uOttawa
L'Université canadienne
Canada's university

أ . د . عبد المطلب الصديق

Towards Digital Twin: Haptics-based Multimedia Environments

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WELCOME
VÄLKOMMEN
BIENVENUE
DOBRO DOŠLI
BIENVENIDA
BIENVENIDOS
ÜDVÖZÖLJÜK
BIENVENUTO
God dag
Tervetuloa
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NI SA BULA VINAKA!
WELKOM
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Ki Ora
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ПАЙВЕТСТВУЕМ ВАС
VÍTÁME VÁS!
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CROESO
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VELKOMMEN
ДОБРО ДОЗДОВТЕ
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DZIEN DOBRY
HITAMY
BENVENUTI
SVEIKI ATVYKĘ!!!
VITEJTE

uOttawa Facts

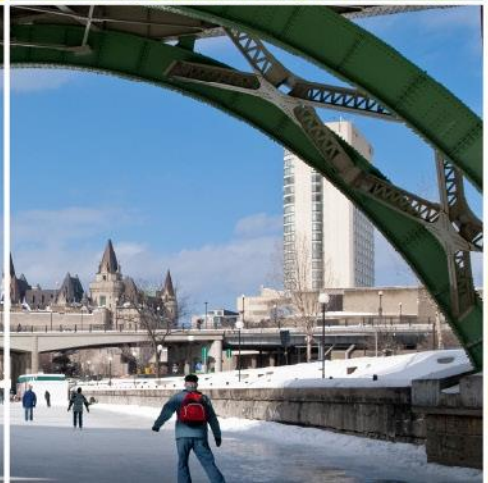
- Established in 1848 initially as Bytown College,
  - Research Intensive University: 2nd in Ontario and 5th in Canada
  - ***Times Higher Education* World University Rankings**
    - ***Top 200***
  - 450 programs in 9 Faculties (Engineering, Natural Science, Health Science, Social Science, Management, Arts, Law, Medicine, Education, & FGPS)
  - ~52,000 undergraduate students; ~7000 graduate students
  - ~1300 Professors
    - 15 Distinguished Professors




The national capital





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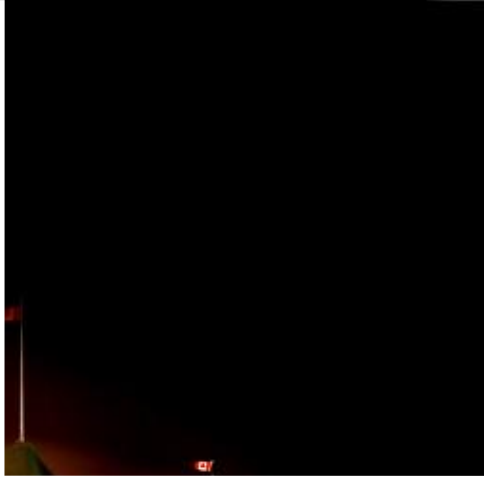
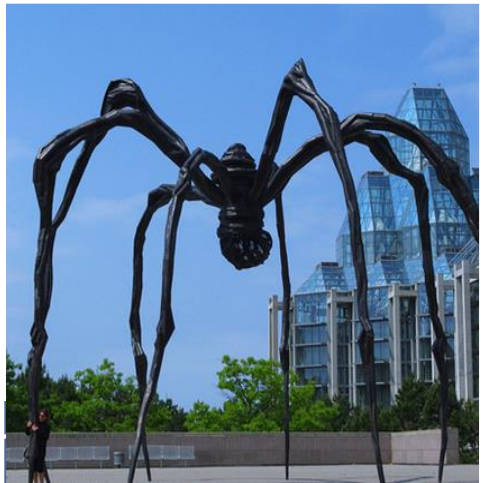


The national capital





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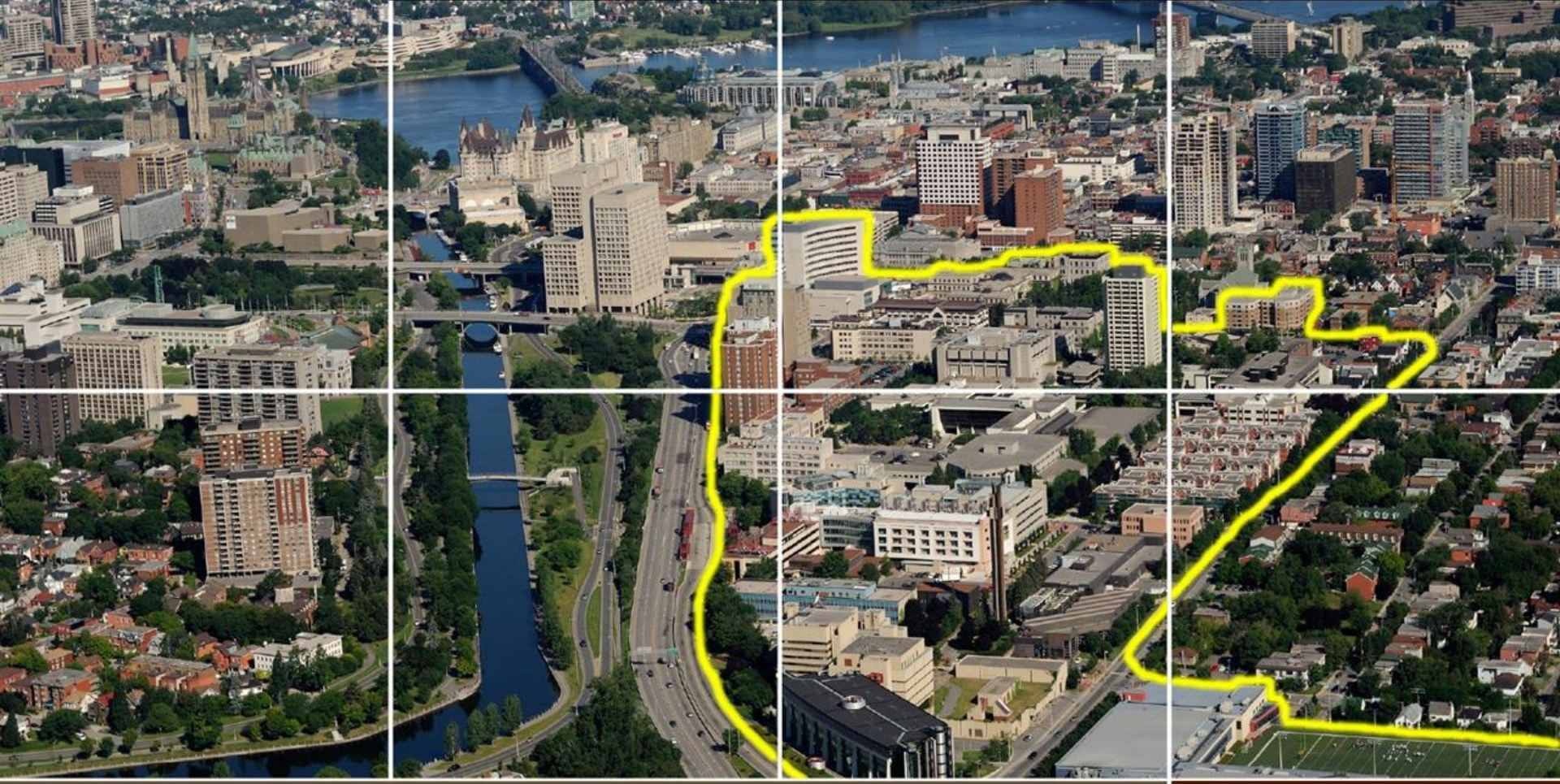
It starts **here.**

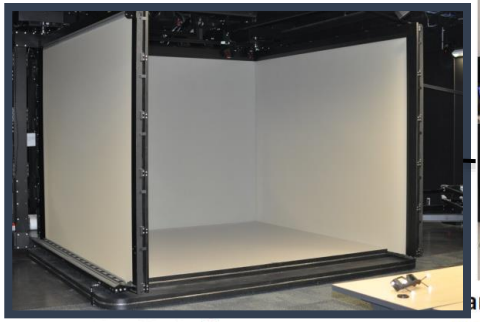


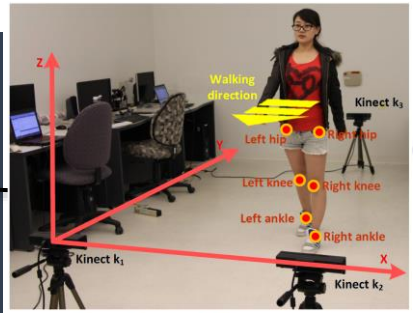
uOttawa

Faculty of Engineering

- The Faculty of Engineering includes three departments (chemical and biological, civil, mechanical engineering) and the **School of Electrical Engineering and Computer Science**, with
  - 126 Faculty members
  - ~3600 undergraduate students (~17%)
  - ~1800 graduate students (~45%)

MCRLab (100 m²)



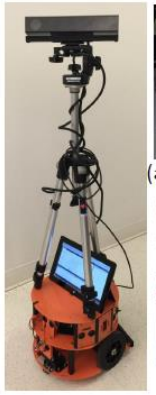


amera Pose Estimation & 3D Reconstruction

Head Segmentation

3D Printer

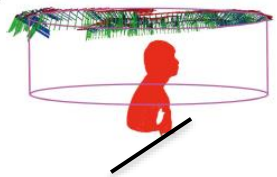
3D Printed Physical Objects



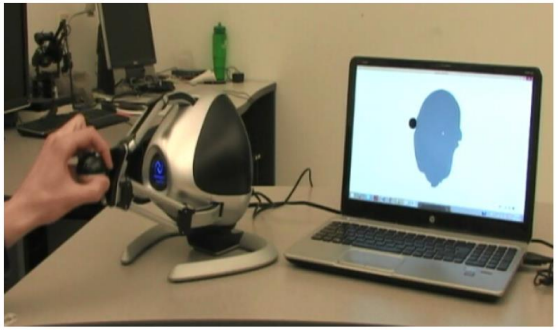
(a) Standard Head Model

(b) Real Human

Continuous Depth Data



Printable 3D File



Digital Twin

A digital twin is a digital replica of a living or non-living physical entity[1].

By bridging the physical and the virtual world, data is transmitted seamlessly allowing the virtual entity to exist simultaneously with the physical entity.

[1] El Saddik, A. (2018). Digital Twins: The Convergence of Multimedia Technologies. *IEEE MultiMedia*, *25*(2), 87-92.

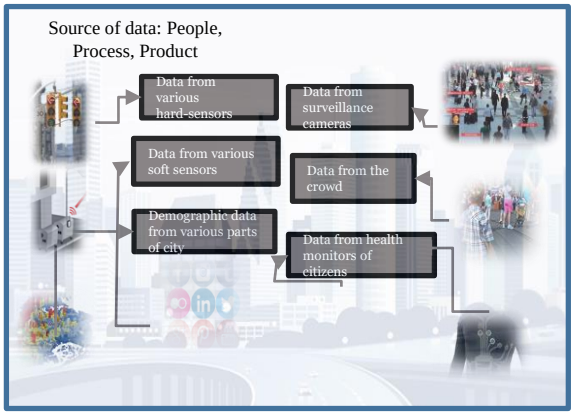
Why is digital twin important

- According to Gartner[1],
  - Digital Twin is the 4th of the top 10 technological trends for 2019
  - More than 50% IoT companies teams have digital twin in their annual plan as a strategic mandate
- According to Market Research Future:
  - it is expected that the digital twin market will reach $15B by 2023

