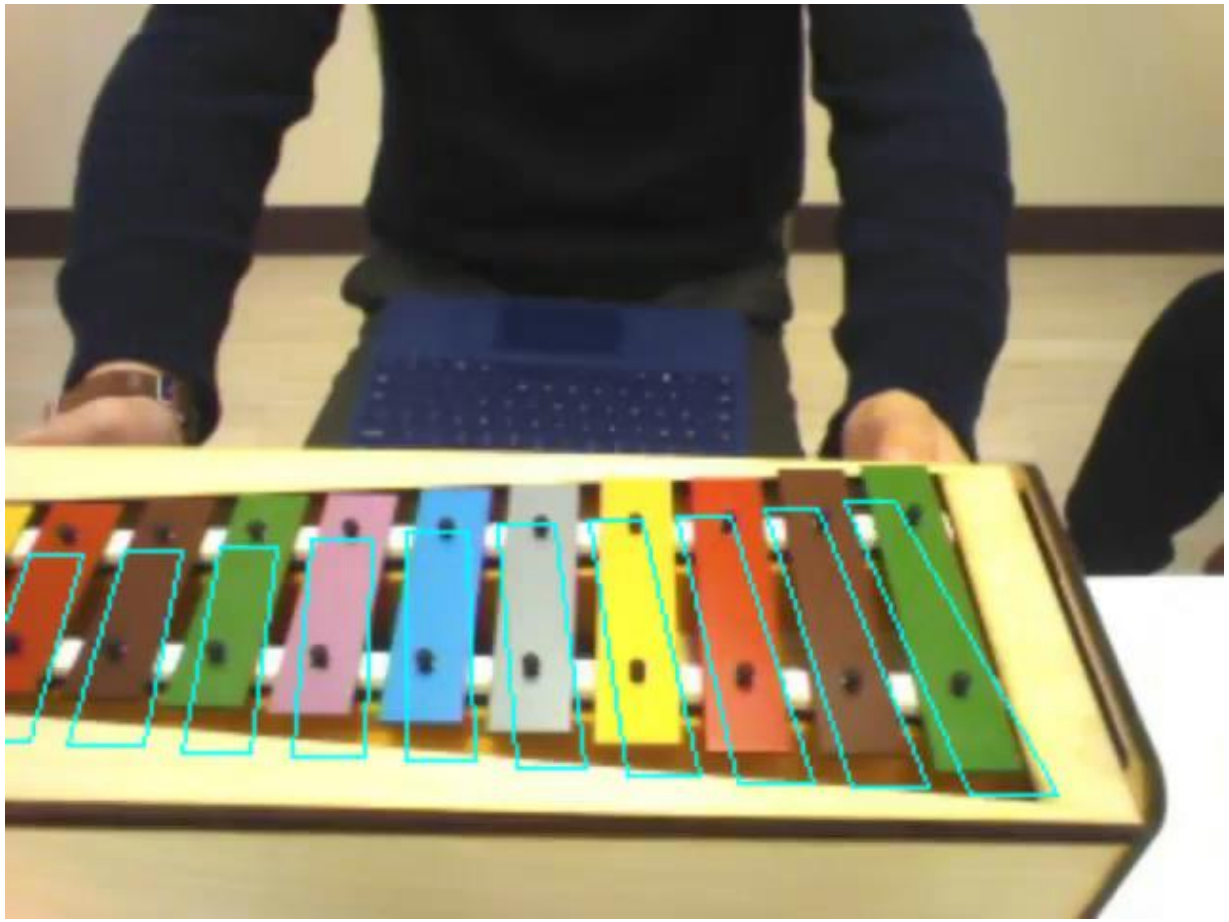


Color-Based Object Tracking

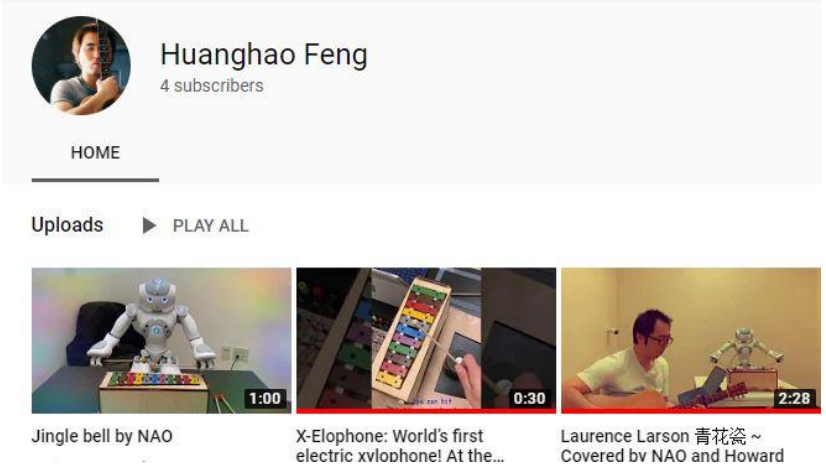
- Find center blue color
- Then will start to find other colors
- Provide estimated outline on object



Color-Based Object Tracking



Joint Trajectory Generator



- 11 notes using hex-decimal number [1,2,3…a,b]
- 0 used represents rest as a music notation
- Map each note into a list of joint angles
- Bezier interpolation by manufacturer-provided API
- Be able to play in-time with any customized song

Real-Time Performance Scoring System

- Real-time Notes Detection
  - Short-time Fourier Transform (STFT)

