From Social Robots for Children to Therapeutic Robotic Assistance

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Assistive Robotics and Tele-Medicine (ART-Med) Lab.

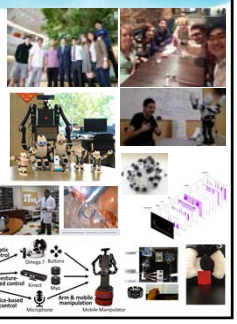
Research Areas:

HRI, Assistive Robotics, Haptics, and Machine Learning

Current Research Themes:

- **Assistive Robotics for Individuals with Disabilities**
  - *Interactive robots* for children with autism through physio-musical engagement
  - *Telepresence robots* for individuals with visual impairments (VI)
  - Grants: ***NIH R01, GW OVPR CDRF, NSF CAREER***
- **Tele-medical Robotics and Interactive Skill Transfer**
  - Mobile and affordable surgical simulation with surgical *skill learning and evaluation*
  - *Tele-medical* robotic assistance and *multimodal* communication
  - Grants: ***CTSI-CN Device Development Award, CTSI-CN Pilot Award, MWN Tech., KIAT***

➔ So our robots can provide Enhanced Living



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Today's Question

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- What can be an area/task/domain of IoT scenario that you can think of, especially for the areas or domains of support for people who have not been assisted in full capacity?

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Research Theme I

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Assistive Robotics

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Motivation for Research: Assistive Robotics

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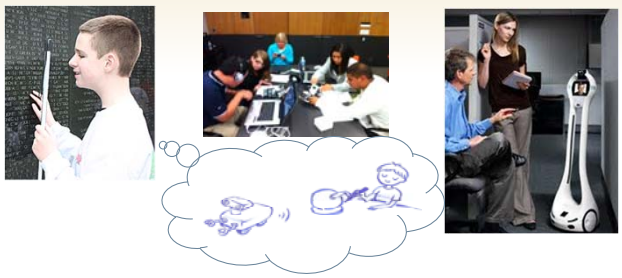

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Multi-modal Telepresence System

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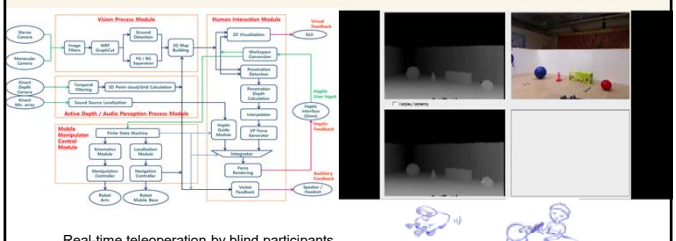

Real-time teleoperation by blind participants
Collaborators: Center for the Visually Impaired (CVI), National Federation for the Blind (NFB)

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Telepresence in Real World

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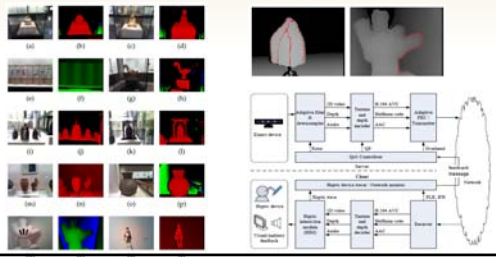
- Extended Tangible Experience to the real world – Museums, Art Galleries



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Outreaches and Domain Knowledge

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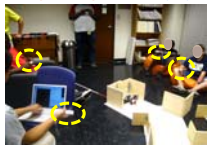
- Baseline: Tactile searching…

Easy to lose your robot…

- Now: *Study with style~! Changing the scenes of STEM for students with disAbility.*



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Learning Moments

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- Assistive Tech for Disability is **NOT** about **deficits** in functionality
- It is about figuring out ***what they actually need***, and ***how they want to take*** the support
- Providing Engineered Assistance in a RIGHT way
- On top of these findings,,, Rewarding Moments-!