[1] https://sdtimes.com/softwaredev/gartners-top-10-technology-trends-for-2019/

Facts

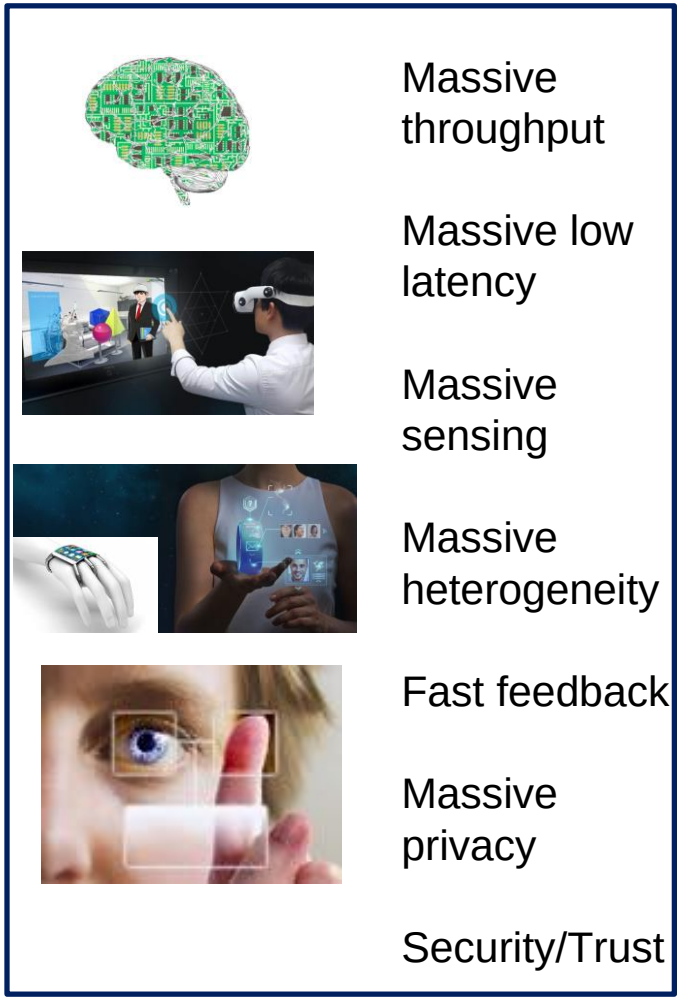
Things and Being are interconnected



BigMM & AI

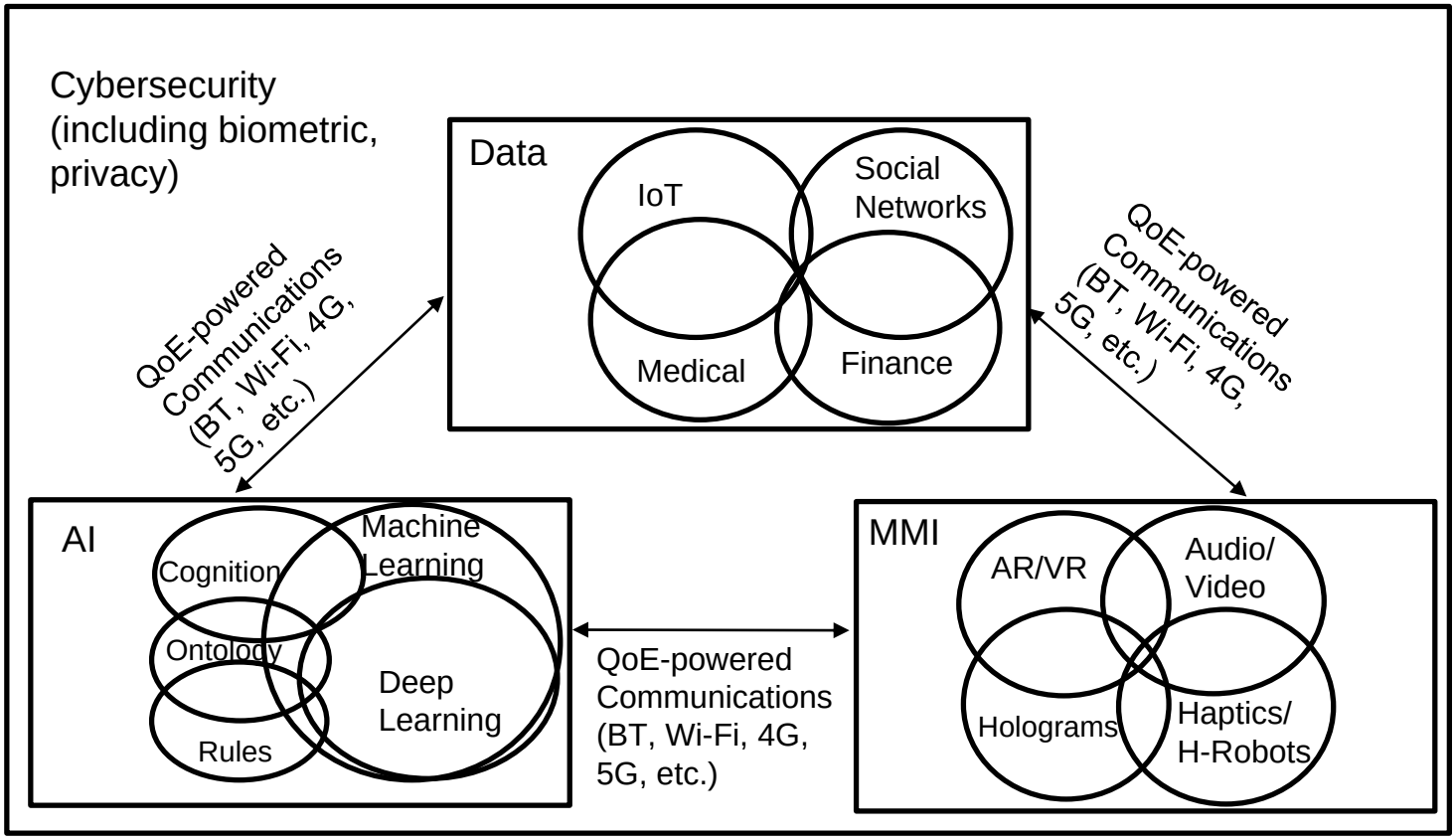
Multimodal Interactions

Cybersecurity & Biometrics



5G & Tactile Internet

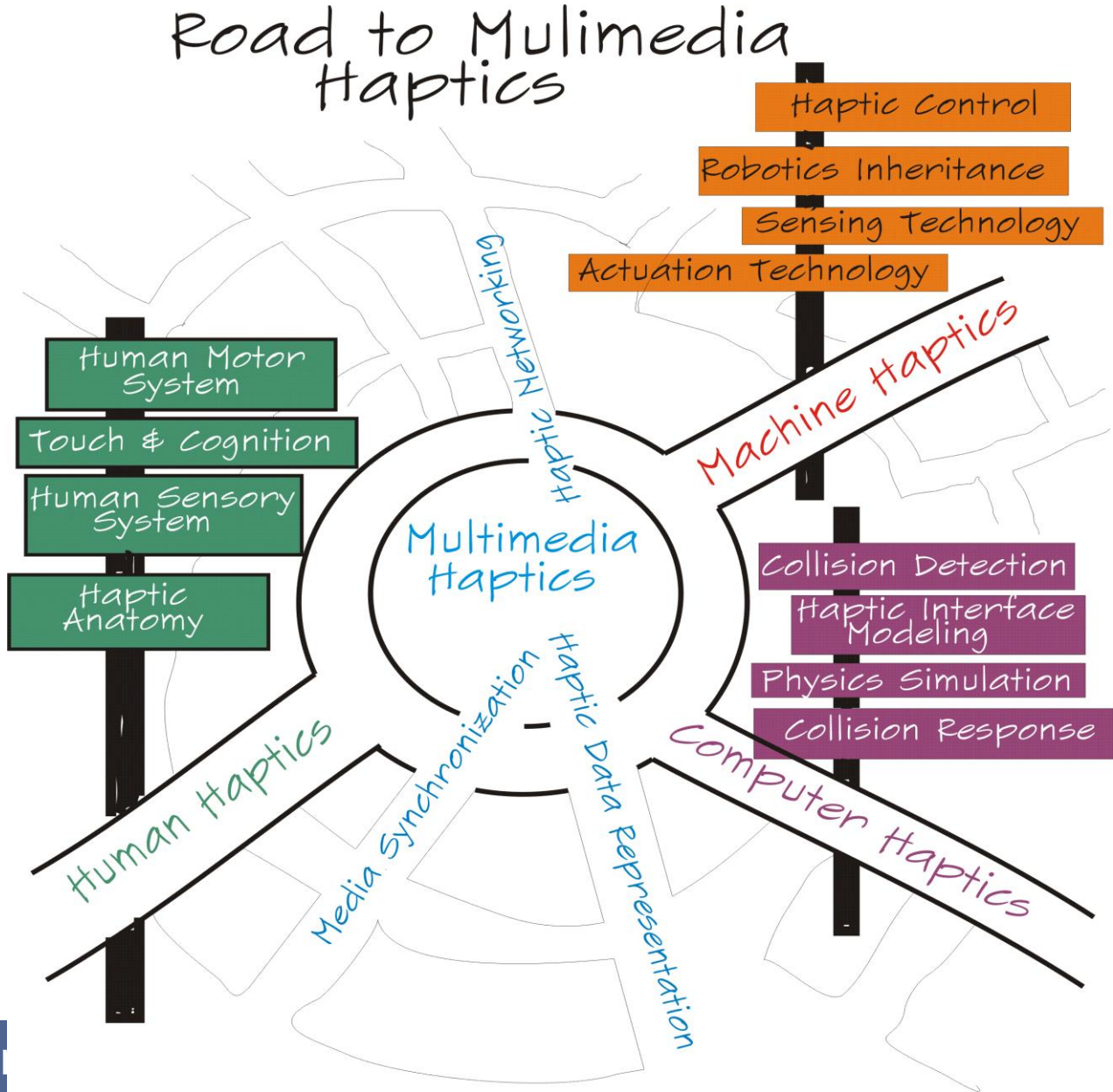
Digital Twin: Convergence of MM Tech



Our journey with Haptic-based Digital Twins

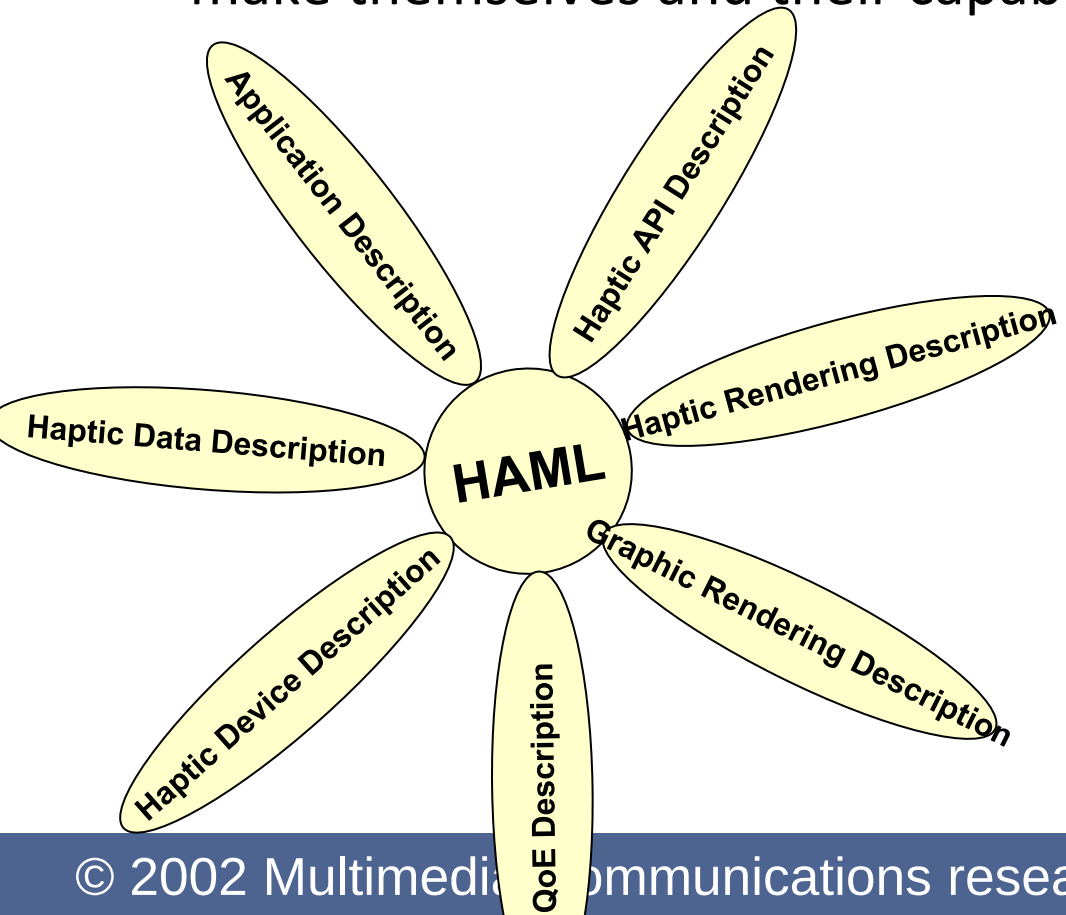
Roadmap to Multimedia Haptics

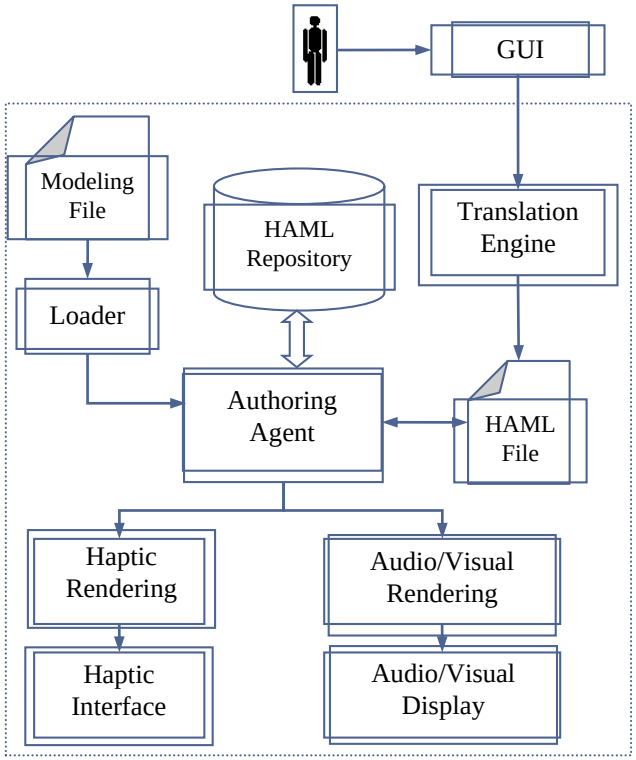
- Haptic media creation
- Haptic media representation
- Haptic media communication



HAML

- provide a technology-neutral description of haptic models
- meta-language by which haptic application components, such as haptic devices, haptic APIs, and graphic models, make themselves and their capabilities known.





HAML content representation

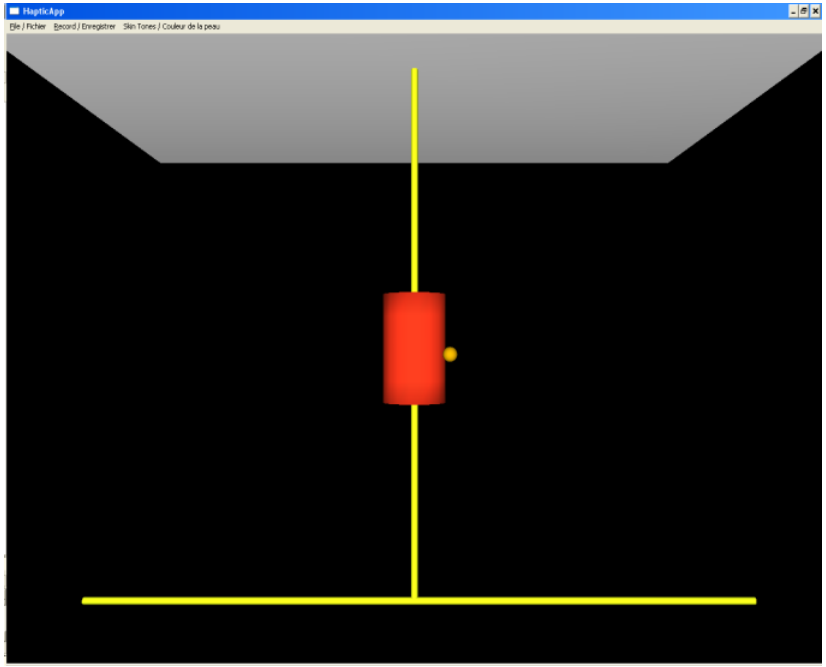
- four DSs of the HAML structure:
  - the application,
  - the author,
  - the system, and
  - the scene

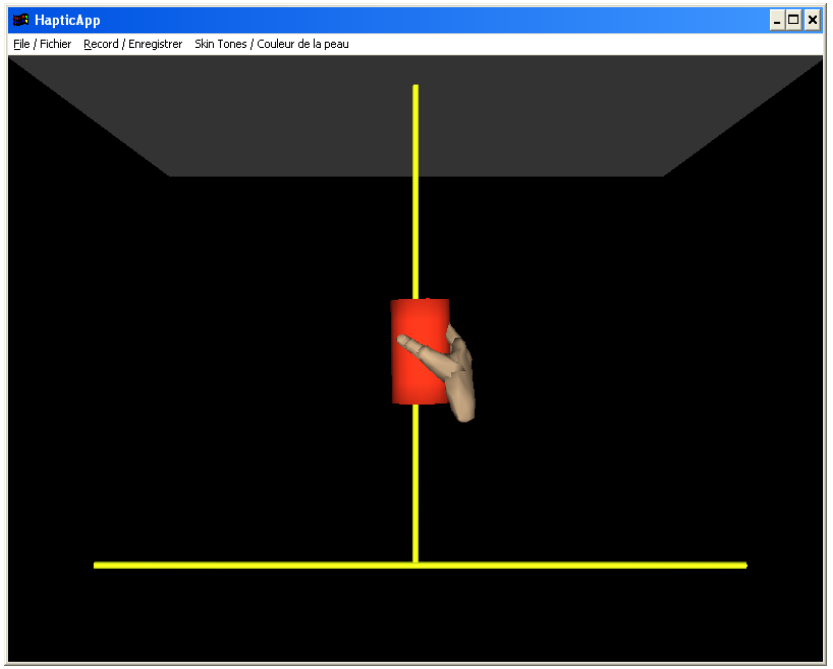
```
<?xml version="1.0"    ?>
<HAML >
    <ApplicationDS  >...</ApplicationDS  >
    <AuthorDS >...</AuthorDS >
    <SystemDS >...</SystemDS >
    <SceneDS >
        <Object >
            <Type >...</Type >
            <Name >...</Name >
            <Location >...</Location >
            <Rotation >...</Rotation >
            <Geometry >
                <VertexList >
                    <Vertex > 0, 1, 0  </Vertex > ...
                </VertexList >
                <FaceList >
                    <Face > 1, 2, 3 </Face > ...
                </FaceList >
            </Geometry >
            <Appearance >
                <Material >...</Material >
            </Appearance >
            <Tactile >
                <Stiffness >0. </Stiffness >
                <Damping >0.9</Damping >
                <SFriction >0.5</SFriction >
                <DFriction >0.3</DFriction >
            </Tactile >
        </Object >
    </SceneDS >
</HAML >
```

Partly incorporated in MPEG V ➔

Thanks to the support of Prof. Ryu, GIST, Korea

Example use of HAML

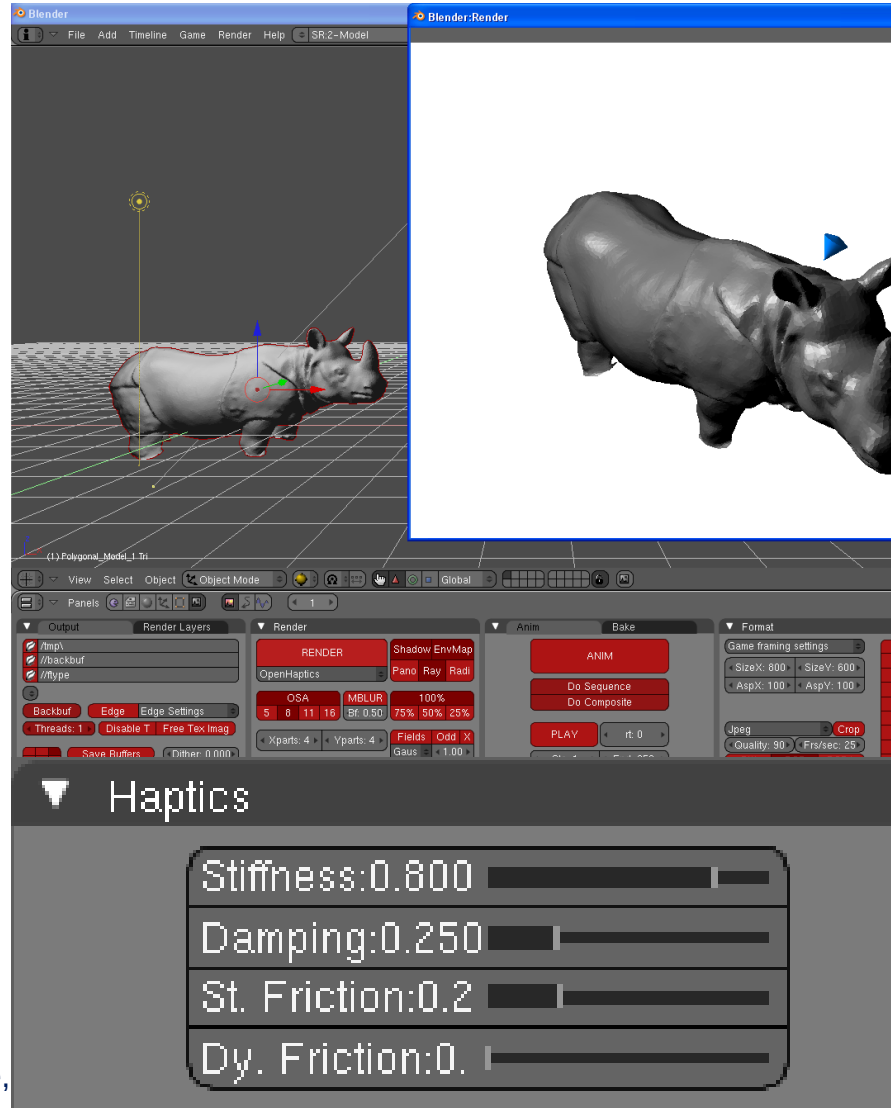




El Far, et al. "**Haptic Applications Meta-Language", Proceedings of the 10th IEEE international symposium on Distributed Simulation and Real-Time Applications , 2006, Pages 261-264**

Haptic Authoring Tool (Video)