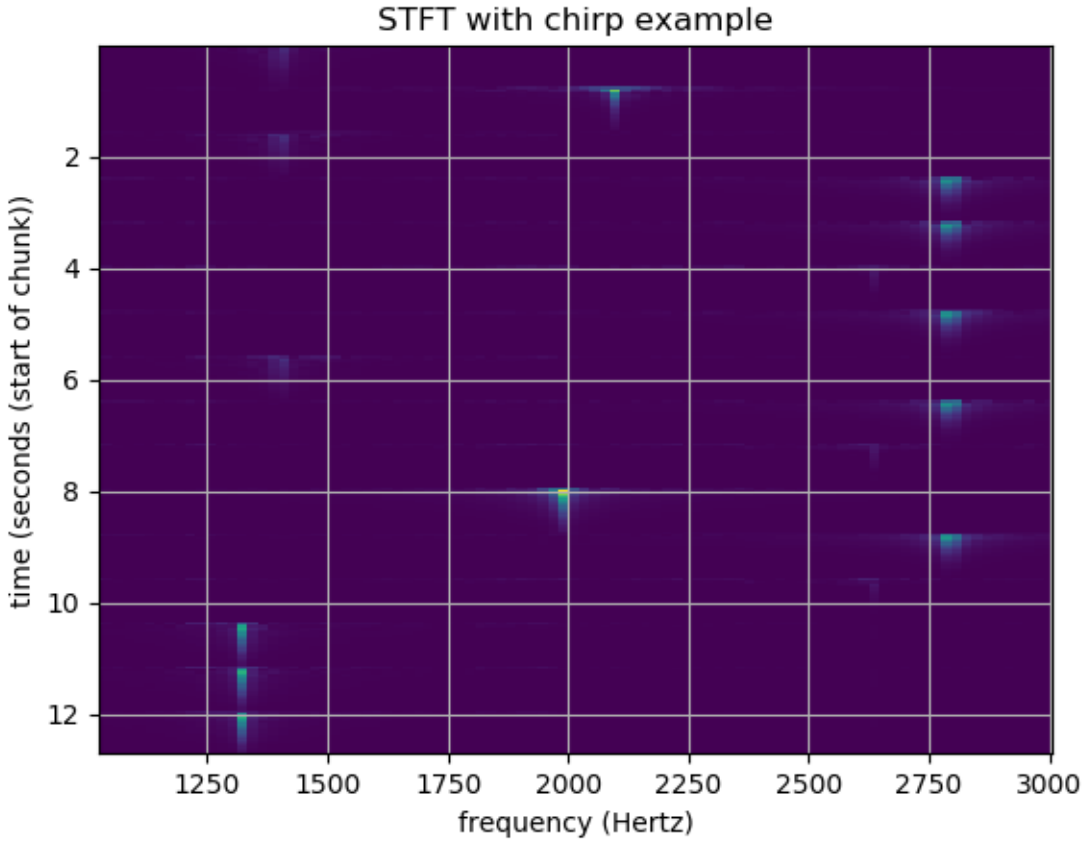
- Intelligent Online Scoring System
  - Levenshtein Distance

Real-time Notes Detection

- Band-pass filter
- STFT to get raw peaks in time domain
- Refine the peaks by finding the local maximum amplitude in order to get targeted frequencies
- High recognition rate

Real-time Notes Detection

- STFT



$$\mathbf{STFT}\{x[n]\}(m,\omega) \equiv X(m,\omega) = \sum_{n=-\infty}^{\infty} x[n]w[n-m]e^{-j\omega n}$$

Intelligent Online Scoring System

- Compare the difference between source sequence of notes with target notes
  - Levenshtein Distance
- Accuracy calculation
- Determine whether add more practice or not

Levenshtein Distance

$$\operatorname{lev}_{a,b}(i,j) = \begin{cases} \max(i,j) & \text{if } \min(i,j) = 0, \\ \min \begin{cases} \operatorname{lev}_{a,b}(i-1,j) + 1 \\ \operatorname{lev}_{a,b}(i,j-1) + 1 \\ \operatorname{lev}_{a,b}(i-1,j-1) + 1_{(a_i \neq b_j)} \end{cases} & \text{otherwise.} \end{cases}$$

Levenshtein Distance

		S	a	t	u	r	d	a	y
	0	1	2	3	4	5	6	7	8
S	1	0	1	2	3	4	5	6	7
u	2	1	1	2	2	3	4	5	6
n	3	2	2	2	3	3	4	5	6
d	4	3	3	3	3	4	3	4	5
a	5	4	3	4	4	4	4	3	4
y	6	5	4	4	5	5	5	4	3

← OPERATION #1 - Delete "a"

← OPERATION #2 - Delete "t"

↖ OPERATION #3 - Transform "r" to "n"

← 3 operations in total

Intelligent Self-determined Practice System

- Calculate *likelihood* to determine play is good or bad

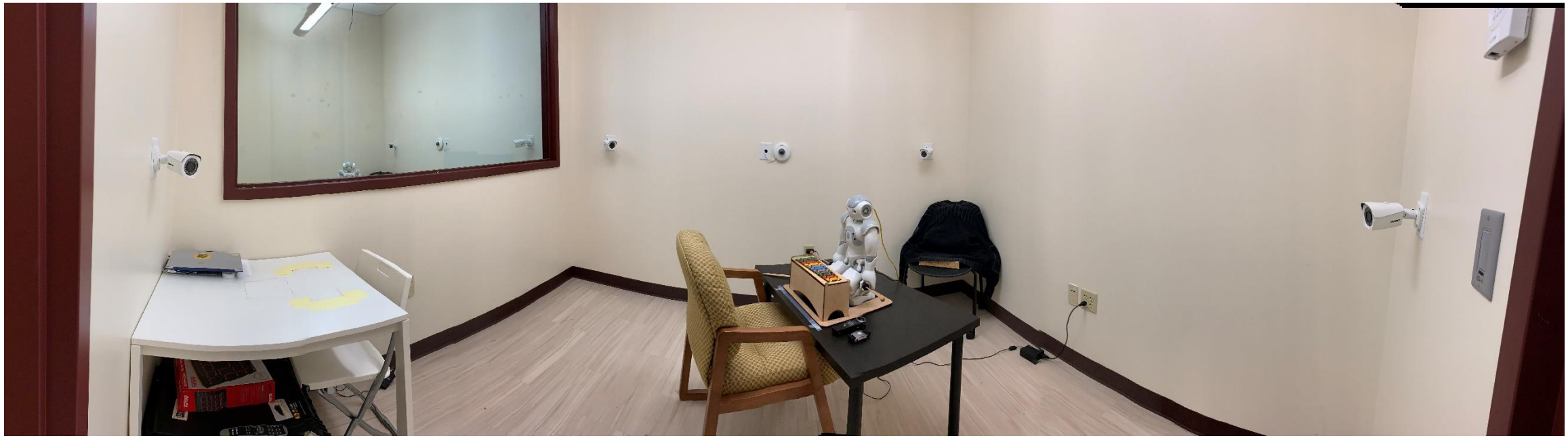
$$likelihood = \frac{len(target) - lev_{target,source}}{len(target)}$$

- Total accuracy will be calculated based on count goods/total number of practice given
- If lower than pre-set threshold 70%, will keep adding more practice
- Minimum 10 and maximum 20 trials

Experiment Session Design

- TD for 2 sessions
  - Baseline session & exit session
- ASD for 6 more session, no more than 8
  - Baseline session & intervention sessions & exit session

Room Setup



- 6 HD Surveillance cameras
- Mini Hidden Microphone
- Size of Room: $11ft \times 9.5ft \times 10ft$

Baseline Session & Exit Session

- Include all activities
  - “Twinkle Twinkle Little Star”
  - Single note play w/ or w/o color hint
  - Multiple notes play w/ or w/o color hint
  - Half song (first and second half) play w/o color hint
  - Whole song play w/o color hint
  - Music game play
    - Enjoy a random song and request a feeling from participant
    - Imitate a random melody with Consonance and dissonance styles generated by robot, request a feeling from participant
    - Free play and challenge robot
- About 30 – 40 mins, depends on how individual perform and engage
- Both ASD and TD groups

Intervention Sessions

- Learn a song selected by participant which they enjoy the most
- Part I: Hitting practice for warm up
- Part II: Learning new song
  - Session 2 & 3 single activity
  - Session 4 & 5 multiple activities (review of session 3)
  - Session 6 + multiple activities (review of session 4, 5)
- Part III: Game play for fun
- ASD only!