National Center for Women & Information Technology (NCWIT) Aspirations in Computing Award

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Main Direction Set from My PhD

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- Main Project Title
  - ARoPAbility
    - Assistive
    - Robotic
    - Programming
    - for students with
    - disAbility
- Research Goal:
  Robots for Empowering People with disAbility

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Robots and autism

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1 in 59 children in the US are diagnosed with ASD

Boys are 4x more likely to be diagnosed than girls

Why Robots?
- Not intimidating
- Less complex than humans
- More intelligent than inanimate toys
- Predictable
- Embodied interactions possible

Robot Roles
- As a diagnostic agent
- As a behavior eliciting agent
- As a friendly playmate
- As a social actor
- As a social mediator

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My First Challenging Project in Academia

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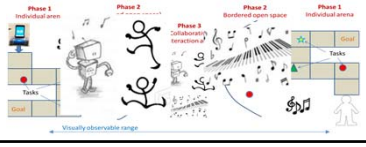
- ASD: 1 in 68. Deficits in social and emotional interaction
- Using Interactive Robots to elicit **emotional** and **social** engagements using ***music and physical interactions*** to provide dynamic ***therapeutic interventions***
- Key mechanisms: ***physio-musical stimuli*** & ***empathizing***



NIH Eunice Kennedy Shriver National Institute of Child Health and Human Development

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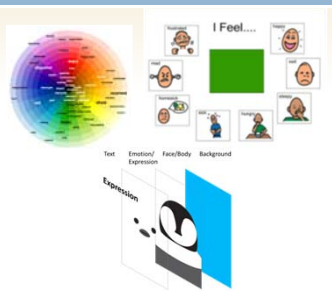
Design | Emotional Expressions | Algorithm (empathy/emotion regulation) | Deployment, Embodied Interactions | Contexts of Intervention | Evaluation

Design principles

- Any verbal expressions must be ***simple*** and ***short***
- No ***complex, patterned background images***
- No horizontal ***scroll bars***
- Background music avoided to ***minimize distractions***
- Minimize use of ***flashing*** or ***moving content***
- Use a ***simple spatial layout*** - minimal information displayed

- Emotion-relevant colors chosen from the color wheel
- Boardmaker samples used in designing facial expressions
- Design layers:
  - Text (stating the name of the emotion)
  - Emotional expression
  - Face structure
  - Background



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Design | **Emotional Expressions** | Algorithm (empathy/emotion regulation) | Deployment, Embodied Interactions | Contexts of Intervention | Evaluation

Emotion library

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Design | Emotional Expressions | **Algorithm** (empathy/emotion regulation) | Deployment, Embodied Interactions | Contexts of Intervention | Evaluation

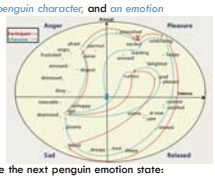
Consensus-based Emotional Interaction

- Consensus theory provides an interaction protocol for the exchange of information between all agents in a network, such that an agreement can be reached regarding a quantity of interest that depends on the states of all the agents
- Contains ***three*** emotional agents: *a human user, the emotionally-expressive penguin character,* and *an emotion goal state* defined specifically to implement ER
- Consensus equation:

$$\dot{x}_P = a_P \sum_j (x_j - x_P) \quad (1)$$

  - x_U : user's emotion state
  - x_P : penguin's emotion state
  - x_G : goal emotion state
  - j is a function of G and U
  - a_P : approach rate
- The character emotion selection function, C(),is then computed to determine the next penguin emotion state:

$$C' = C(x_P + \dot{x}_P) \quad (2)$$



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Design | Emotional Expressions | Algorithm (empathy/emotion regulation) | **Deployment, Embodied Interactions** | Contexts of Intervention | Evaluation

Deployment to robot for embodied interactions

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Design | Emotional Expressions | Algorithm (empathy/emotion regulation) | Deployment, Embodied Interactions | **Contexts of Intervention** | Evaluation

Sensory station game

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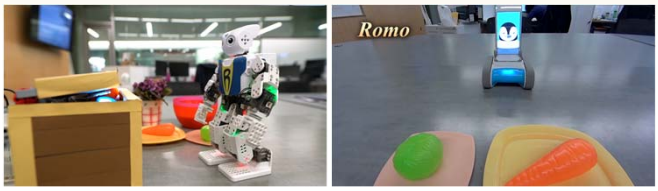
Robotic Actions for Socio-Emotional Interaction

- Sensory Modality Processing
  - Affects Emotion regulation, Motor processing delay…



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Emotion Guessing Game with ASD kids (8-12)