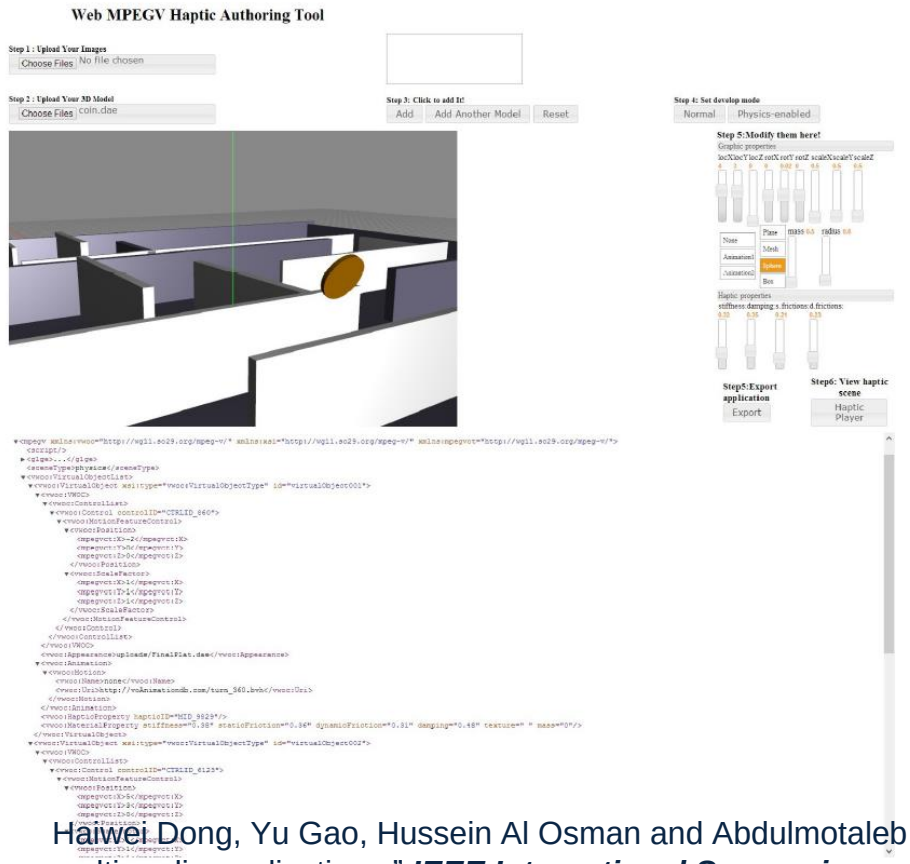
- Multimedia contents
  - Graphic images
  - 3D models
  - Audio and video files
  - And recently haptic stimuli
- Multimedia authoring tools
  - Integrate the disparate media elements into a cohesive multimedia application
  - Based on Blender

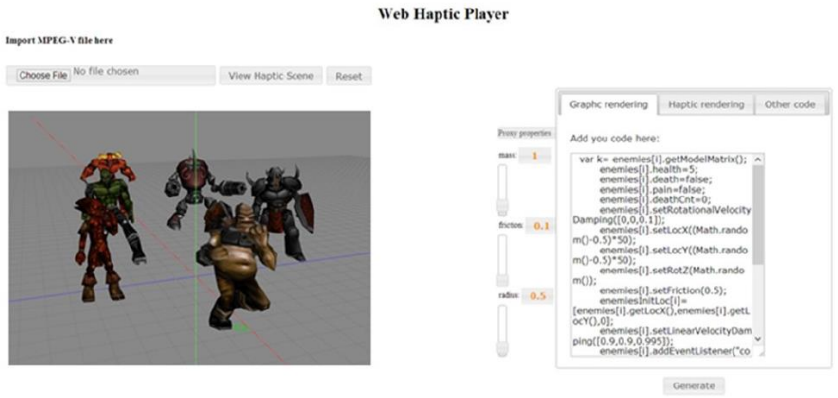


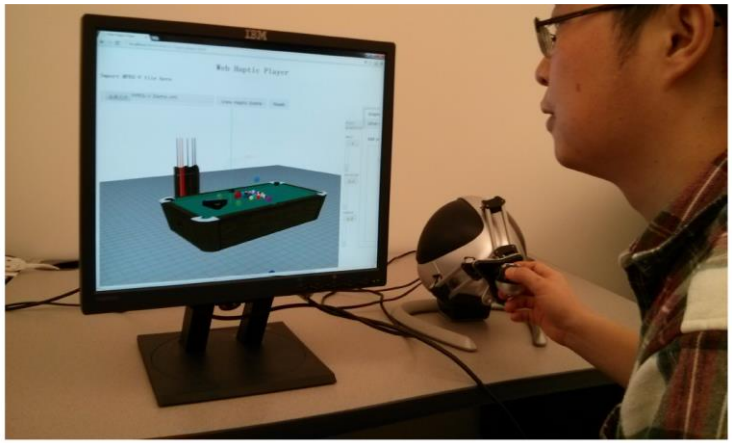
Eid et al. "HAMLAT: A HAML-based Authoring Tool for Haptic Application Development", In Proc. of the EuroHaptics 2008 conference, pp. 857-866, June 12-14, Madrid, Spain

Haptics Authoring Tool

- Based on HTML5 canvas tag with support of WebGL and HTML5 Haptic plugin
- 3D game runs in browser
- Integrates haptics into the web as PLUG & PLAY







Haiwei Dong, Yu Gao, Hussein Al Osman and Abdulmotaleb El Saddik, “Development of a web-based haptic authoring tool for multimedia applications,” ***IEEE International Symposium on Multimedia (ISM 2015)***, 2015. (accepted)

Mobile Haptic Feedback (SMS)

The app is on google store (Mobile Haptic Feedback (SMS)

https://play.google.com/store/apps/details?id=com.uottawa.hapticfeedback

uOttawa
L'Université canadienne
Canada's university

Intelligent 3D Avatar with Contactless Haptic Feedback


Lin Yang


Faisal Arafsha


Longyu Zhang


Basim Hafidh

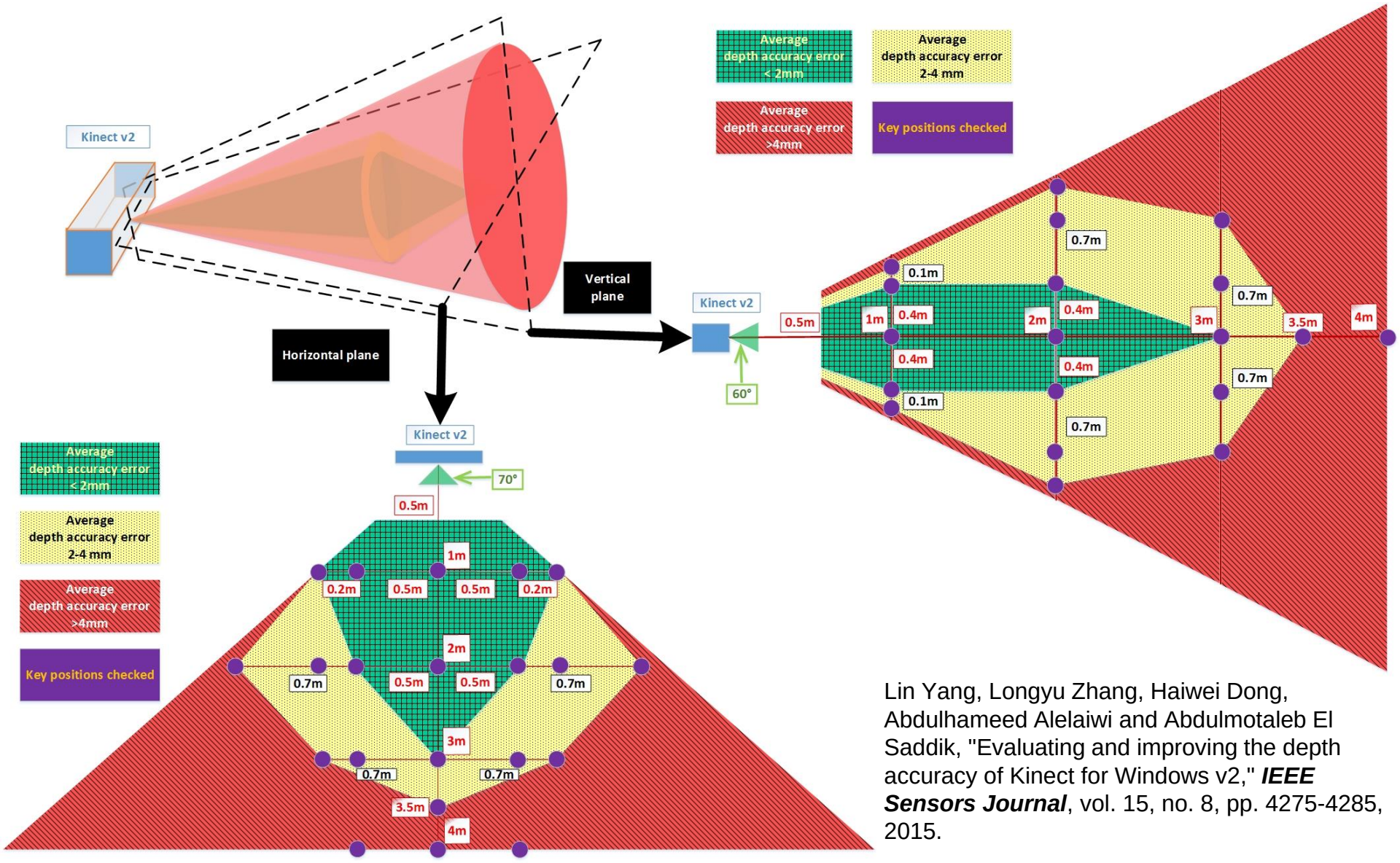

Amani Albraikan


Haiwei Dong


Abdulmotaleb El Saddik FIEEE, FCAE, FEIC

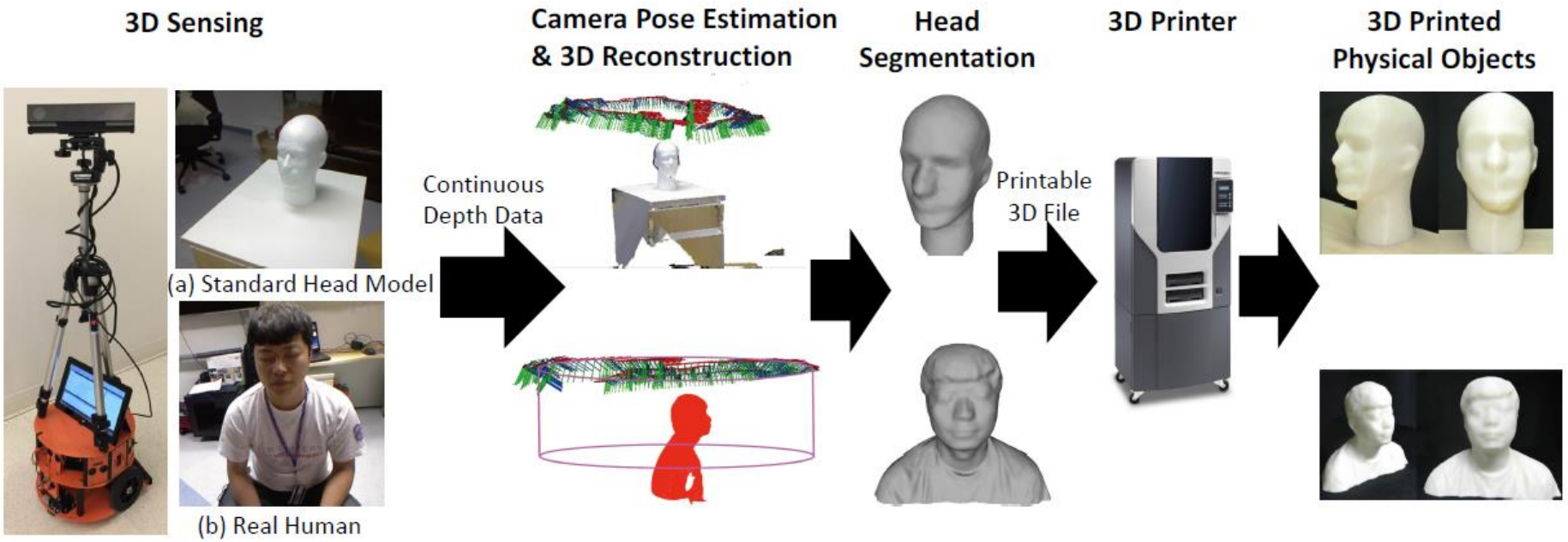
Depth image accuracy evaluation

Accuracy Distribution – Result : elliptical cone



Lin Yang, Longyu Zhang, Haiwei Dong, Abdulhameed Alelaiwi and Abdulmotaleb El Saddik, "Evaluating and improving the depth accuracy of Kinect for Windows v2," ***IEEE Sensors Journal***, vol. 15, no. 8, pp. 4275-4285, 2015.

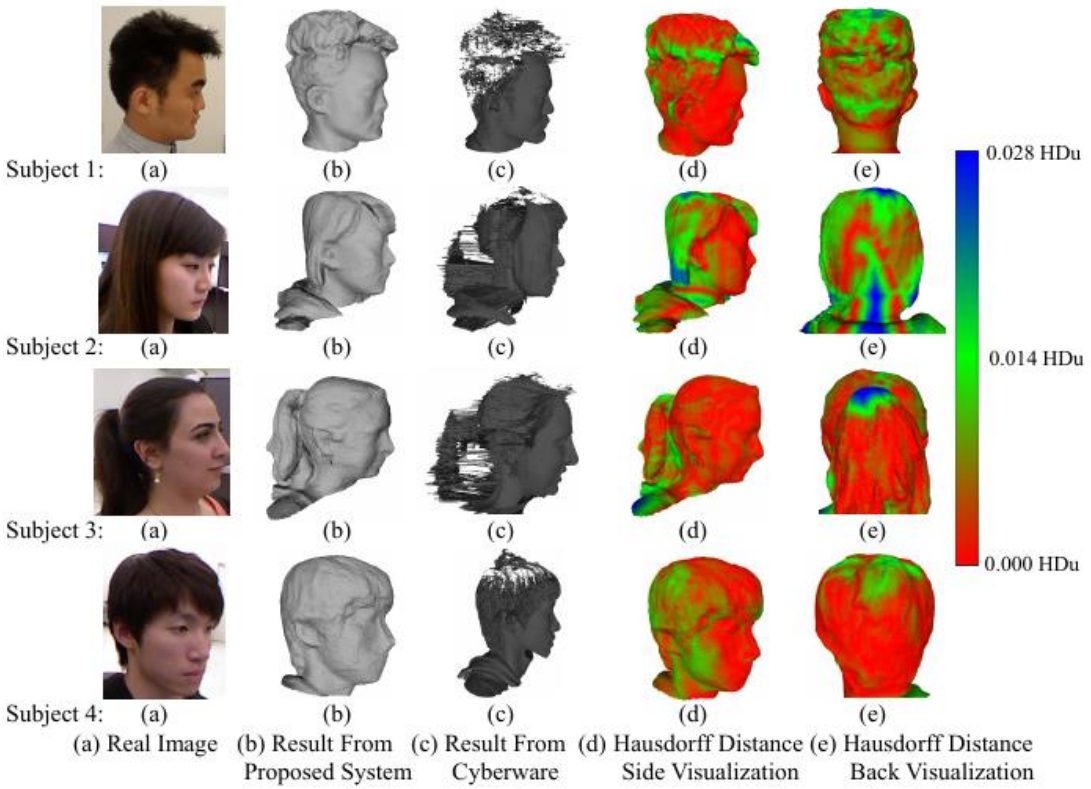
Development of an Automatic 3D Human Head Scanning-Printing System



Nadia Figueroa, Haiwei Dong and Abdulmotaleb El Saddik, “A combined approach towards consistent reconstructions of indoor spaces based on 6D RGB-D odometry and KinectFusion,” ***ACM Transactions on Intelligent Systems and Technology***, vol. 6, no. 2, pp. 14:1-10, 2015.

Development of an Automatic 3D Human Head Scanning-Printing System

Male and female subjects' real image, scanned results from our proposed system and Cyberware separately, and the Hausdorff distance visualization results.