Measurements

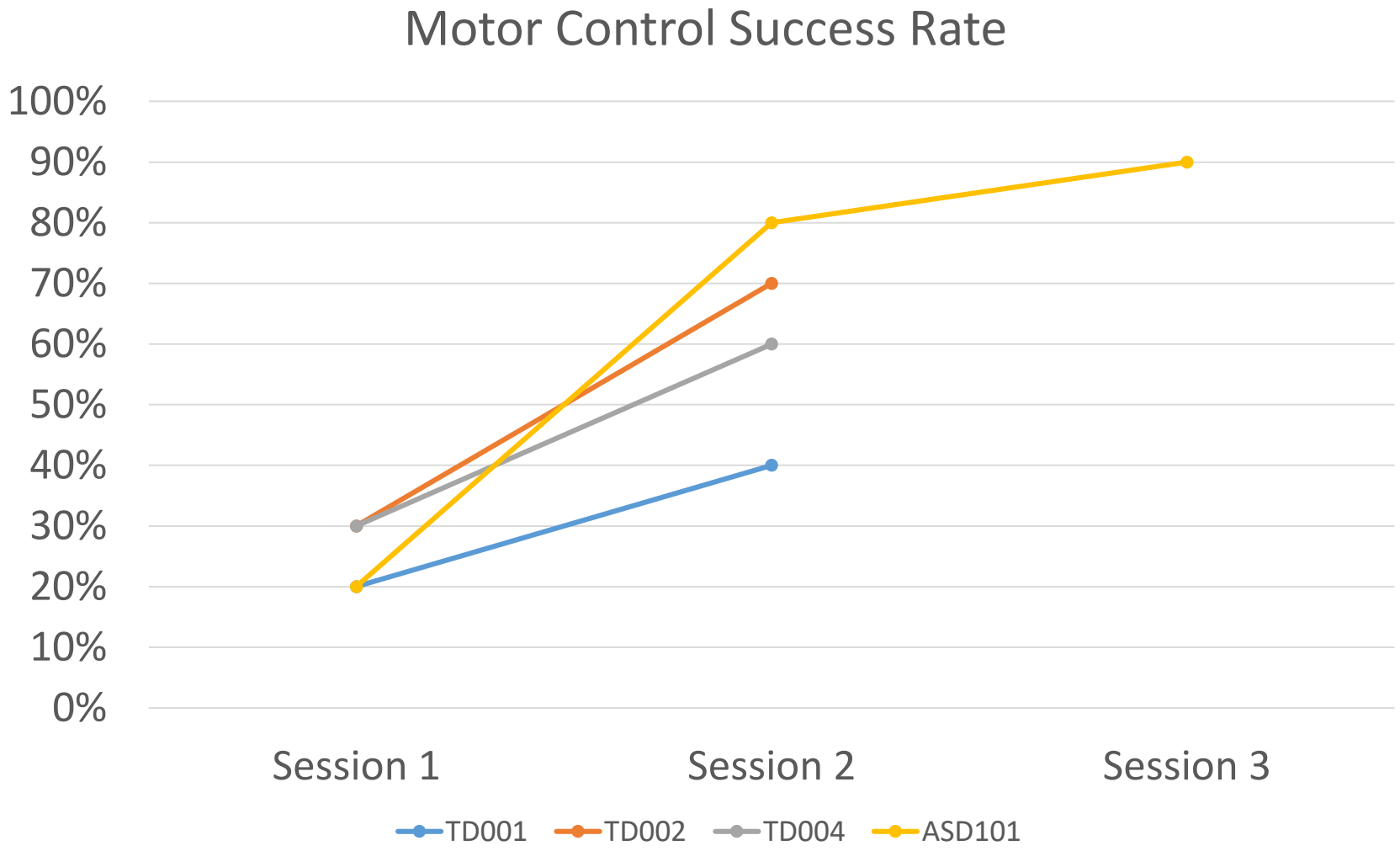
- Eye-Gaze and Joint Attention
  - Video/Audio annotation
- Motor Control
  - Real-time audio analysis system
- Emotion Engagement
  - Q-sensor
- Music Emotion
  - Self-express
  - Q-sensor

Motor Control

- Based on STFT output, only consider if perform the proper strikes

	Baseline	Exit	Inter 2	Inter 3
TD001	~20%	~40%	N/A	N/A
TD002	~30%	~70%	N/A	N/A
TD004	~30%	~60%	N/A	N/A
ASD101	~20%	N/A	~80%	~90%

Motor Control



Emotional Engagement

- A pre-study: Event based emotion classification
  - Electrodermal activity (Galvanic skin response)
  - Continuous wavelet transform
  - Support vector machine