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Automated Monitoring: Emotion Analysis from Motion

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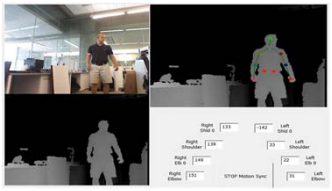
- Laban Motion Analysis (LMA) is a well-known method to document, categorize, and interpret the various differences in human movement and body language



$$\frac{\sum^{\omega_i}}{N} = \frac{\sum^{r_i * F_i * \sin(\theta_i)}}{N}$$

Weight Term Equation, Joint i (i), Total Number of Joints Measured (N)

$$\frac{\sum^{\omega_i}}{N}$$

Time Term Equation, Joint i (i), Angular Velocity (ω)

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Automated Monitoring: Emotion Analysis from Motion

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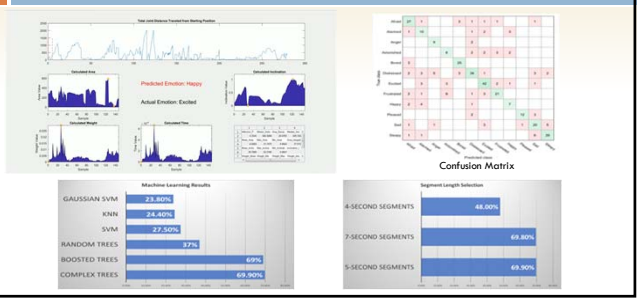

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Automated Monitoring: Emotion Analysis from Voice

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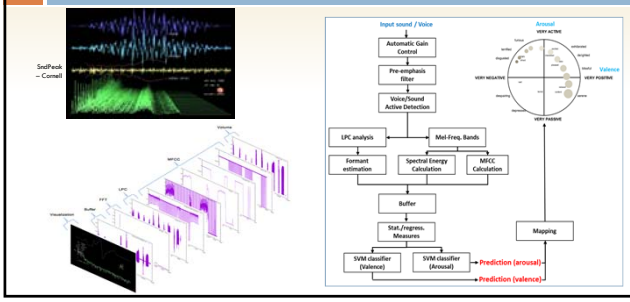

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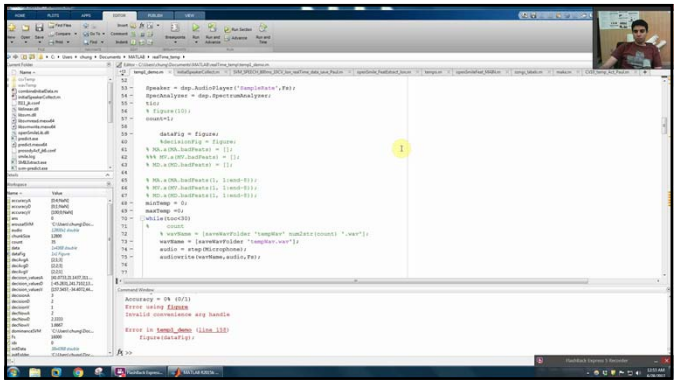

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Design and Measurement of Engagement Index

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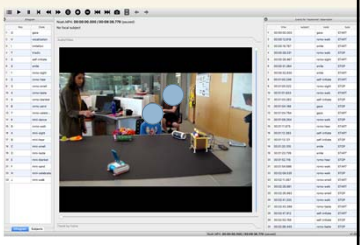
- Key measure: ***Engagement index***
- Derived from video data coding results
- Target behaviors annotated in the videos:
  1. *Eye gaze focus*
  2. *Imitation*
  3. *Self-initiated interactions*
  4. *Smile*
  5. *Vocalizations*
  6. *Triadic interactions*

Purpose: Identify any trends in the performance of participants in the sensory game and the preceding emotional interaction game



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Data Analysis - Engagement Index and Effectiveness of Robot Actions

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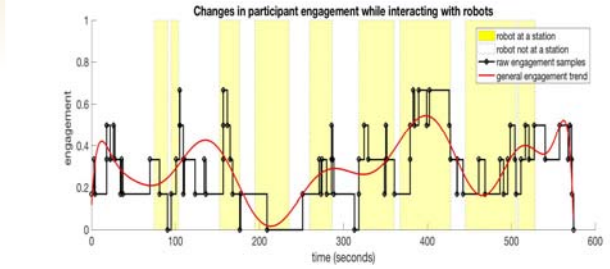