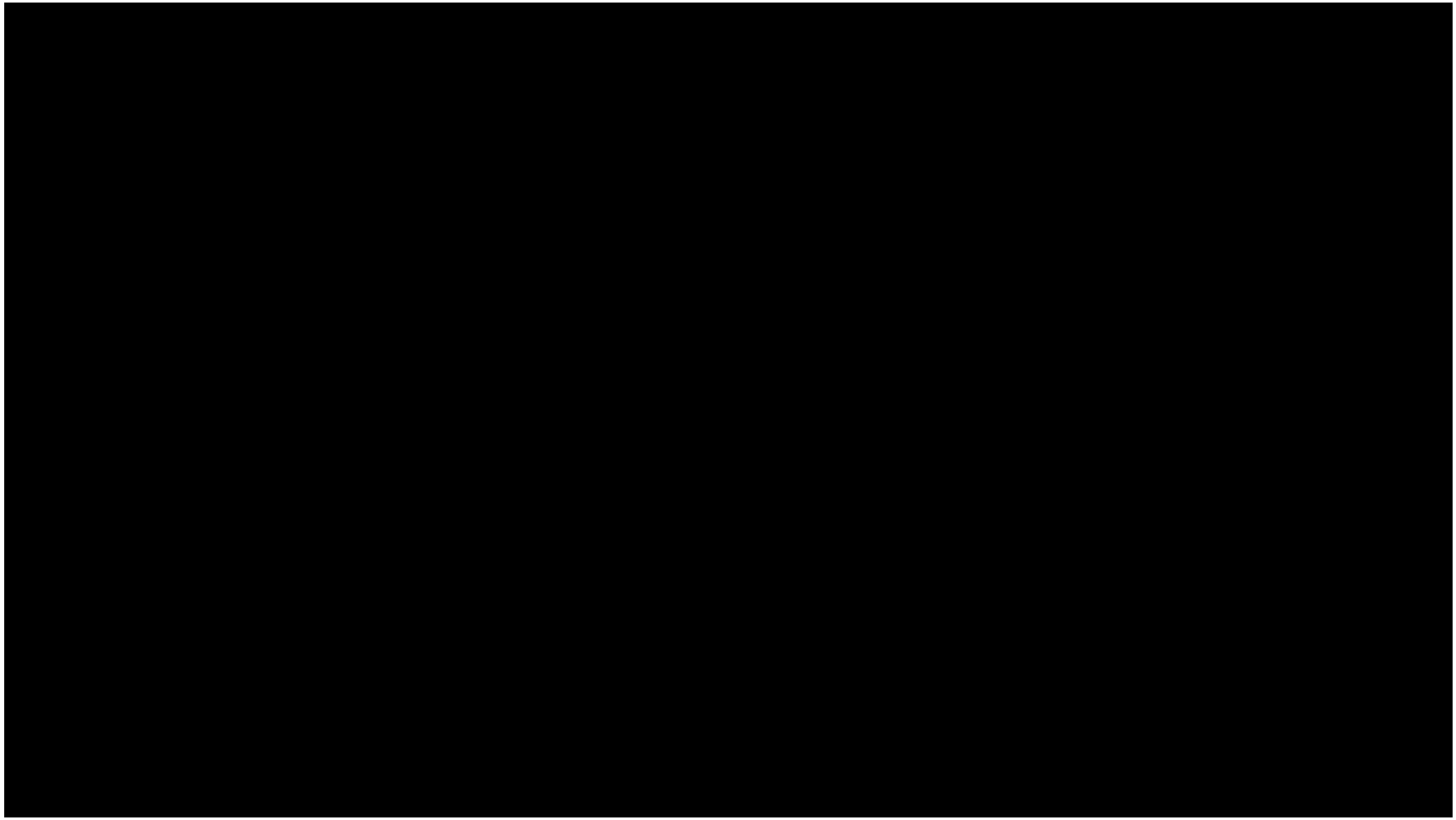


Experimental results of real human scanning

To validate the capabilities of our proposed scanning system, a visualized 3D CAD model of a standard human head model is prototyped, 3D printed and scanned separately by our proposed scanning system and by a commercial handheld 3D laser scanner FastSCAN. Furthermore, **we computed the geometric differences** (represented by *Hausdorff distances*) between the two scanned 3D models and the ground-truth model separately

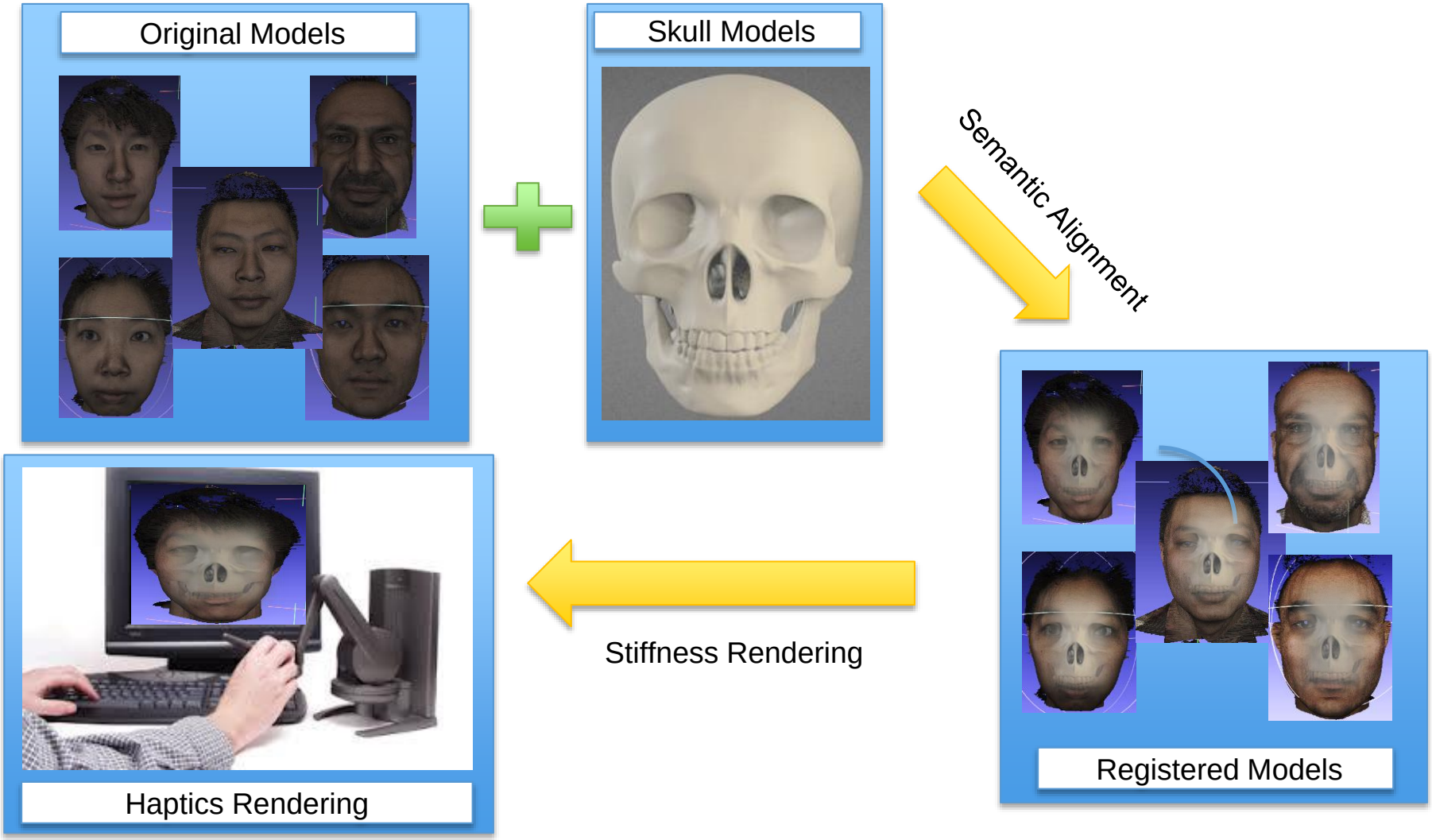
Longyu Zhang, Bote Han, Haiwei Dong and **Abdulmotaleb El Saddik**, "Development of an Automatic 3D Human Head Scanning-Printing System", Springer Multimedia Tools and Applications (2016). doi:10.1007/s11042-016-3949-2

1 min scanner

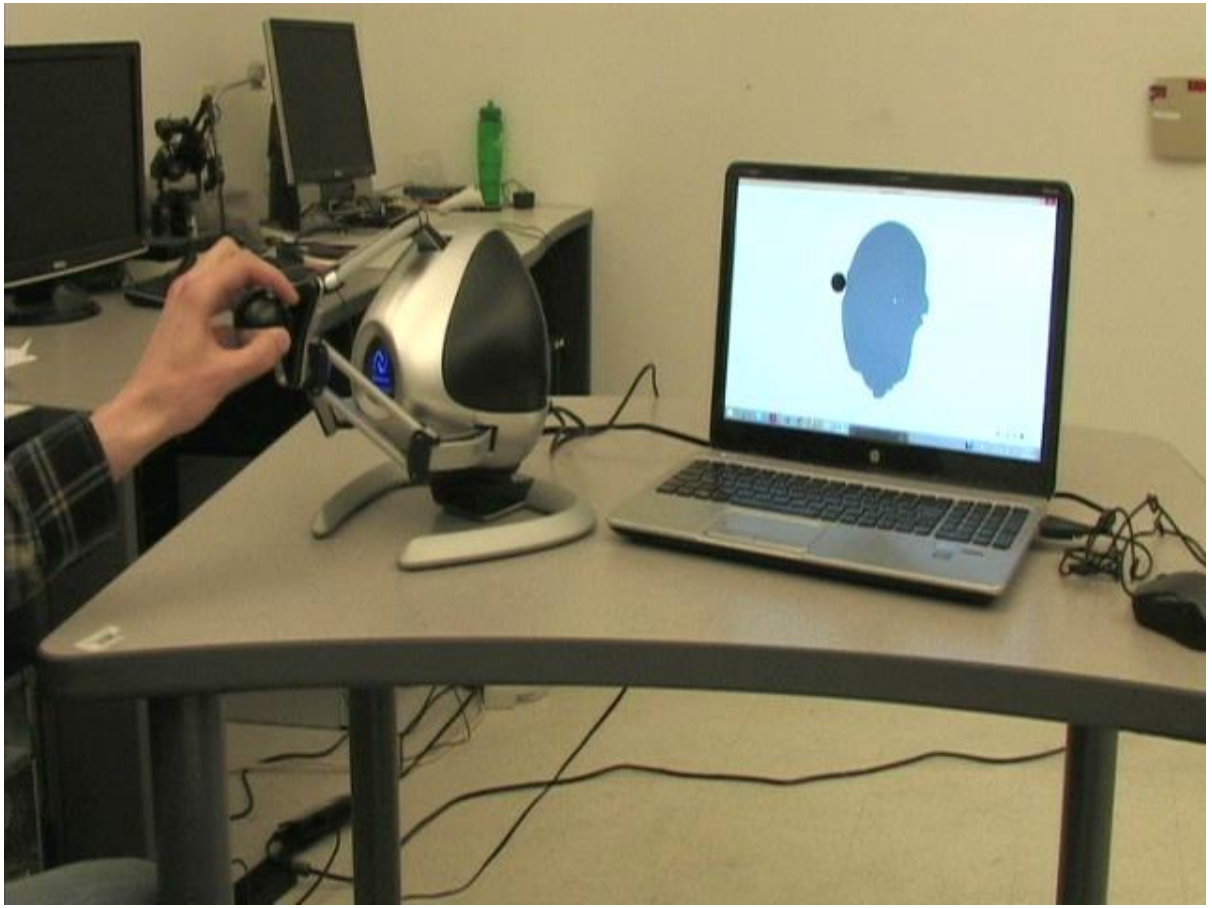


Longyu Zhang, Bote Han, Haiwei Dong and **Abdulmotaleb El Saddik**, “Development of an Automatic 3D Human Head Scanning-Printing System”, Springer Multimedia Tools and Applications (2016). doi:10.1007/s11042-016-3949-2

Head Stiffness Rendering



Head Stiffness Rendering

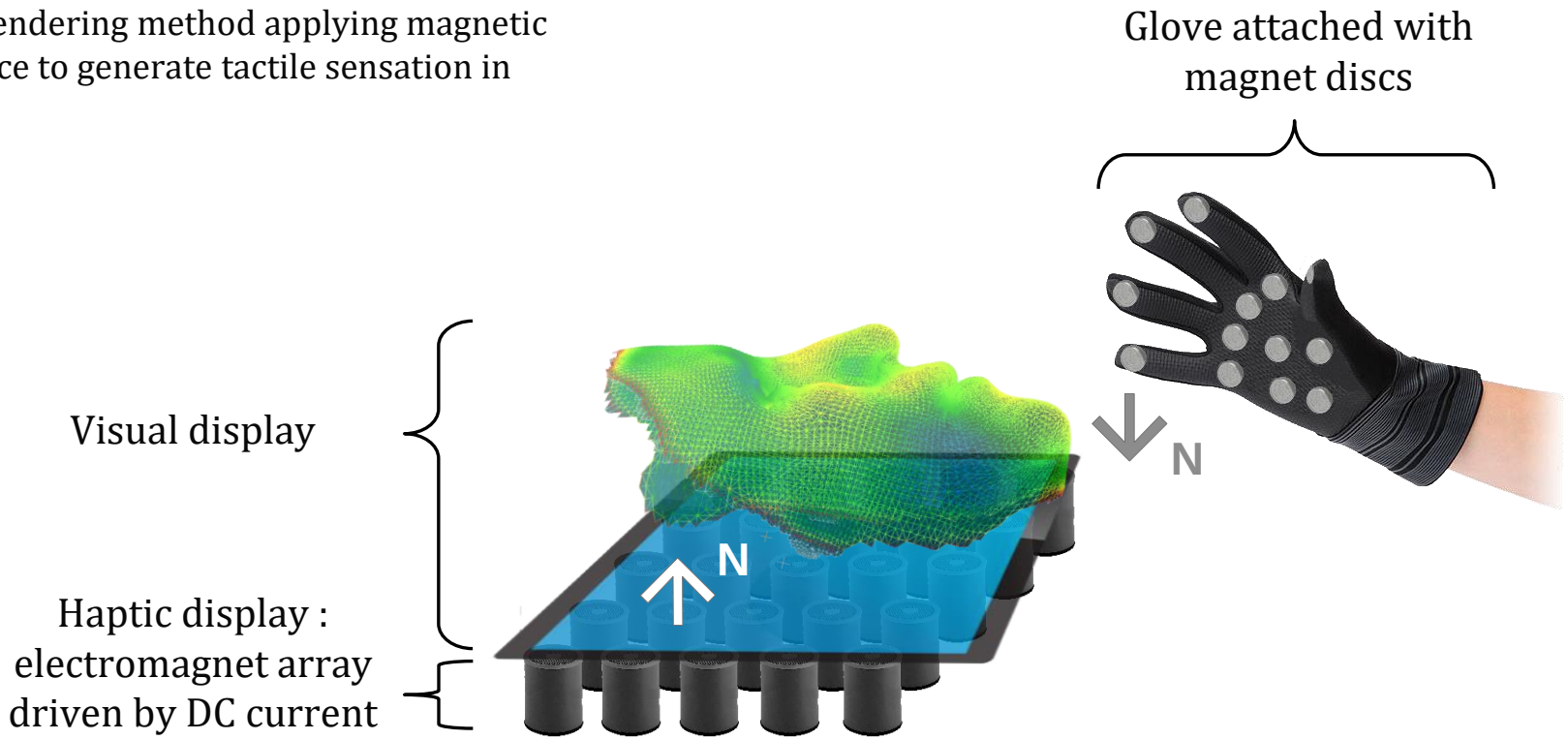


Minggao Wei, Yang Liu, Haiwei Dong, and **Abdulmotaleb El Saddik** "Human Head Stiffness Rendering", IEEE Transactions on Instrumentation & Measurement, Vol 66(8), pp: 2083-2096, DOI: : 10.1109/TIM.2017.2676258

Magnetic Rendering

Introducing a new way of haptic volumetric shape rendering

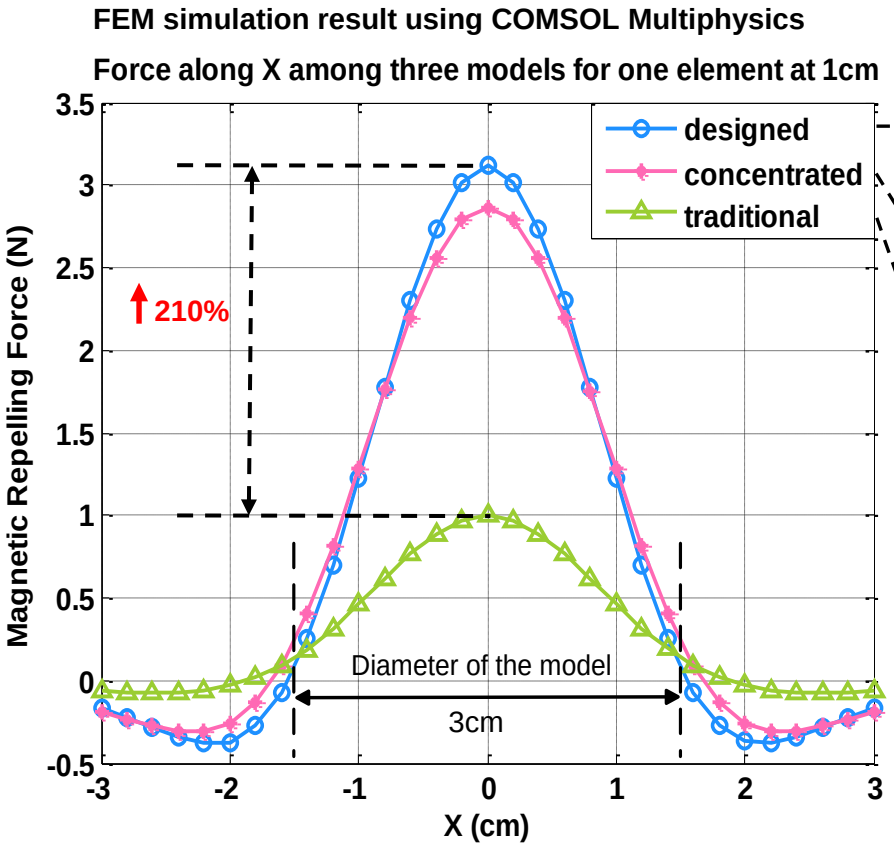
As a haptic rendering method applying magnetic repulsive force to generate tactile sensation in mid-air