Q-Sensor

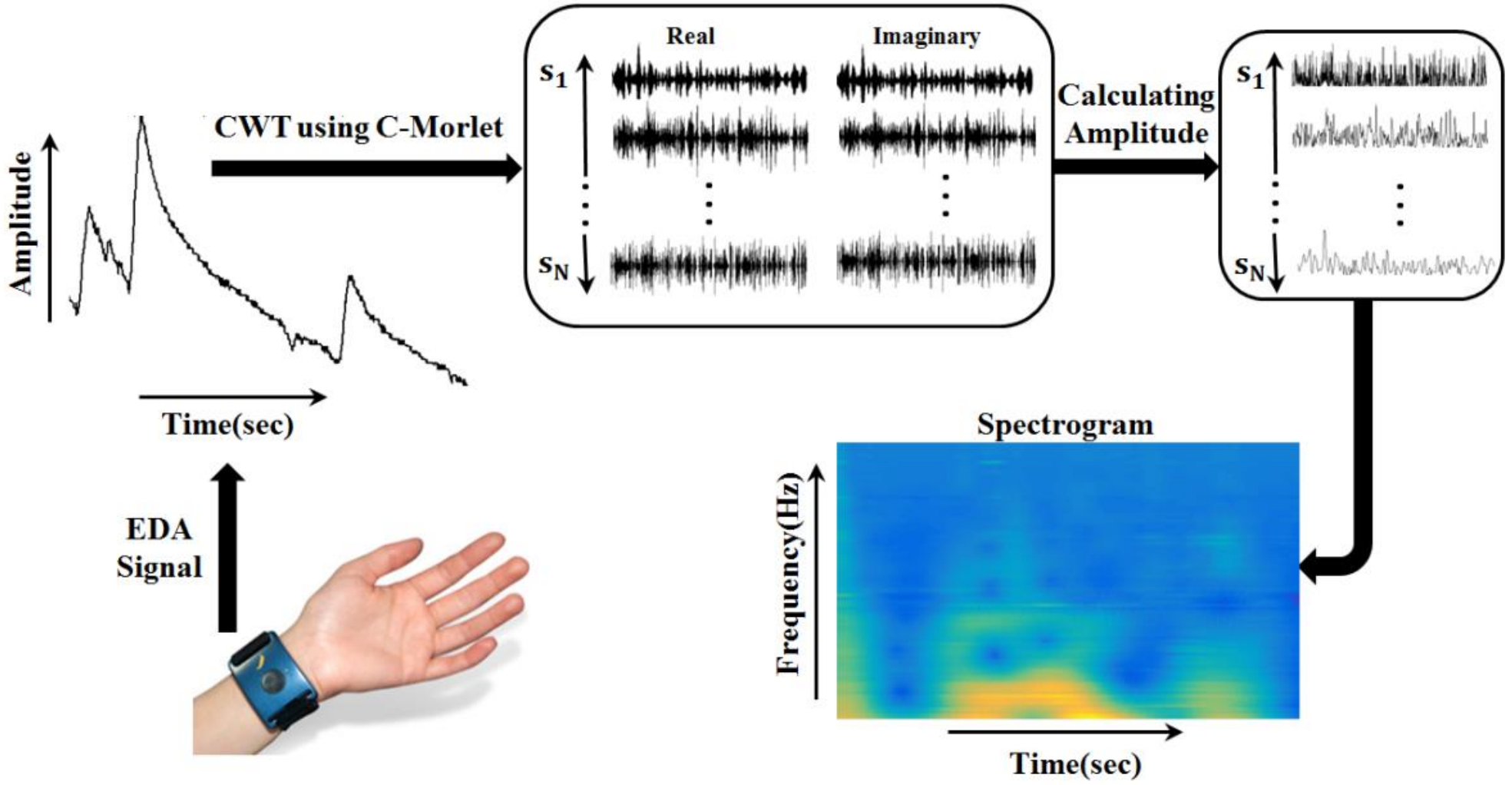
Related Work

- Lin, Y. P., Wang, C. H., Wu, T. L., Jeng, S. K., & Chen, J. H. (2007, October). Multilayer perceptron for EEG signal classification during listening to emotional music. *In TENCON 2007-2007 IEEE Region 10 Conference* (pp. 1-3). IEEE.

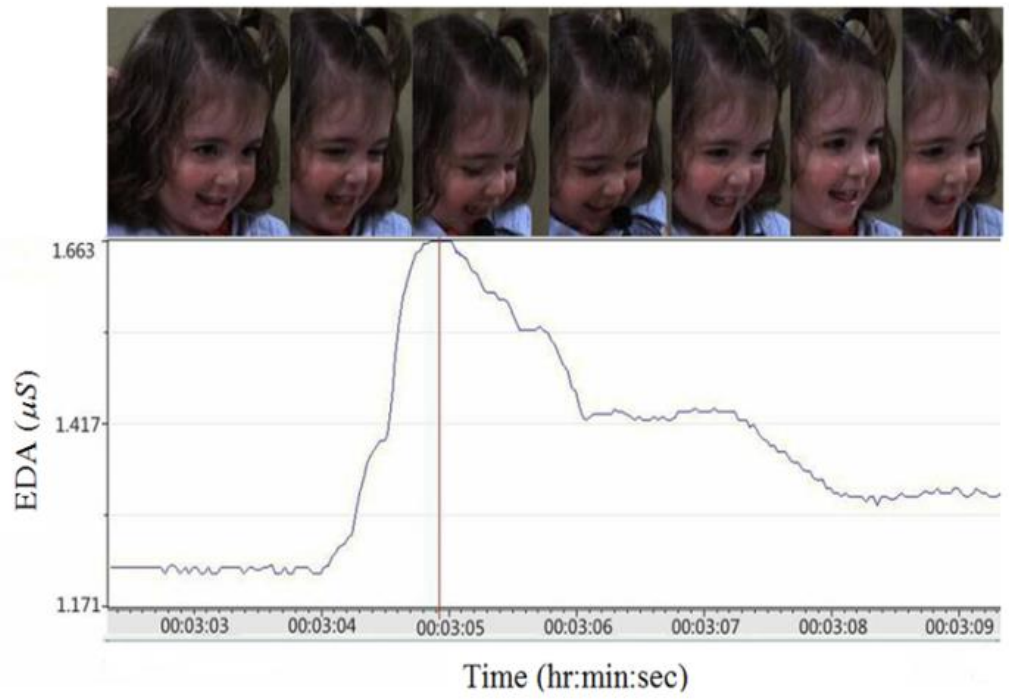
- Sano, A., & Picard, R. W. (2011). Toward a taxonomy of autonomic sleep patterns with electrodermal activity. *In Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE* (pp. 777-780).

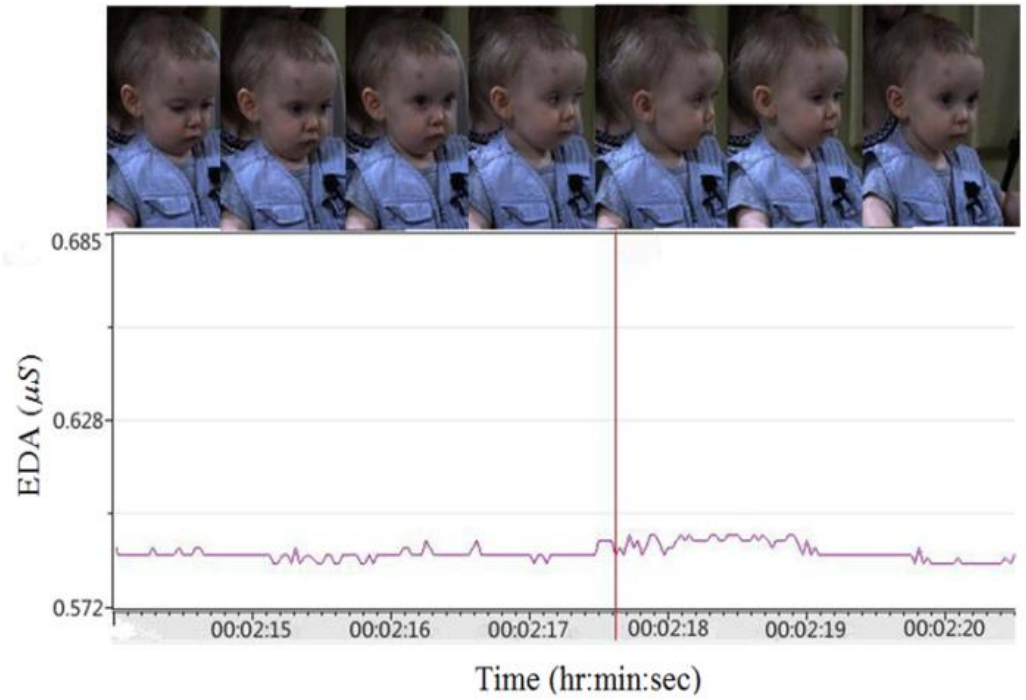
- Amershi, S., Conati, C., & McLaren, H. (2006). Using feature selection and unsupervised clustering to identify affective expressions in educational games. *In Workshop in Motivational and Affective Issues in ITS, 8th International Conference on Intelligent Tutoring Systems*, Jhongli, Taiwan.