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Scenes with Human Participants

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Autism and Neurodevelopmental Disorders Institute (ANDI) at VSTC

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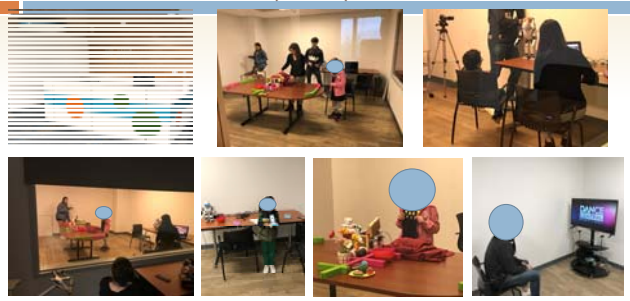

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Dancing with Robots

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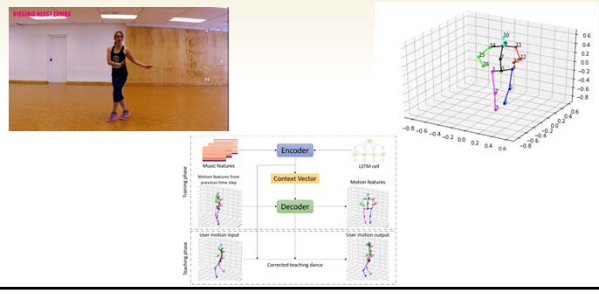

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Research Theme II

Robotic Learning

Tele-medical Robotics

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Motivation for Theme 2: Tele-medical Robotics and Interactive Robotic Learning

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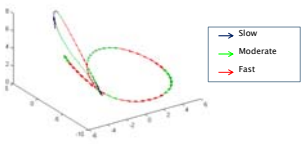
- *Hmmm, I want to build a smart robot~!*
- Can it learn how to write, like humans?
  - Handwriting: quite complex spatio-temporal task
  - Line-stroke, circle-stroke, and the sequential combinations of 3D motions



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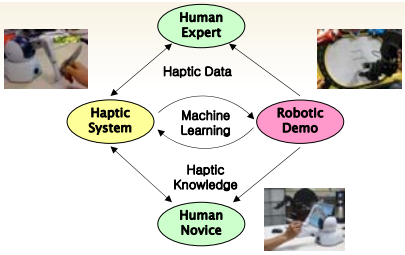
Skill Transfer through Robotic Learning



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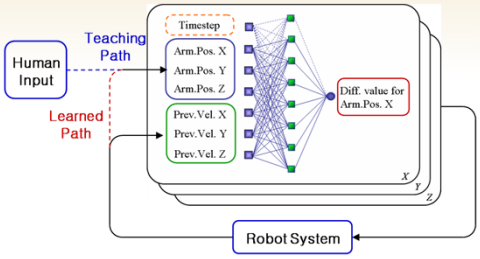
Recurrent Neural Network for Full Task Regeneration



2009. Pre-TF era

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Machine Learning of Medical Skills

VR Surgical Simulator

Human Gesture Recognition / Physiological Signal Learning

Robots in Medical Environment?

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VR Surgical Simulator

- Interactive Surgical Simulation

MISTELS system (McGill Inanimate System for Training and Evaluation of Laparoscopic Skills) Cost: $8K

- ✓Low-cost
- ✓Mobile platform
- ✓Interactive
- ✓Skill evaluation, compared with the surgical actions of expert doctors
- ✓You get to exercise, too!

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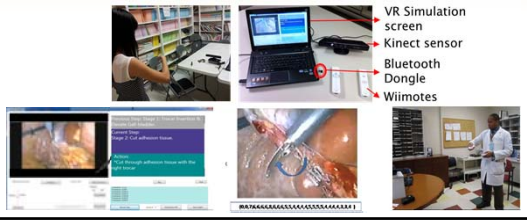
Multi-modal Interaction System for Learning at $300 ?!!!