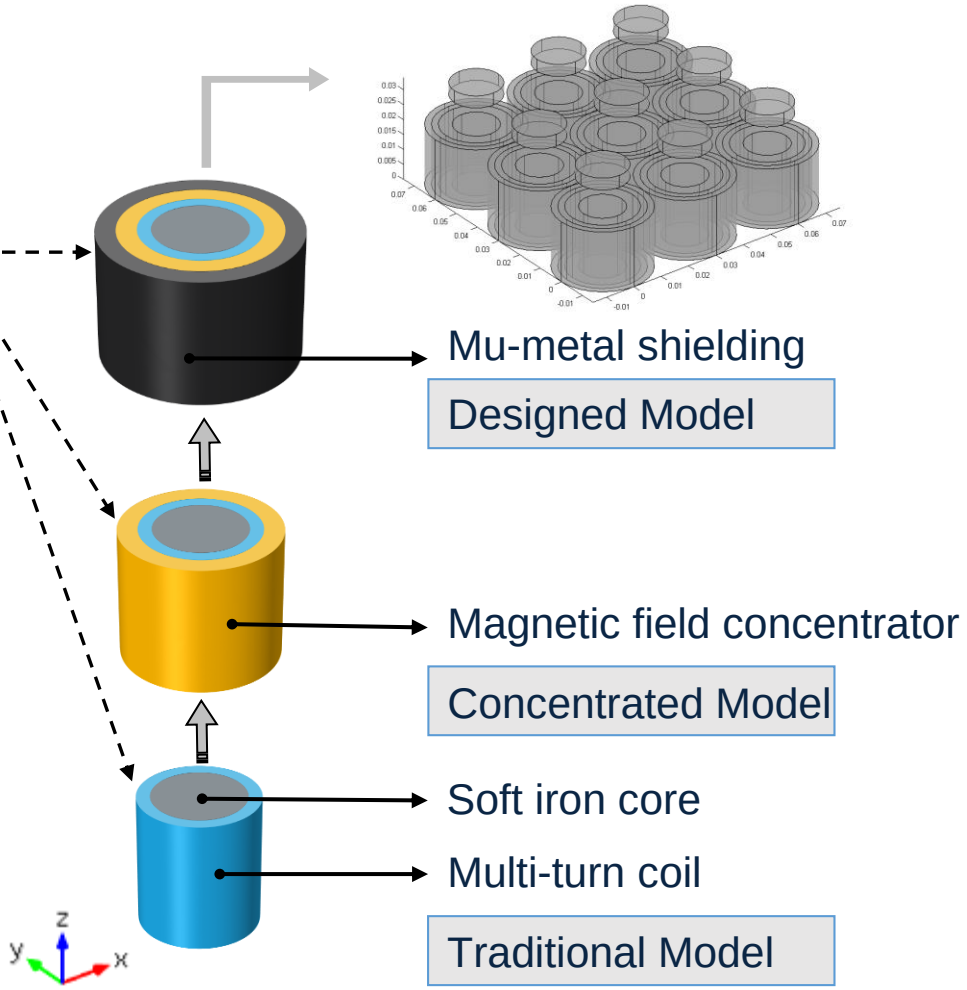


Magnetic Rendering

Design of a powerful electromagnet model

Magnetic Field Concentrate Electromagnet





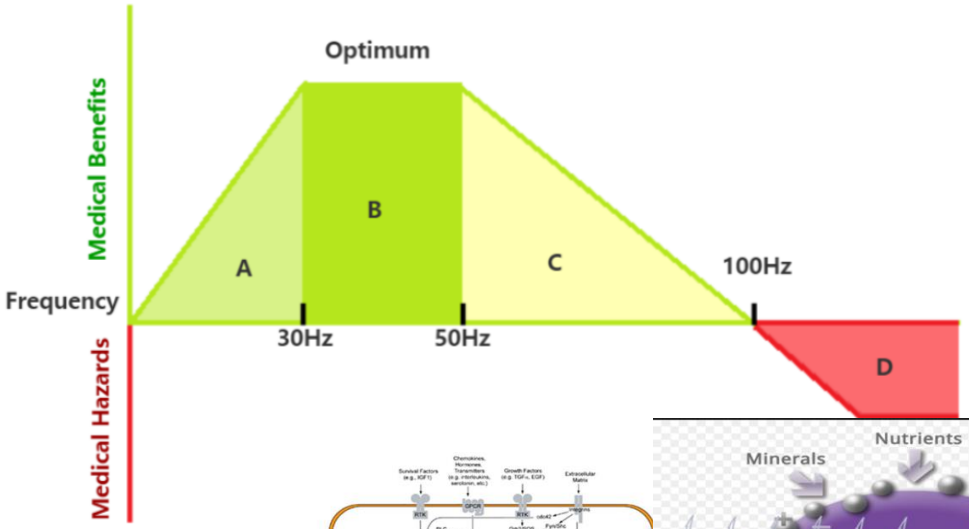
Magnetic Rendering

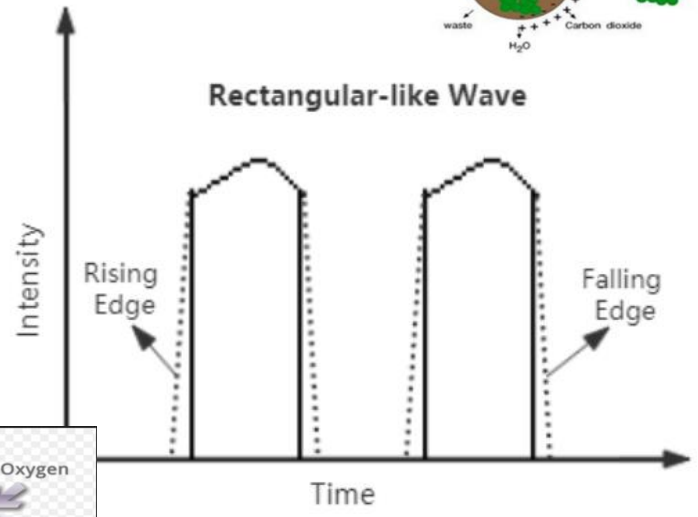
Qi Zhang, Haiwei Dong, and **Abdulmotaleb El Saddik**, “Magnetic Field Control for Haptic Display: System Design and Simulation” IEEE Access , Vol 4, 2016, pp 299-311, DOI: 10.1109/ACCESS.2016.2514978

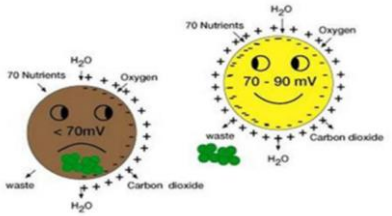
Design Requirements

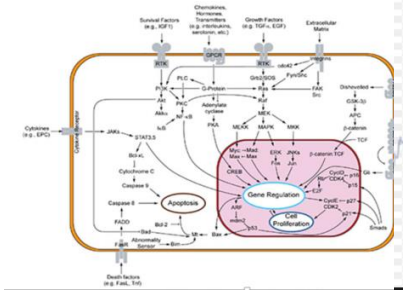
Define the desired waveform

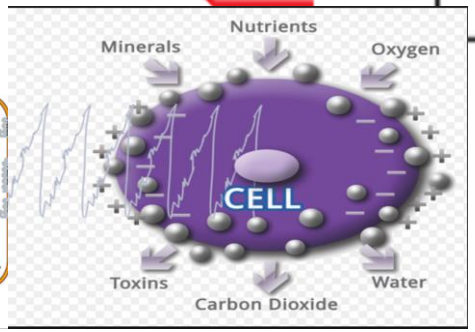
- Frequency of the UPEMF wave (30Hz)
- Shape of the UPEMF wave (Rectangular)
- Intensity of the UPEMF wave (0.12T)





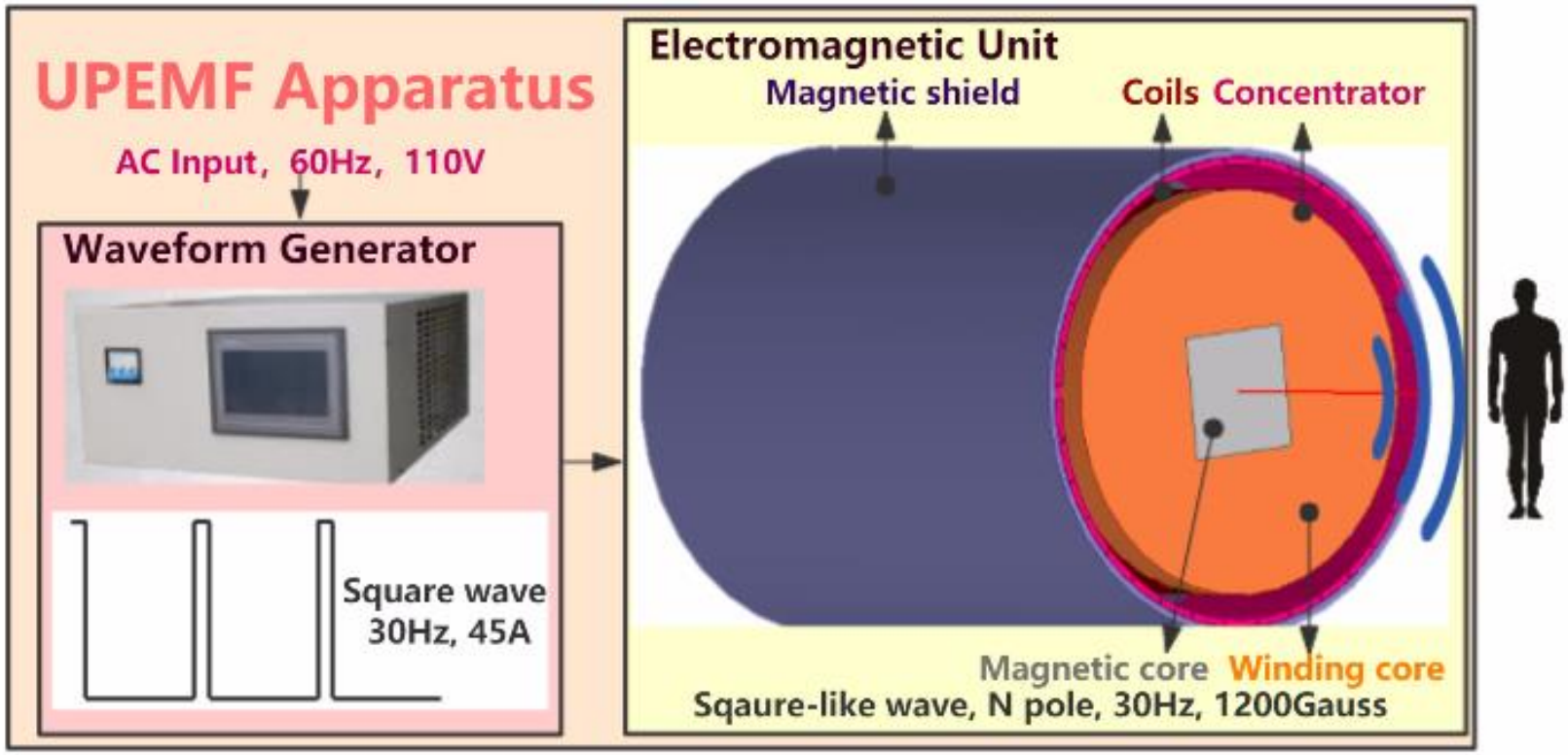




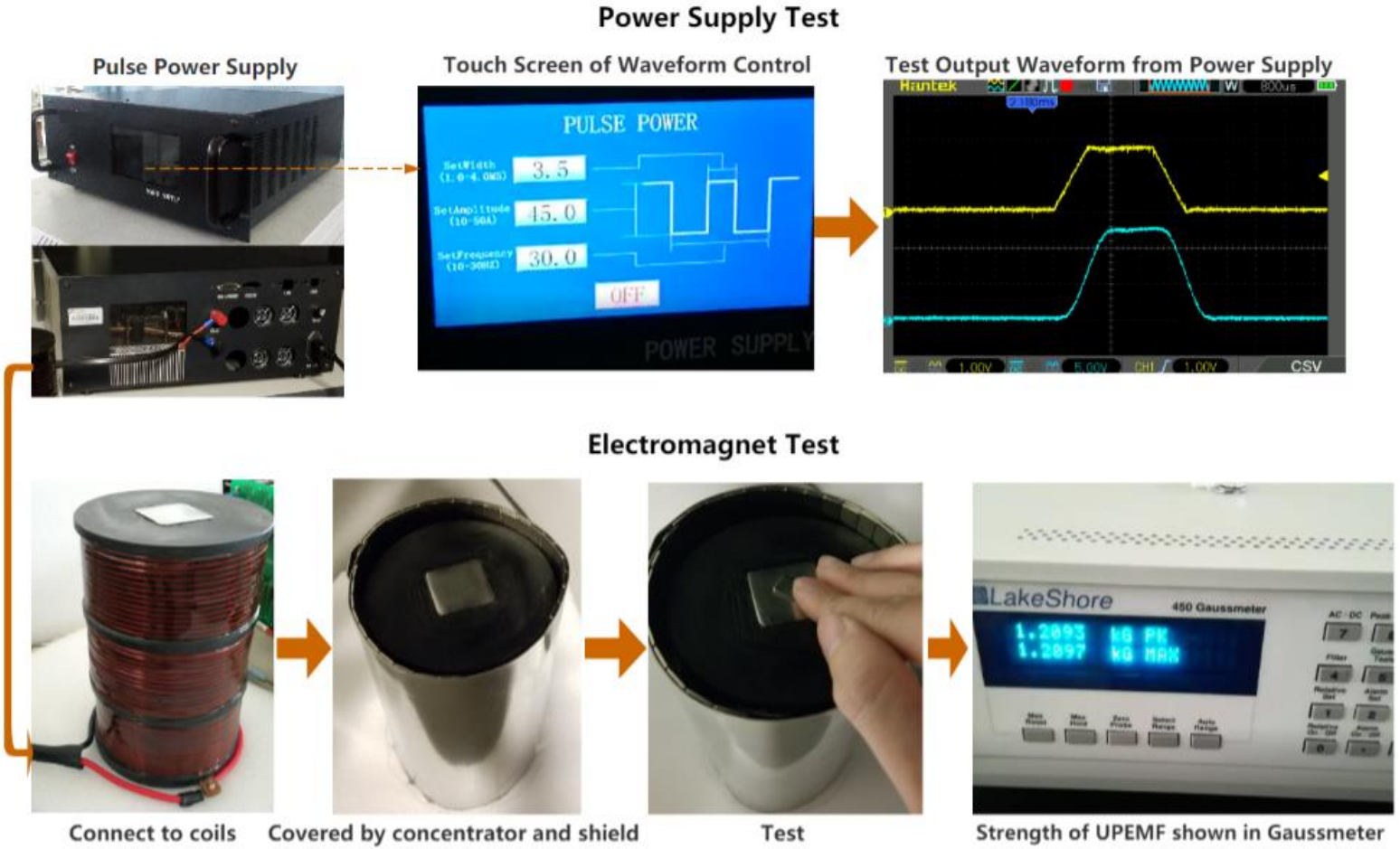


System Design

- Proposed UPEMF system

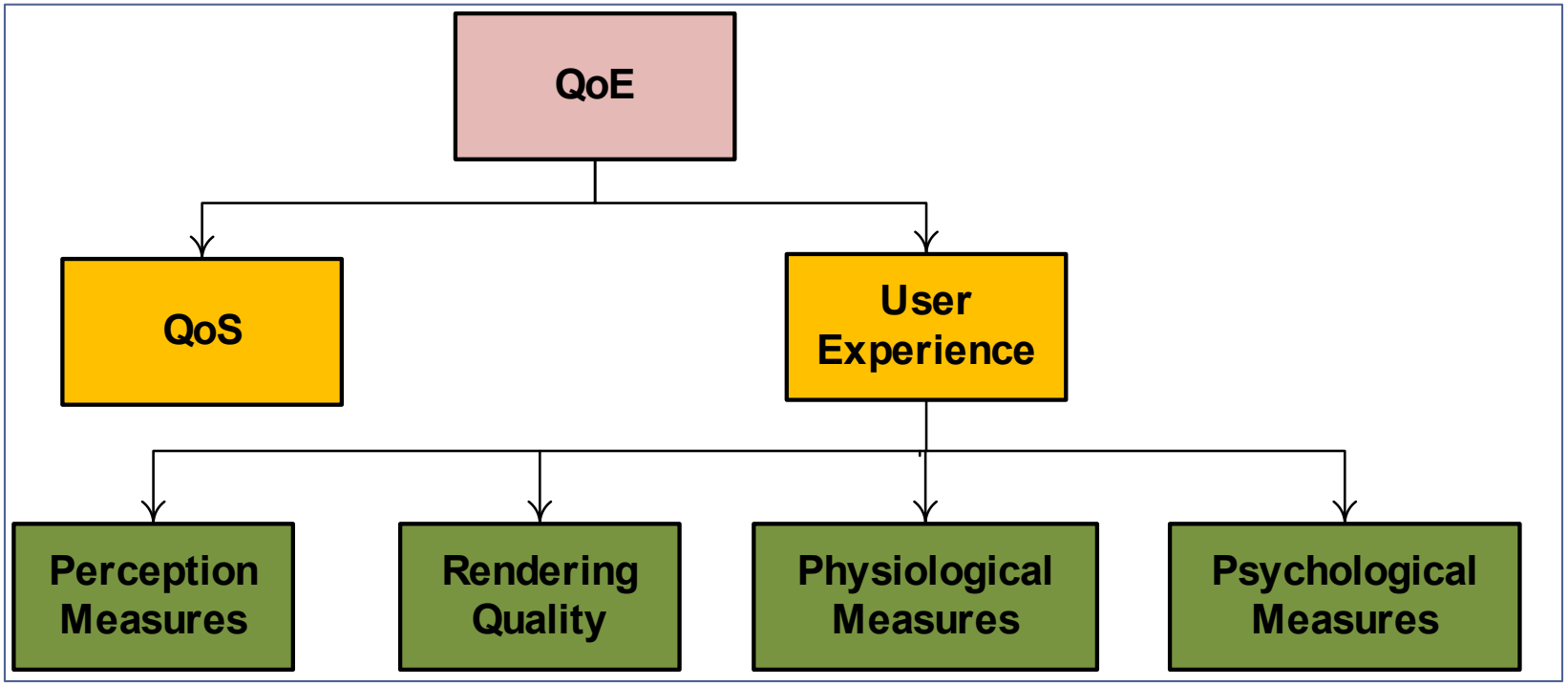


Test



Yuxiang Jiang, Haiwei Dong, Abdulmotaleb El Saddik, “A Unipolar Pulse Electromagnetic Field Apparatus for Magnetic Therapy” IEEE Instrumentation & Measurement Magazine (2018)

Quality of Experience

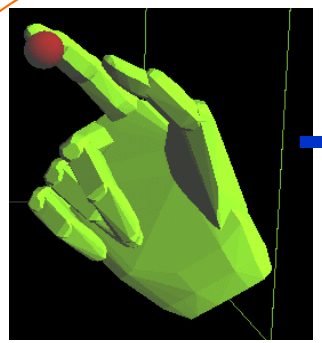


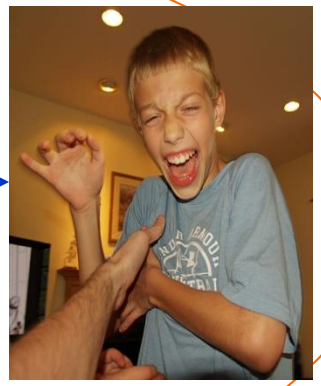
ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM) Nicolas D. Georgans **Best Paper Award** 2015 for the article "A Quality of Experience Model for Haptic Virtual Environments" (TOMM vol.10, Issue 3)

Best Paper Award at the 7th International Workshop on Quality of Multimedia Experience (QoMEX 2015) sponsored by Youtube Google, 26-29 May 2015, Costa Navarino, Messinia, Greece

Why Haptics – Biometrics?