Electrodermal activity (EDA)



EDA Signal with Expression Change





Classification Result

TABLE I. COMPARISON OF DIFFERENT WAVELET FUNCTIONS ON THE FEATURE EXTRACTION AND EMOTION CLASSIFICATION PERFORMANCE (%)

	Kernels	db1	coif1	sym2	C-Morlet
Acc-Bor	Linear	61	56	61	75
Acc-Joy		50	46	50	69
Bor-Joy		51	69	57	90
Bor-Joy-Acc		51	35	39	66
Acc-Bor	Polynomial	51	56	58	64
Acc-Joy		54	54	57	81
Bor-Joy		55	64	69	86
Bor-Joy-Acc		43	46	50	61
Acc-Bor	RBF	59	60	58	74
Acc-Joy		55	44	57	84
Bor-Joy		68	51	69	89
Bor-Joy-Acc		45	35	50	69

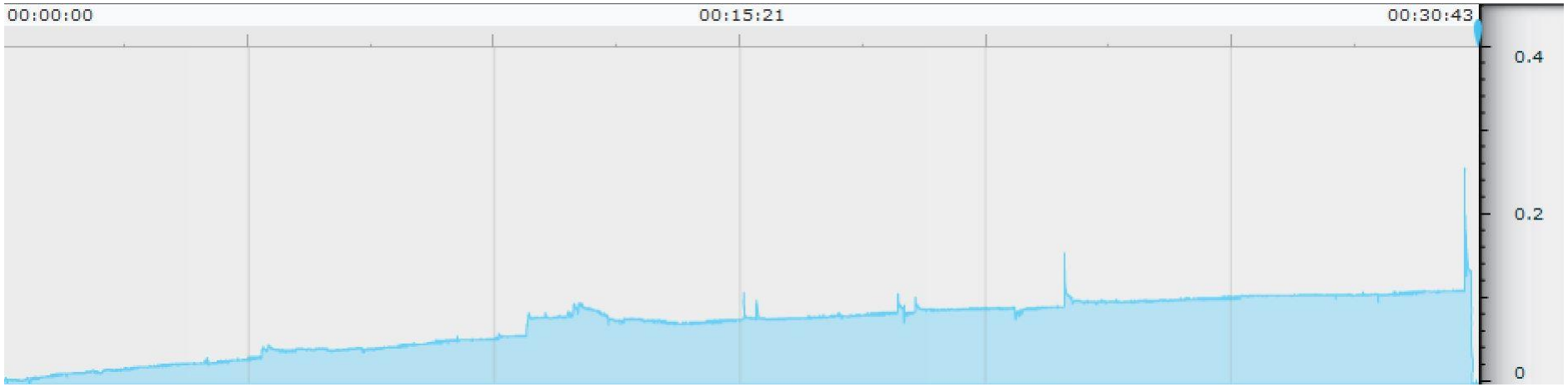
- This work has published at *Expert System with Applications* :

Feng H, Golshan HM, Mahoor MH. A wavelet-based approach to emotion classification using EDA signals. Expert Systems with Applications. 2018 Dec 1;112:77-86.