- Skill Recognition and Evaluation for Training
  - Mobile, low-cost, and interactive simulation platform
  - Real-time evaluation of user's performance with expert's skills



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Mobile Interactive Surgical Simulator / Trainer

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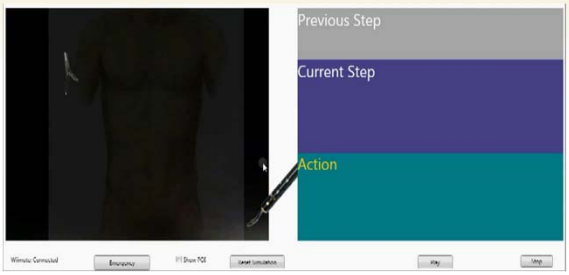

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Mobile Interactive Surgical Simulator / Trainer

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- Skill Recognition and Evaluation for Training
  - Task completion time, error counts.

Non-medical students, over 3-day trials

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VR + Robot in Medical Environments

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Gesture Registration and Classification using OpenPose and Deep Learning

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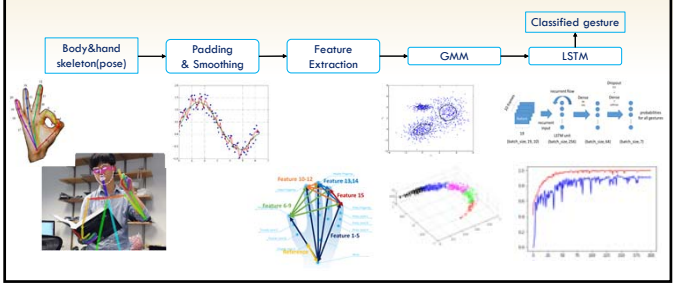

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Personalizable Hand Gesture Recognition and Classificzzzation

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Gesture Registration and Classification using OpenPose and Deep Learning

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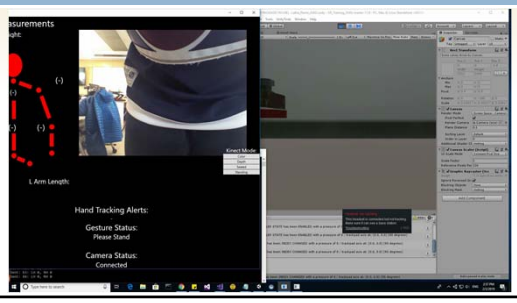

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Gesture Classification with EMG Signals

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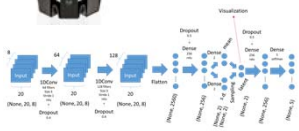
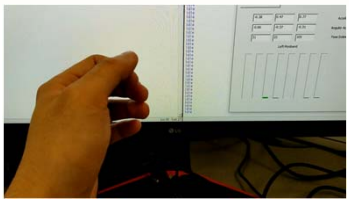
- ✓ CNN-based classifier model implemented
- ✓ Real-time classification program implemented

Myo-band
: 8ch EMG sensors





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Soft Hand – With EMG Control

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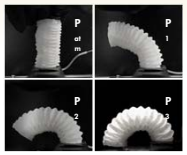
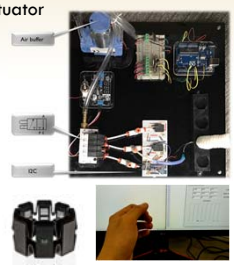
- Origami-based soft actuator





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What about STRESS in HRI ?

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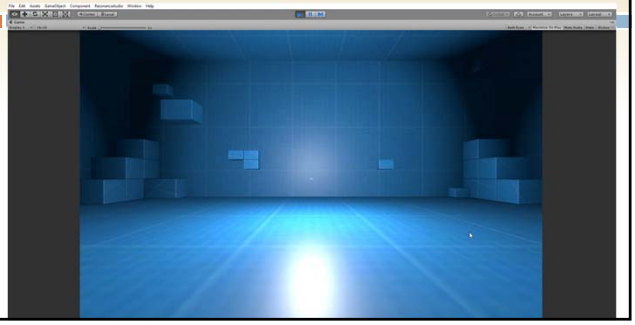

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Today's Question

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- What can be an area/task/domain of IoT scenario that you can think of, especially for the areas or domains of support for people who have not been assisted in full capacity?
  - Why do we need it?
  - Is it feasible with current tech, cost aspects, etc.?
  - How much useful?

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