Haptic Systems



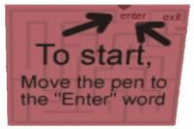


The problem with Biometrics without Haptics (movie)

Biometrics Systems

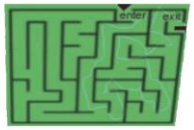
Case Study: Identifying Human

The Experiment



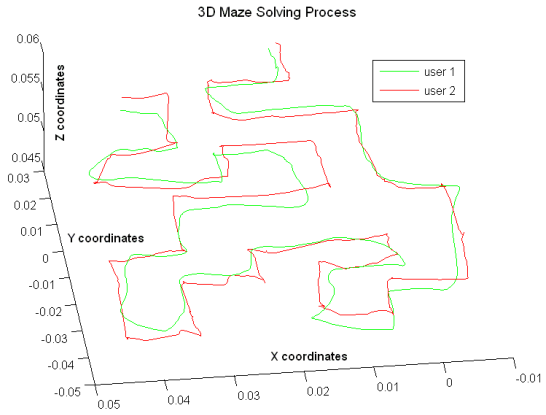
Before Recording

During Recording



After Recording

Graphic Representation



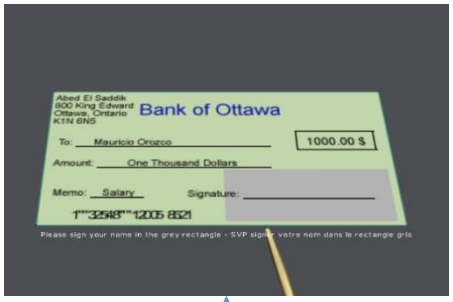
$$MS = \sum_{c=1}^{3} \sum_{i=1}^{N} \left(d^{1}_{c,i} - I^{2}_{c,i}\left(t^{p}\right) \right)^{2}$$

Methodology

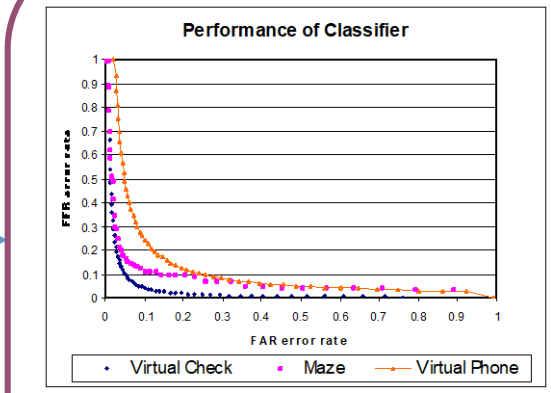
- **Dynamic Time Warping :**
  - **+ Nelder-Mead non-linear minimization**
- **Spectral analysis: Fast Fourier Transform**
- **Unsupervised Method: K-Means**

Verifying such feasibility

Virtual Check

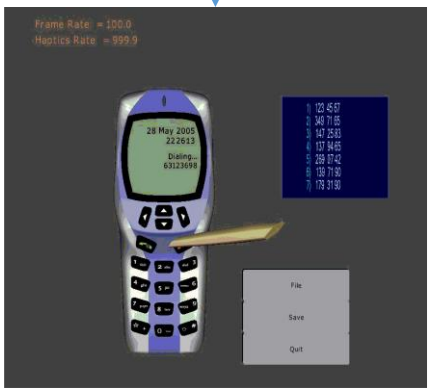


Ambient Intelligent Engine



Performance

Virtual Mobile Phone

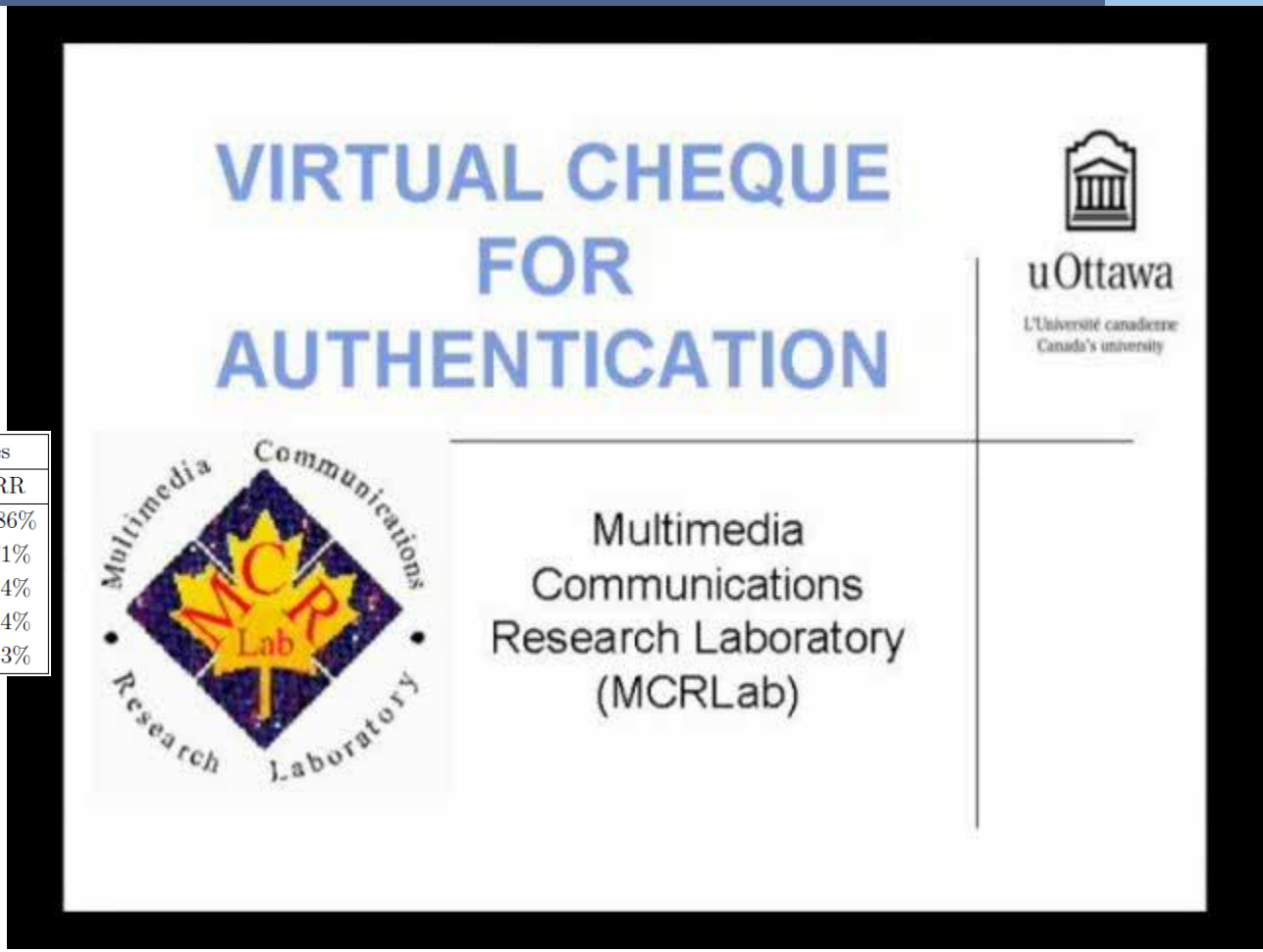


El Saddik et al., “A Novel Biometric System for Identification and Verification of Haptic Users”, IEEE Transactions on Instrumentation and Measurement, Vol.56, No. 3 (2007), pp: 895 – 906.

Virtual Check

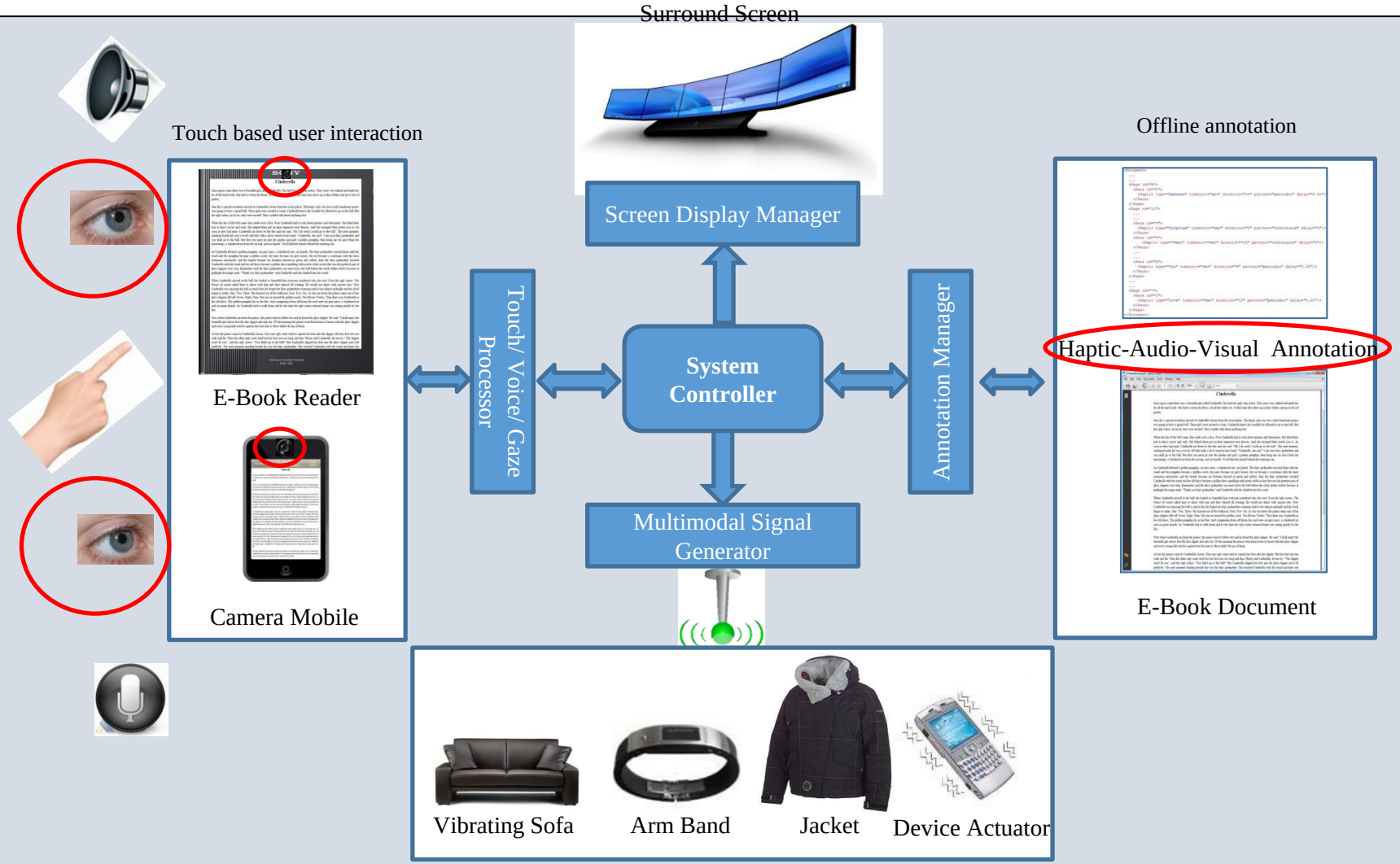
FAR = ~7%
FRR = ~12%

Classifier	NN		RandomForest		NaiveBayes	
Time	FAR	FRR	FAR	FRR	FAR	FRR
5s	5.57%	17.71%	2.50%	16.57%	18.21%	10.86%
10s	6.0%	16.85%	2.00%	15.50%	19.14%	7.71%
20s	6.0%	12.28%	1.57%	13.50%	16.57%	7.14%
30s	5.14%	11.28%	1.79%	13.64%	13.86%	7.14%
60s	6.0%	11.92%	1.29%	11.93%	15.50%	2.43%



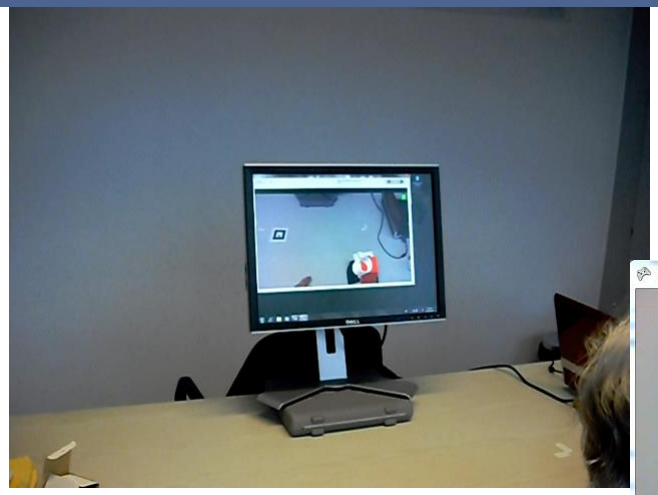
Nizar Sakr, Fawaz Alsulaiman, Julio J. Valdes and Abdulmotaleb El Saddik, “Identity Verification based on Haptic Handwritten Signatures using Genetic Programming” ACM Transactions on Multimedia Computing Communications and Applications Vol 9(2), 2013

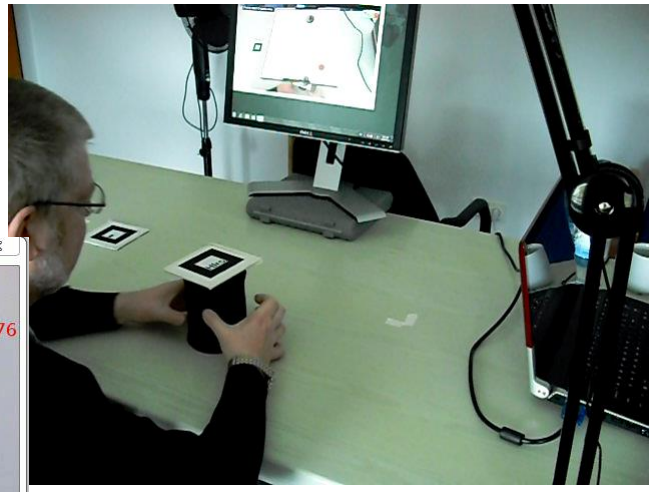
Haptic Book

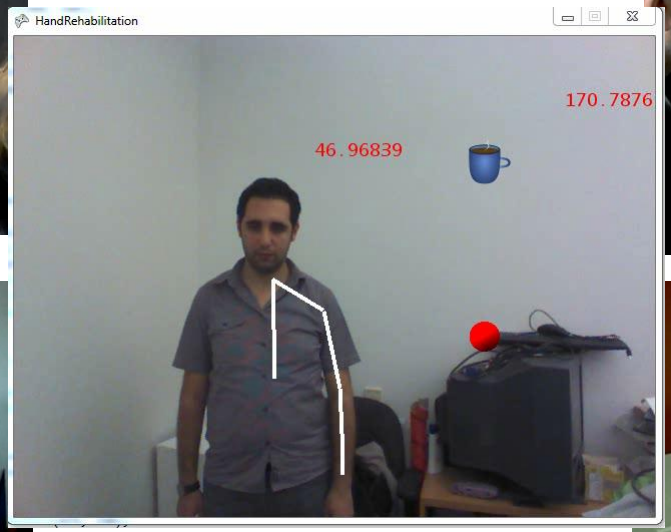


Kazi Masudul Alam, Abu Saleh Md Mahfujur Rahman, and **Abdulmotaleb El Saddik**, "Mobile Haptic Ebook System to Support 3D Immersive Reading in Ubiquitous Environments", ACM Transactions on Multimedia Computing Communications and Applications, Volume 9, Issue 4, pp. 27:1: 27:20, 2013