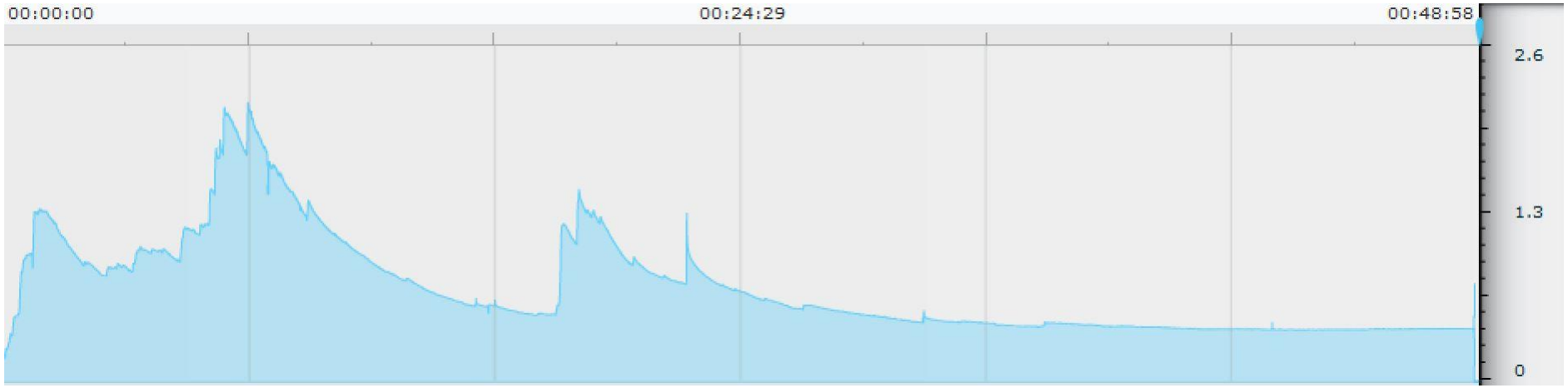
EDA Signal in Current Study

TD004

- Baseline session

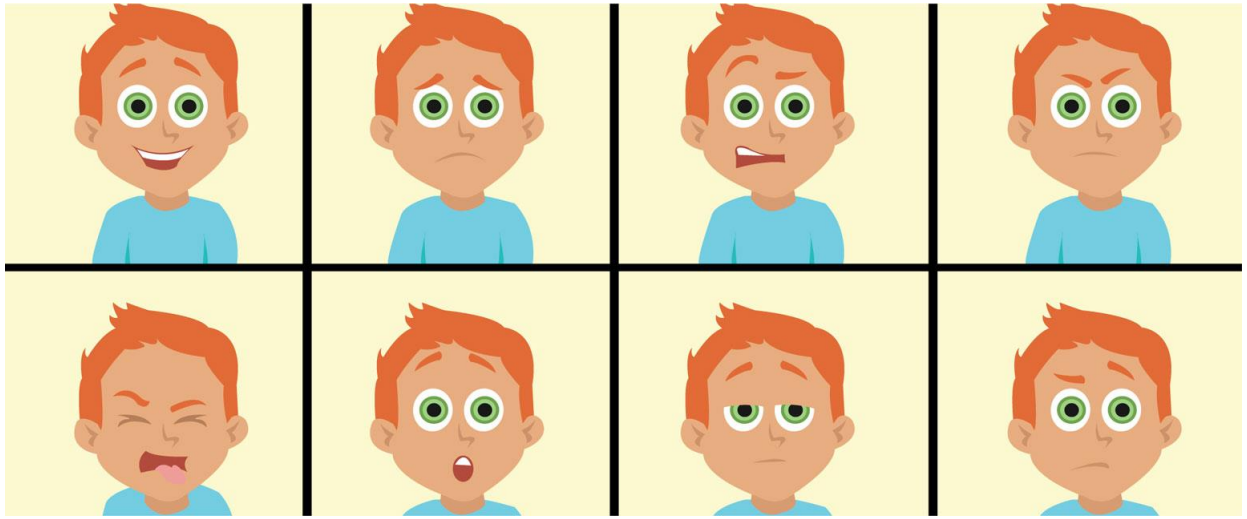


- Exit session



Music Emotion

- Robot generate 8 or 16 notes length random music based on consonance and dissonance style
  - Consonance:
  - Dissonance:
- Be included in the game section
  - Robot play music
  - Ask participants how do they feel

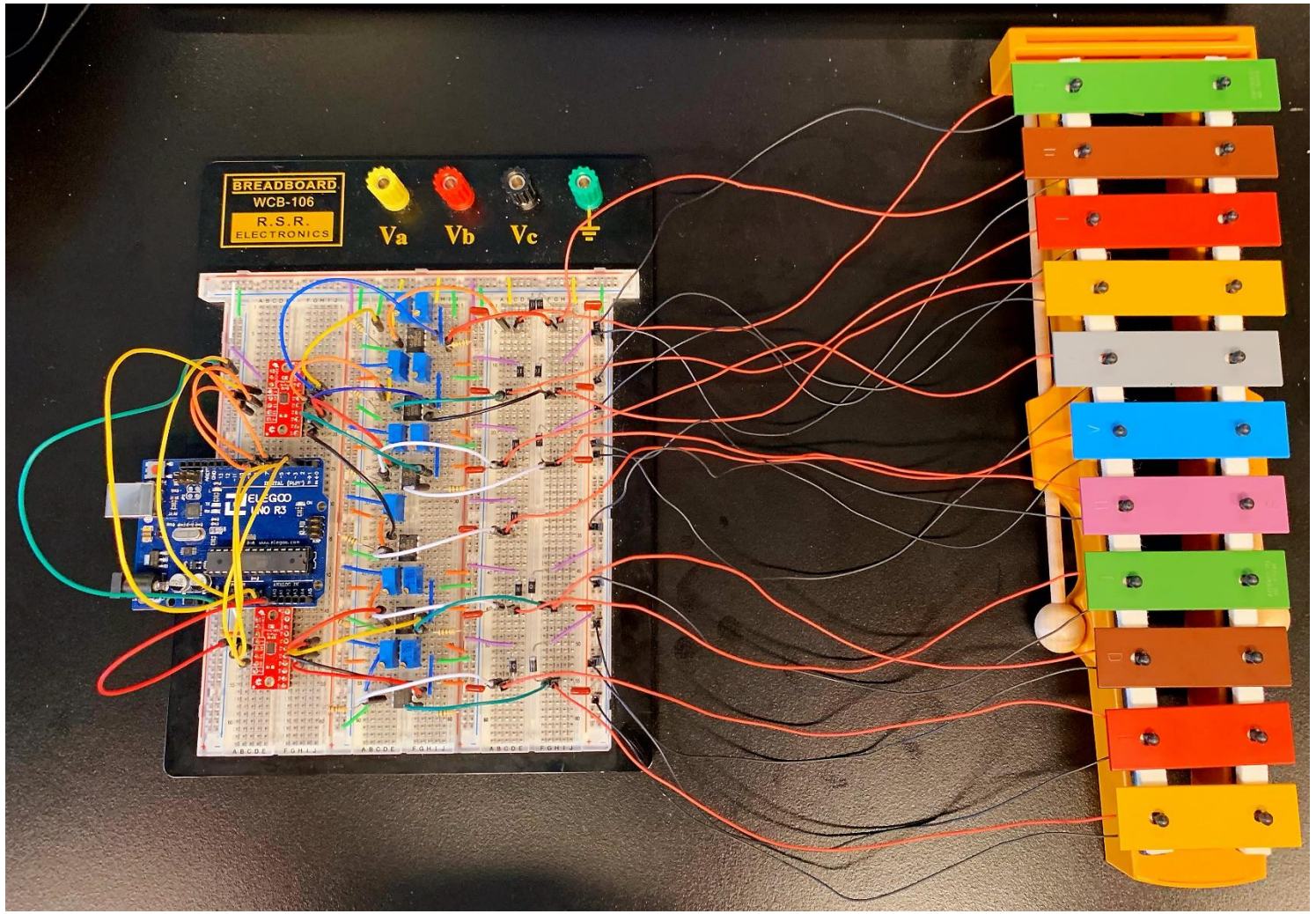


Music Emotion Result

- According the experience during sessions
  - Approximate half of the participants describe the feelings
  - Some were worried about how to play that specific piece
  - Some consider as no feeling

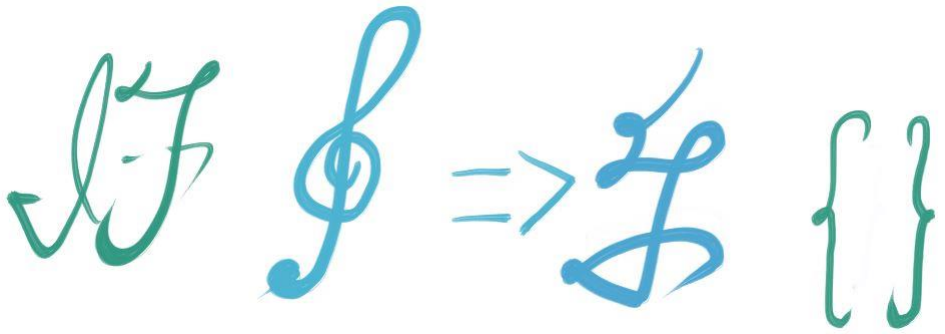
- Improvement
  - Play two songs in different keys and have participants compare
  - Change of method to create better strong feeling music
  - New instrument design