Post Stroke rehabilitation

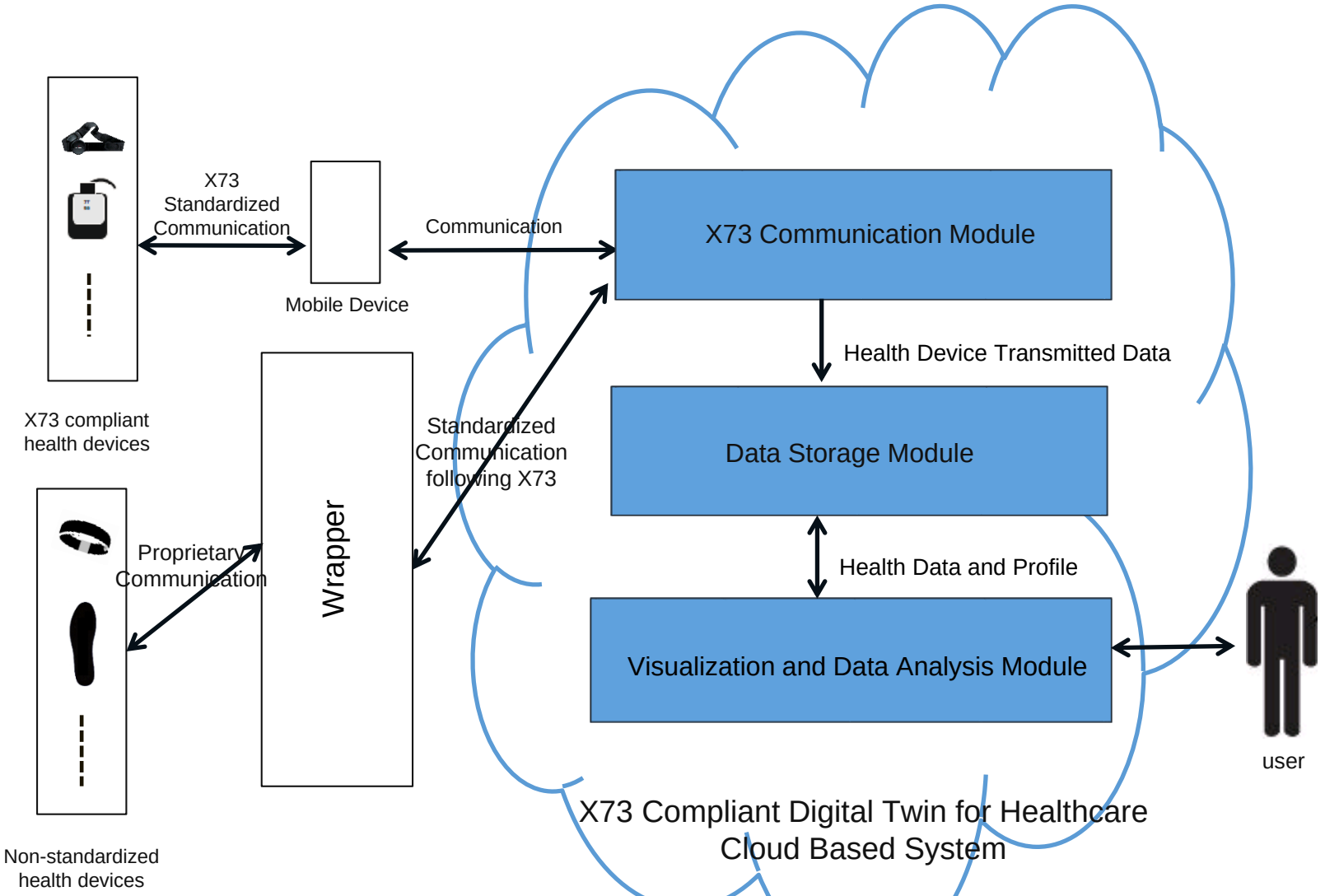






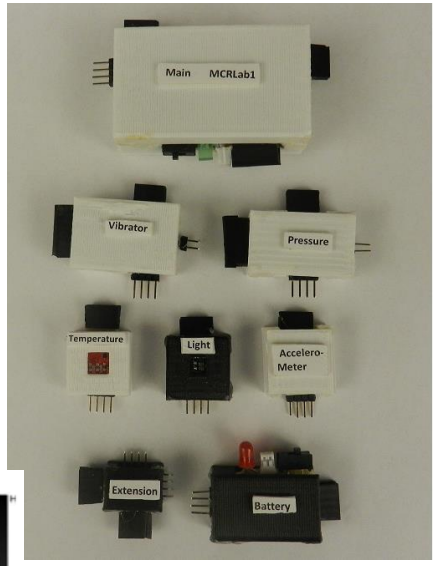
- Ali Karime, Hussein Al-Osman, Jihad Mohamad Alja'am, Wail Gueaieb, and Abdulmotaleb El Saddik, “Tele-Wobble: A Tele-Rehabilitation Wobble Board for Lower Extremity Therapy”, IEEE Transactions on Instrumentation and Measurements, 61 (7), 1816-1824 , 2012
- Atif Alamri, Jongeun Cha, and Abdulmotaleb El Saddik, “AR-REHAB: an Augmented Reality Framework for Post-Stroke Patients Rehabilitation”, IEEE Transactions on Instrumentation and Measurements, Vol. 59(10), pp: 2554 – 2563, 2010

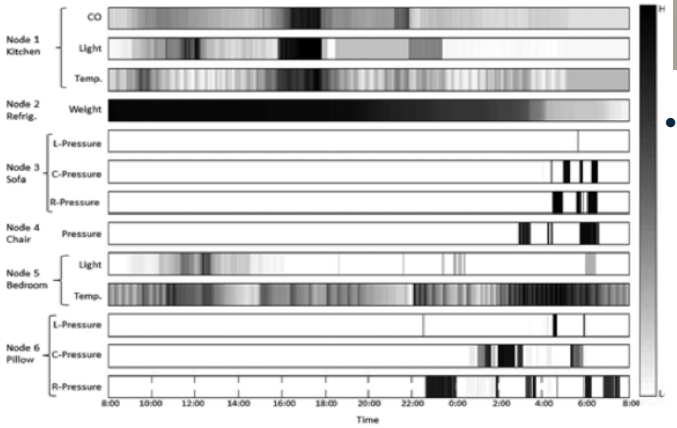
IEEE X73 Platform 4 DT



Reconfigurable Transducer Network

- Multiple types of sensors are developed, such as pressure sensor, light sensor, temperature sensor, accelerometer, CO-gas sensor, etc.



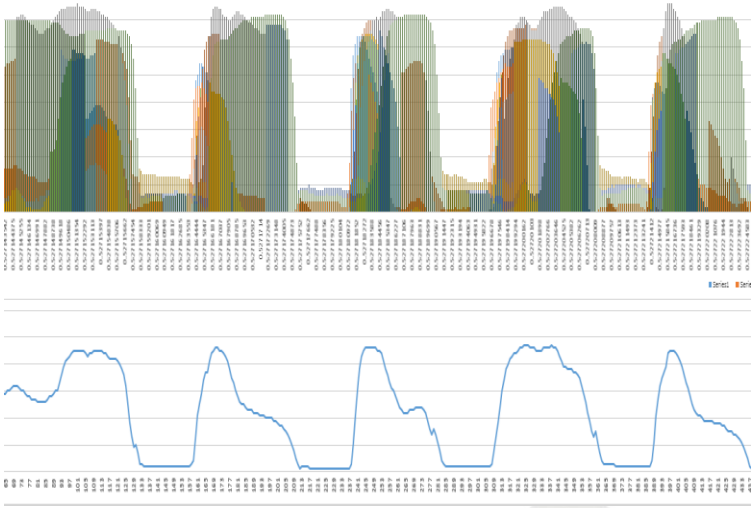


- The dynamic condition of a multiple rooms during a period of 24 hours is monitored. Recommendations are given by fuzzy logic.

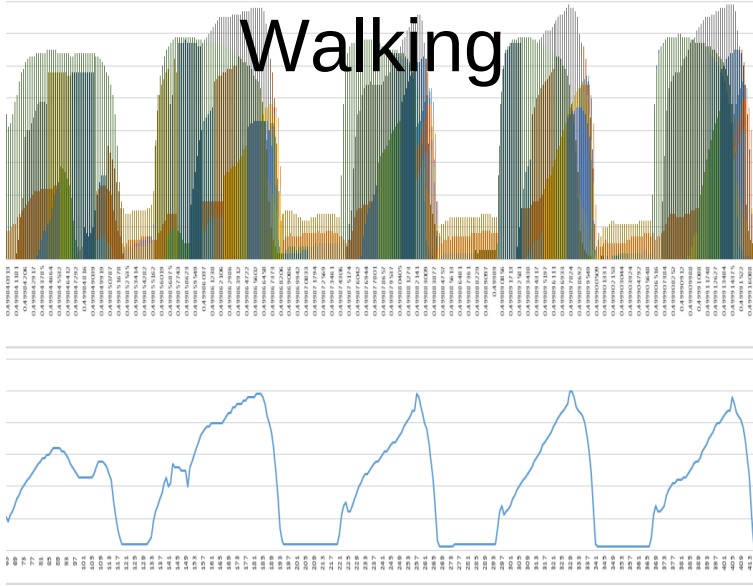
Basim Hafidh, Hussein Al Osman, Haiwei Dong and Abdulmotaleb El Saddik ,“A framework of reconfigurable transducer networks and its XML-based communication,” ***IEEE Embedded Systems Letters***, vol. 7, no. 3, pp. 81-84, 2015.

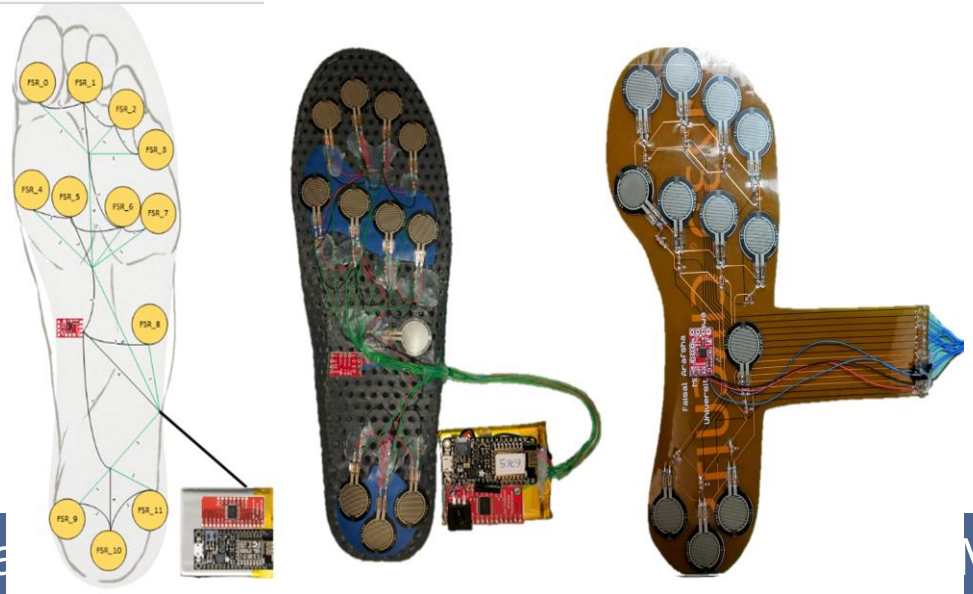
Smart Insole

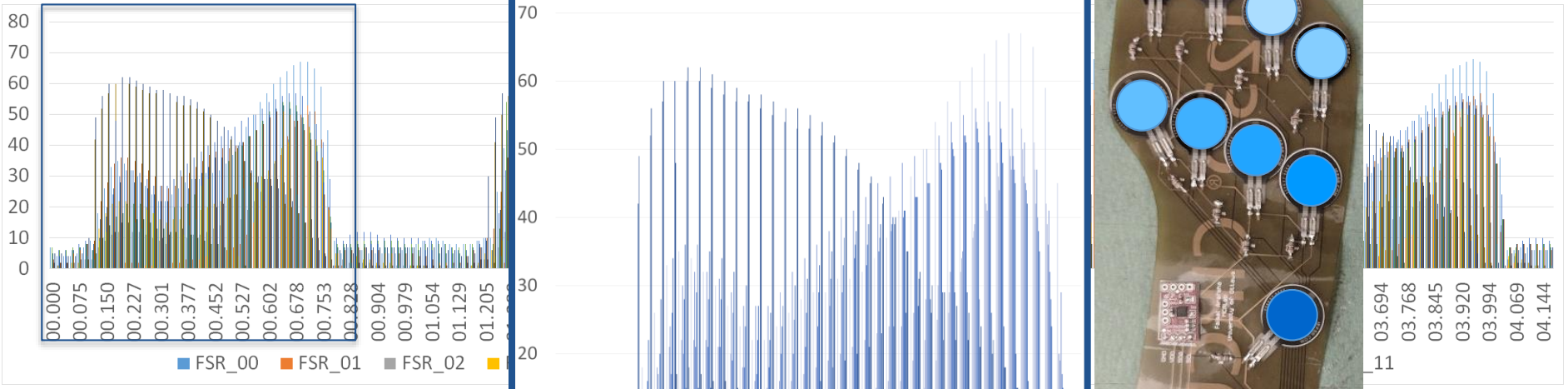
Forward Walking



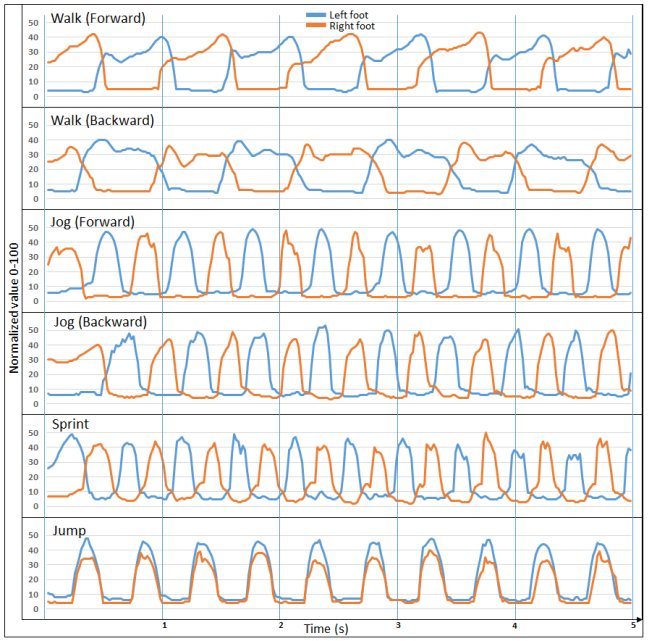
Backward Walking

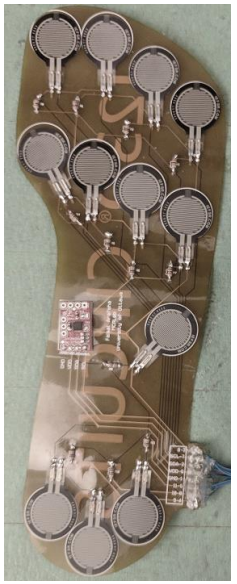






Results





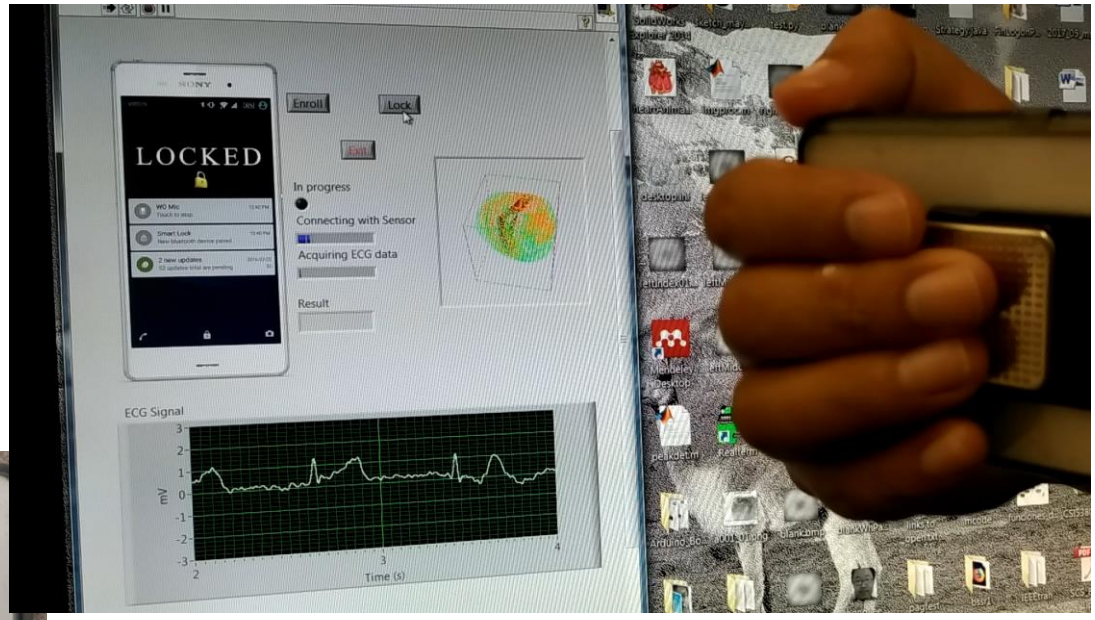
Faisal Arafsha , Christina Hanna, Ahmed Aboualmagd, Sarah Fraser and Abdulmotaleb El Saddik, “Instrumented Wireless SmartInsole System for Mobile Gait Analysis: A Validation Pilot Study with Tekscan Strideway”, J. Sens. Actuator Netw. 2018, 7(3), 36; doi:10.3390/jsan7030036