X-ylophone



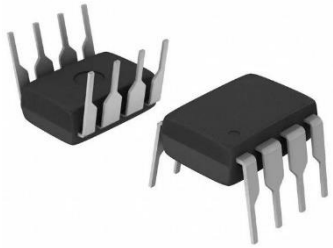
Purpose of New Design

- Some participants requested digital music
- Wider frequency range
- Major and minor key switch
- Better emotion expression
- Less motor control skill required
- Easy to learn and have fun with



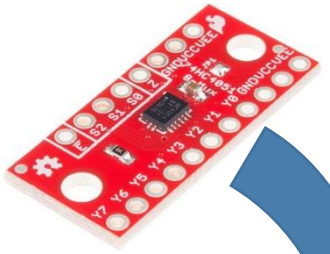
Component Selection

Piezo Vibration Sensor



MCP6002-I/P-ND
Op-Amp

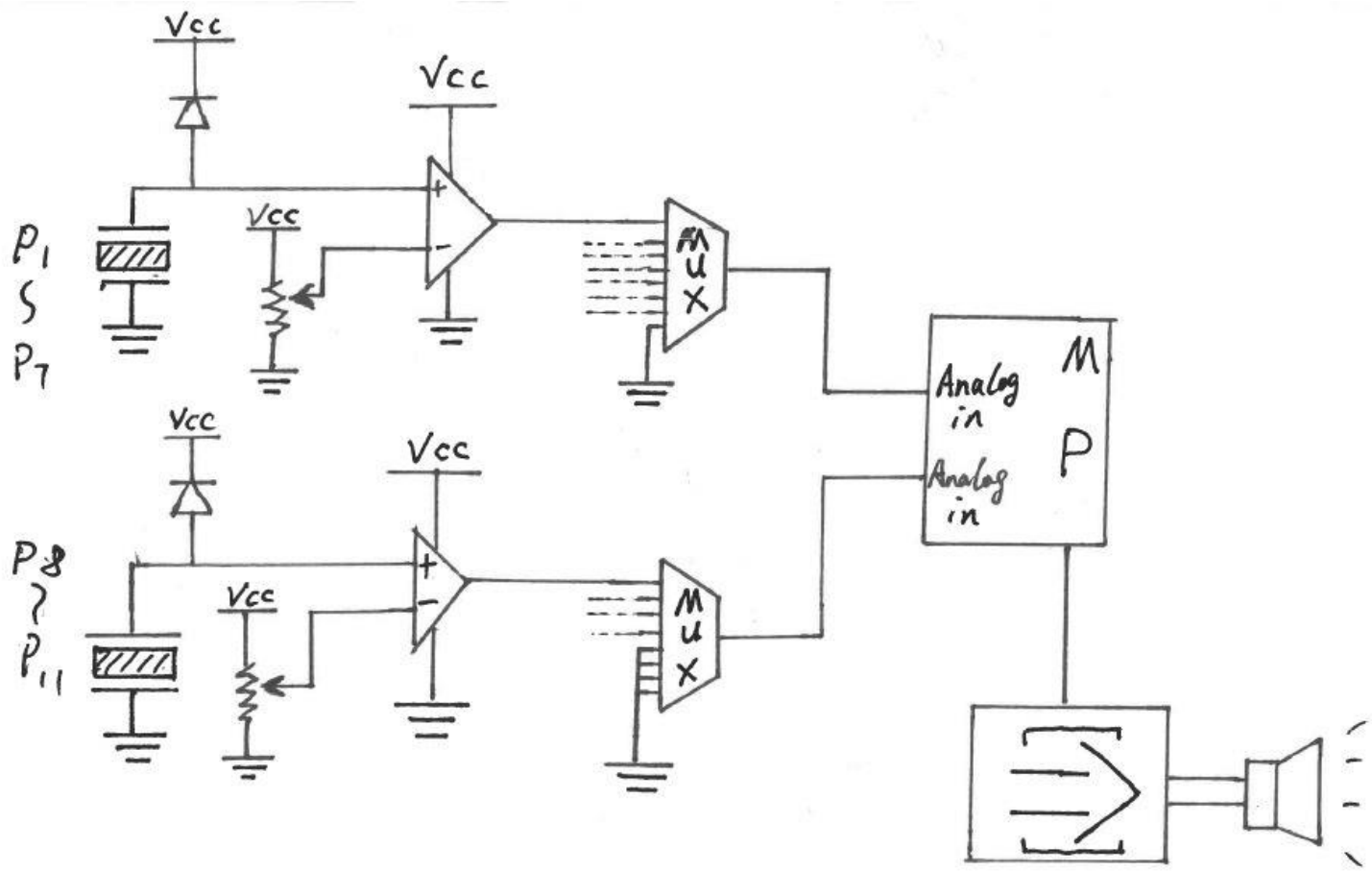
SparkFun Multiplexer Breakout
8 Channel (74HC4051)



Arduino Uno
Microprocessor

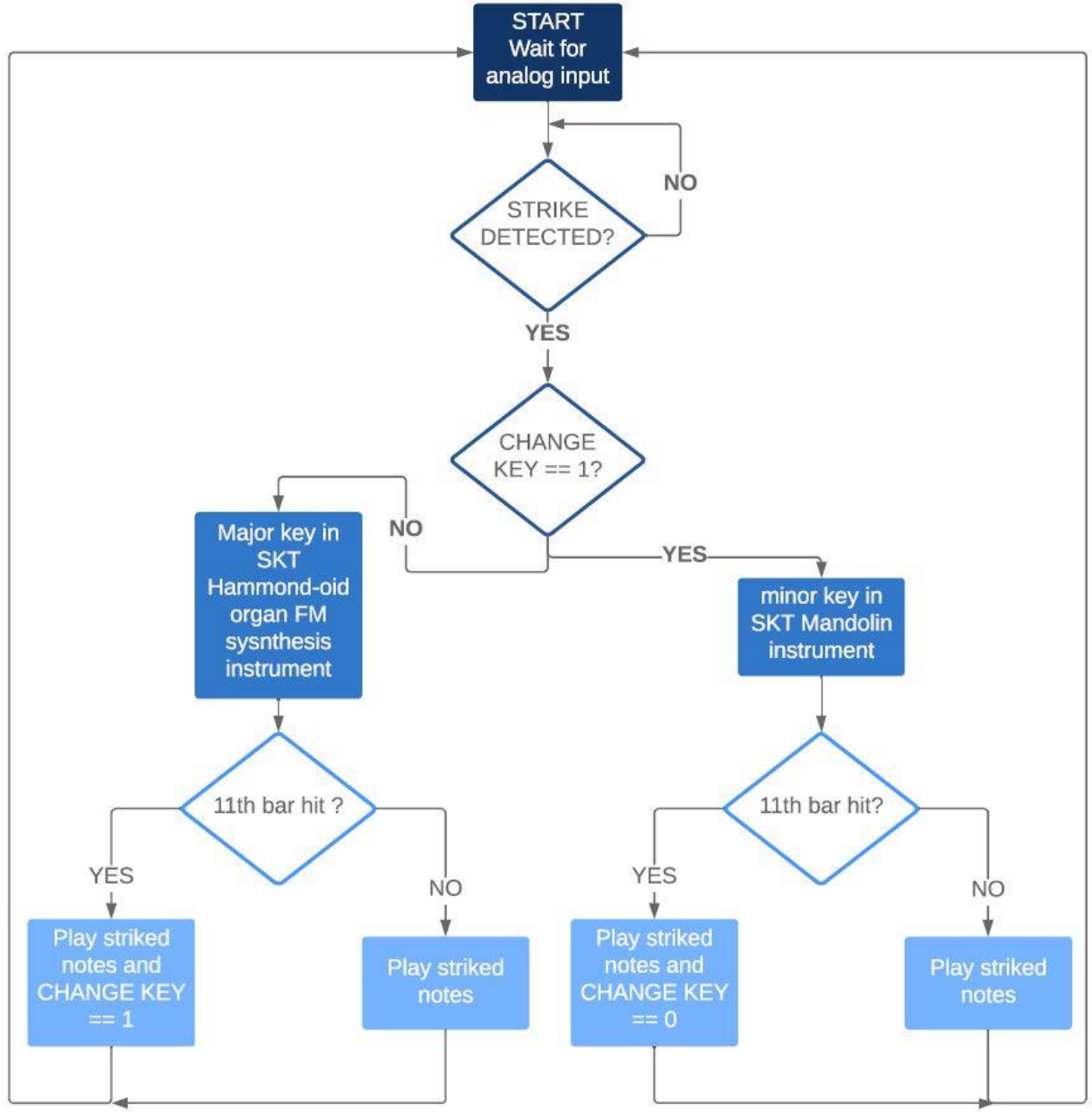
ChucK: A Music
Programming
Language

Circuit Schematic



ChucK

- On-the-fly music programming language
- Built for real-time audio synthesis and performance
- Variety of instrument selection



Wang G. The ChucK audio programming language.“A strongly-timed and on-the-fly environ/mentality”. Princeton University; 2008.

Experiment Concept Design

- Music emotion prime
- Major and minor
- Different sound generators for different feelings
- Interactive play
- Music composing in Pentatonic scale
- Any other suggestions?

International Impact: DIFAT

Contribution

- A wavelet-based approach to emotion classification using EDA signals
- Autonomous interactive robot music teaching system for children with autism
  - System can also be use in all age groups and easy to customize
- New design of xylophone brings more possibilities for music composing
  - Great tool for early age music learning and understanding

Contribution

Publications List:

Journals:

- Huanghao Feng, Hosein Golshan, Mohammad H. Mahoor, 2018. “A wavelet-based feature extraction approach for emotion classification using the EDA signals”, *Journal of Expert Systems and Applications*, 112, pp.77-86.

Contribution

Publications List:

Selected Conferences:

- S.M.Mavadati, Huanghao Feng, M.Salvador, S.Silver, A.Gutierrez, M.Mahoor, “Robot-Based Therapeutic Protocol for Training Children, with Autism”, 2016. *25th International Symposium on Robot and Human Interactive Communication*, *IEEE RO-MAN*, pp. 855-860, New York, NY (RSJ/KROS Distinguished Interdisciplinary Research Award)

- Huanghao Feng, Anibal Gutierrez, Jun Zhang, Mohammad H Mahoor, 2013. “Can NAO robot improve eye-gaze attention of children with high functioning autism?”, *IEEE International Conference on Healthcare Information (ICHI)*, pp. 484-484, Philadelphia, PA

Contribution

Posters and Oral Presentations:

- Huanghao Feng, Farzaneh Askari, Mohammad H. Mahoor, 2017. “Socially Assistive Robotics Helps Children with Autism”, DU-EXPO, poster presentation at University of Denver, Denver, CO
- S.M.Mavadati, Huanghao Feng, S.Silver, A.Gutierrez and M.Mahoor, 2014. “Children-Robot Interaction: Eye Gaze Analysis of Children with Autism during Social Interactions”, *International Meeting for Autism Research (IMFAR)*, abstract and poster presentation at Atlanta, GA
- Huanghao Feng, M.Mahoor, A.Gutierrez, Marry.Kustner and Jun Zhang, 2013. “Using Social Robots at Improving Eye Gaze Attention of Children with Autism Spectrum Disorders”, Proceeding of *International Meeting for Autism Research (IMFAR)*, poster presentation at Donostia, San Sebastian, Basque County, Spain
- Huanghao Feng and A.Gutierrez, 2013. “Using Social Robots to Improve Directed Eye Gaze of Children with Autism Spectrum Disorders”, oral presentation at *Texas Autism Research Conference (TARRC)*, San Marcos, TX

Contribution

Invited Talks & Demonstrations & PRESS

- July 2019. “Denver International Festival of Art and Technology” Symposium, demonstration of the new robot music system at Newman Center, University of Denver
- July 2017. “Robotics STEM Night, Robots in 3D Opening Event”, keynote speaker and demonstration at University of Colorado South Denver
- June 2016. “Robots 3D”, keynote speaker and panel discussion with Michelle Salvador at Denver Museum of Nature and Science
- March 2016. “DU Robot Night”, robot demonstration at Denver Museum of Nature and Science
- October 2015. “Psych Research Night”, robot demonstration with Prof. Mohammad Mahoor at University of Denver.
- March 2015. “Robot helps children with autism by teaching them social skills”, FOX31 Denver TV interview with Sophie Silver and Prof. Mohammad Mahoor.
- August 2013. “Robot May Help Kids with Autism Become More Sociable”, robot demonstration with Prof. Mohammad Mahoor at Colorado Public Radio Station

Future Work

- Hand-eye self-calibration system complete
  - Robot be able to adjust arm position in order to find proper location of bars
- X-Elophone complete
  - PCB board design
- Data collection
  - More ASD participants needed
- Data analysis
  - Video & Audio annotation
  - Emotion engagement analysis
  - Music emotion analysis using X-Elophone

THANK YOU SO MUCH!