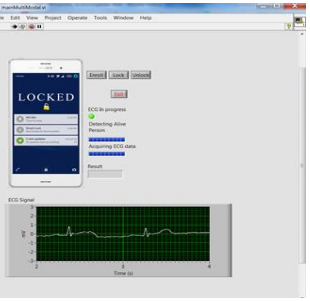
The Future

Haptics
Mobile/Wearables
Emotions

Instant biofeedback over
Tactile Internet
4
The Well-Being of Citizens

Mobile Haptic & ECG Biometrics



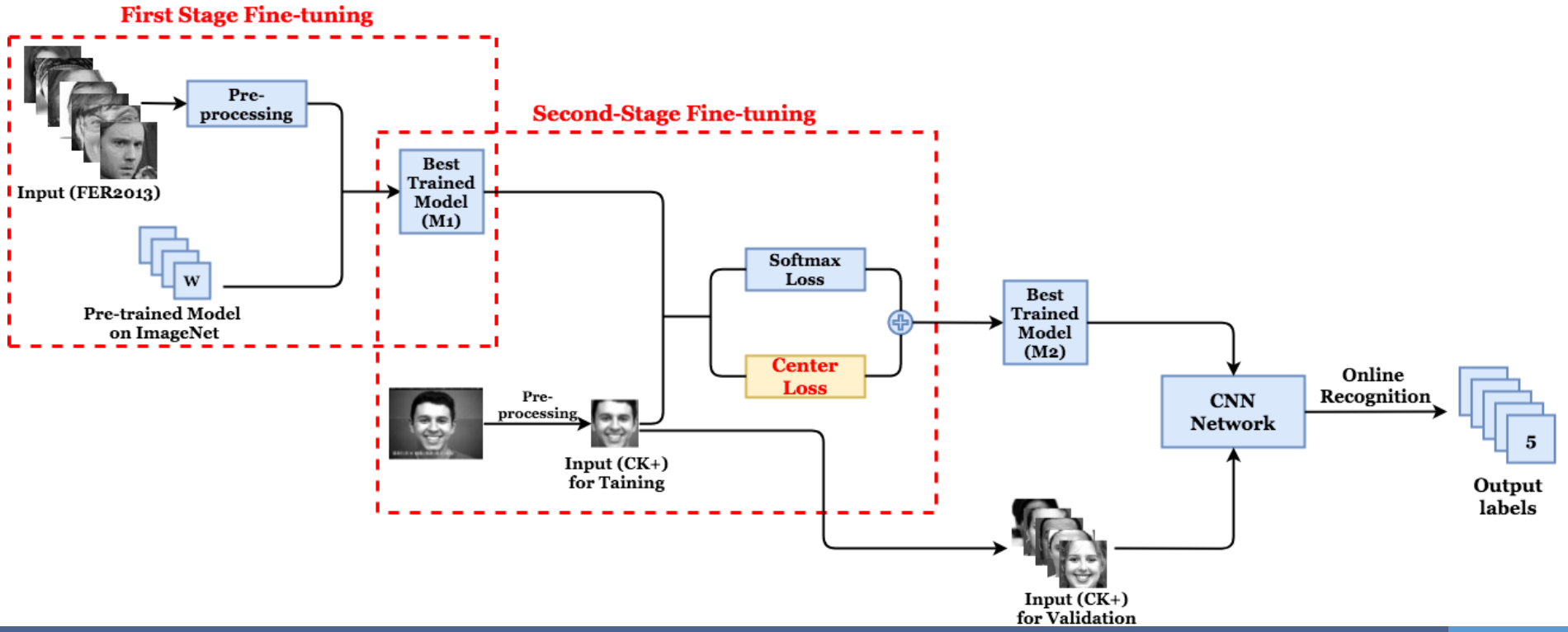


- We obtained 84.93% for TAR and 1.29% for FAR, with the advantage that the required time to perform the authentication with our proposed algorithm is 4 seconds only.

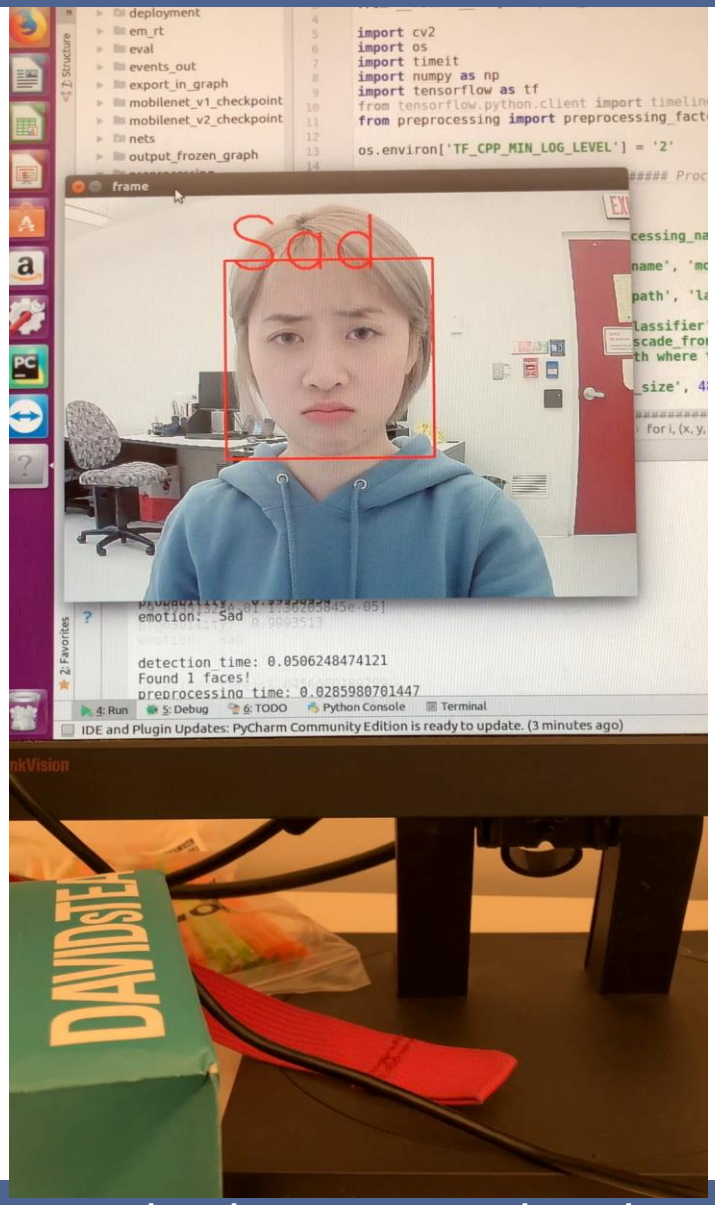
- US Patent: US9699182B2 "Electrocardiogram (ECG) biometric authentication" by A. El Saddik, J, Arteaga Falconi & H. Al Osman
- ECG Authentication for Mobile Devices, Juan Sebastian Arteaga-Falconi ; Hussein Al Osman ; Abdulmotaleb El Saddik
- IEEE Transactions on Instrumentation and MeasurementYear: 2016, Volume: 65, Issue: 3, Pages: 591 - 600

Capturing Emotions

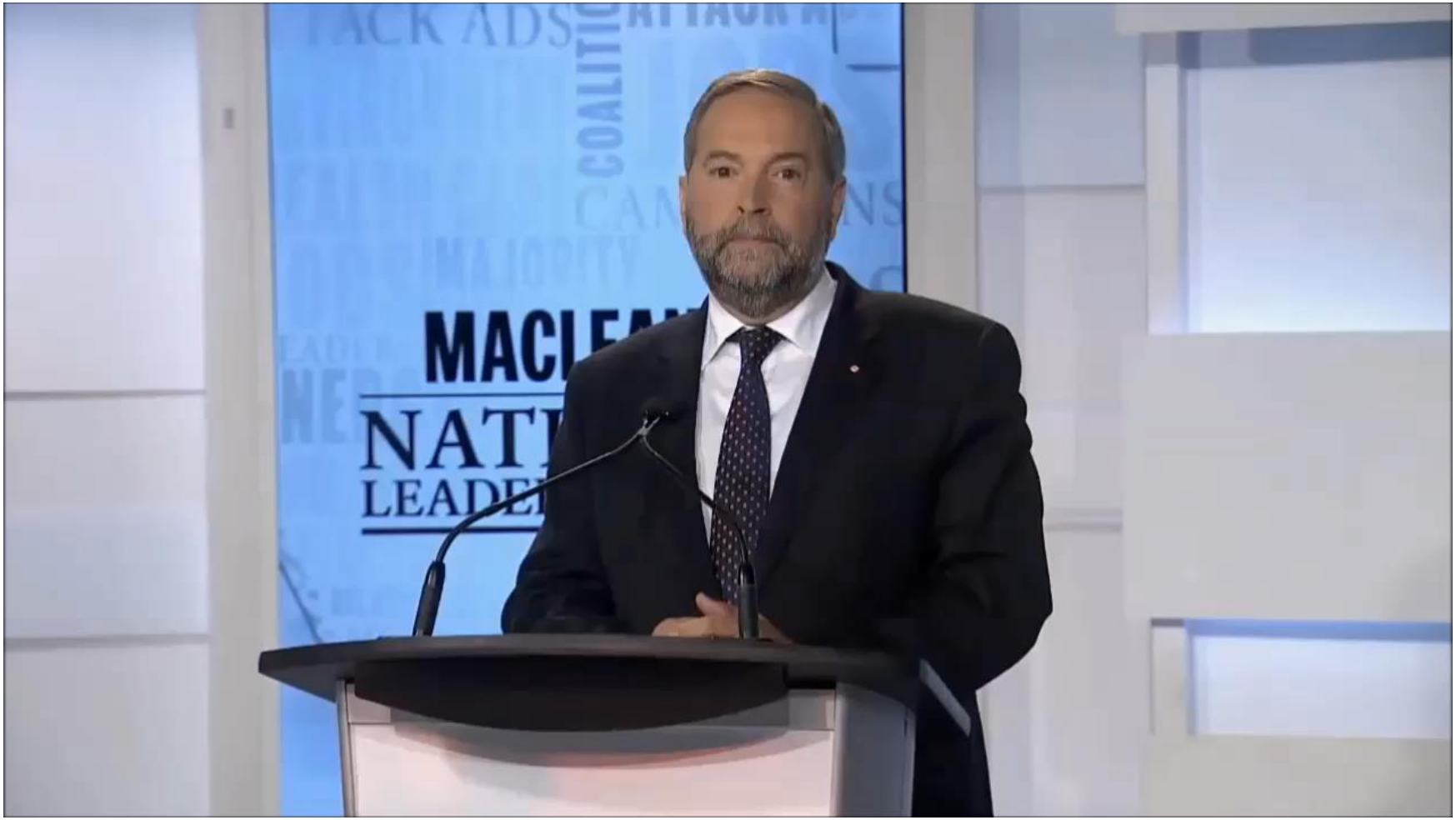
- Image pre-processing
- CNN training process
  - Two-stage fine-tuning
  - Center Loss



Real-time Experiments

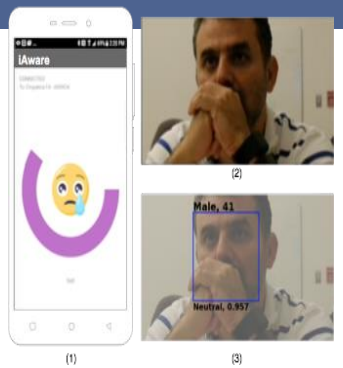


HR from Videos :16, :52, 1:32

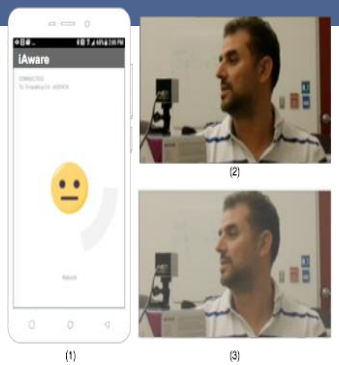


Real-time Emotion (DL) and Feedback

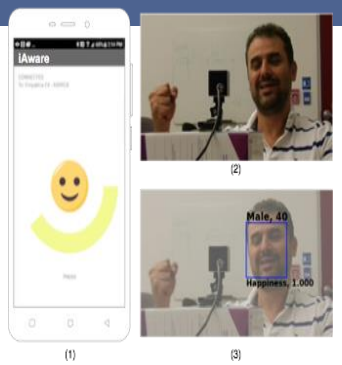
Stimuli: Argentina's player injured



Stimuli: Conversations with a friend

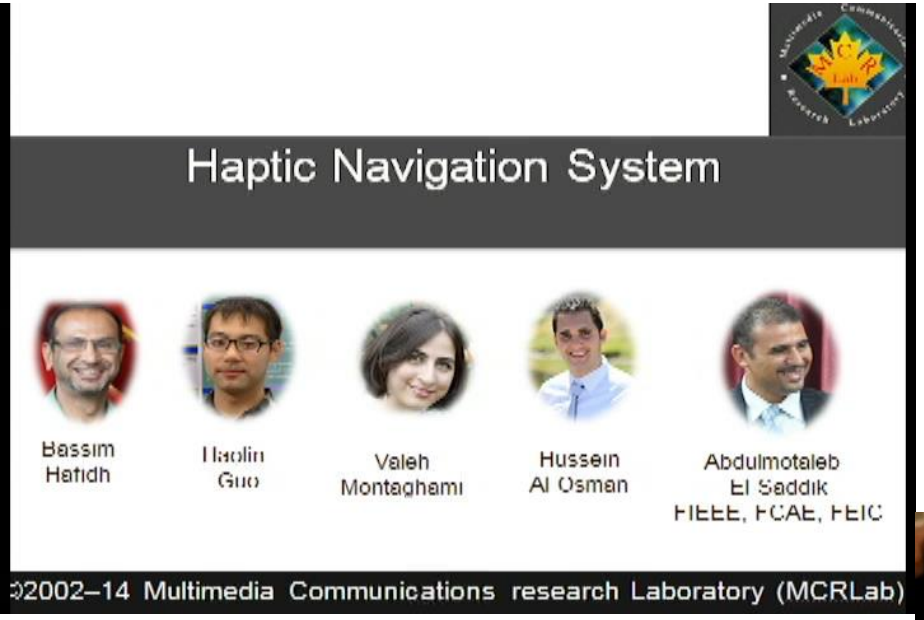


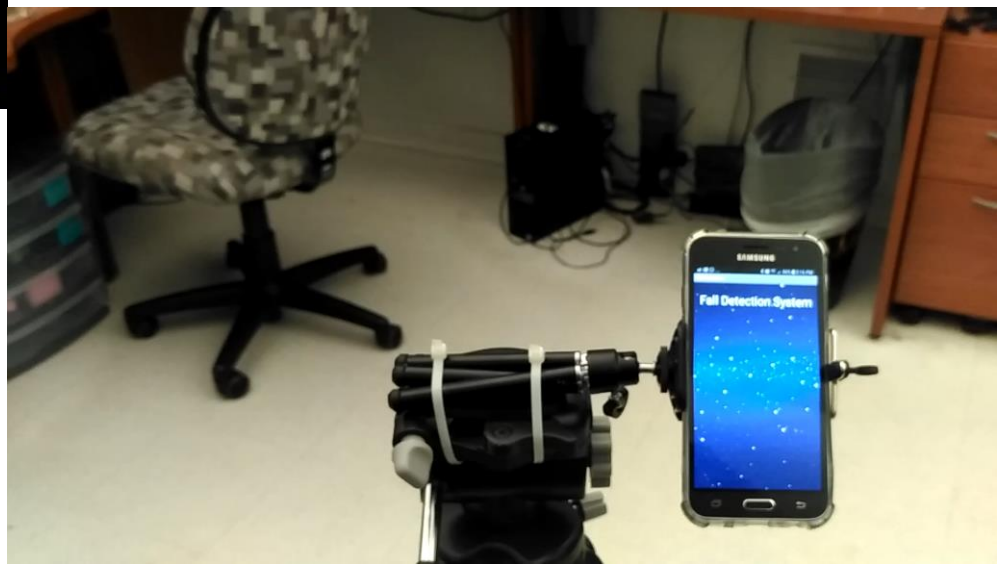
Stimuli: Argentina scored the first goal



Amani Albraikan, Diana Patricia Tobón Vallejo, and Abdulmotaleb El Saddik, “Toward User-Independent Emotion Recognition using Physiological Signals”, IEEE Sensors (accepted)

Health and Well-being





Smart gloves for diabetics

ALS – Eye Gaze, Sensors

A Novel Eye-Gaze-Controlled Wheelchair System for Navigating Unknown Environments: Case Study With a Person With ALS. M. Eid, N Giakoumidis, A El-Saddik, IEEE Access 4, 558-573

Applications

- Digital Data Ownership & Security:
  - my digital twin knows about me and he is acting. By saying this we can tackle also privacy as the information is stored within digital and not at home in the mind of common person
- Immortality:
  - You become immortal as your digital twin through its AI evolution can decide what info to give to whom. It can also decide when to delete itself and hence delete the complete e-legacy of the real twin
- Dating:
  - With digital twins, people will automatically receive information regarding their date. Digital twins can also simulate real-life situations giving the real twins insights to determine whether they are a perfect match

Applications (2/2)

- Health:
  - In terms of health, a digital twin can show what is happening inside their real twin's body. Thus it can predict the occurrence of an illness by analyzing the symptoms . The digital twin has all the necessary elements for the prediction: the personal history, health related and non-health related; and the current context such as location, time and activities.
- Well-being:
  - Digital twins can play an important role in well-being. In terms of stress relief, the digital twin can detect stress level using sensory technology and can determine the causes for stress.

Final Thoughts

- Digital twin will fit in very well the AI strategy which every country has.
- Digital twin is democracy of data in its truest sense.
  - It's going to shake the norms and laws of privacy and we will as a society have to revisit what value do we perceive.
- We need to balance convenience versus privacy
  - technology ethics will be the newest branch of ethics that's going to be out there
- Is it ethical to smart surveillance people and know their emotions or heart rates






Thank you for your attention!

شكراً