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أ . د . عبد المطلب الصديق

Digital Twin: the Convergence of Multimedia Technologies

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WELCOME
שלום
VÄLKOMMEN
BIENVENUE
Ki Ora
DOBRO DOŠLI
BIENVENIDA
BIENVENIDOS
ÜDVÖZÖLJÜK
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HOTTAKELSE
TERE TULEMAST
BEM-VINDO
नमस्ते
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SVEIKS
CHÀO MỪNG
Ni sa bula vinaka!
Grüezi
VELKOM
SAWU BONA!
Waytk
Moin Moin
VILLKOMMEN
HI Y'ALL
어서 오십시오
いらっしゃいませ
ПРИВЕТСТВУЕМ ВАС
مرحبا
VÍTÁME VÁS!
ברוכים הבאים
CROESO
ONGI ETORRI
Wolkom
"Kia ORA"
BITAEMO
SELAMAT DATANG
BENVINGUTS
COMPANYS!
歡迎
Wolkom
欢迎
CEAD MILE FAILTE
ようこそ
Bon Dia
GRIASZ EICH!
VITEJTE
M'inuw'ilvm Si'em
SERVUS
Tansi
VELKOMMEN
ДОБРО ДОЈДОВТЕ
DZIEN DOBRY
HITAMY
BENVENUTI
SVEIKI ATVYKĘ!!!
GiliKasla
Hoşgeldiniz
ยินดีต้อนรับ
めんそうれ

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.

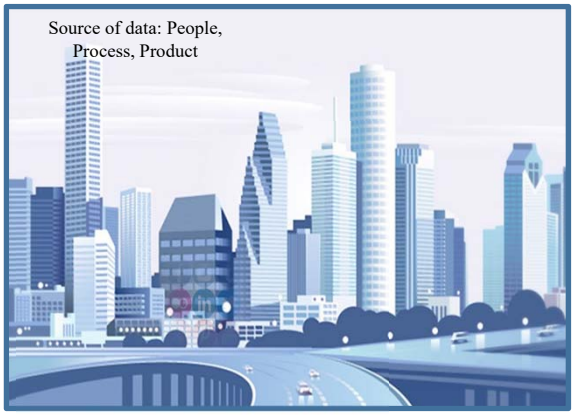
[1] El Saddik, A. (2018). Digital Twins: The Convergence of Multimedia Technologies. *IEEE MultiMedia*, *25*(2), 87-92.

Why is digital twin important

- According to Gartner,
  - 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
- Smart Cities becoming the new political mandate

Facts

Things and Being are interconnected



BigMM & AI

Multimodal Interactions

Cybersecurity & Biometrics

Massive throughput

Massive low latency

Massive sensing

Massive heterogeneity

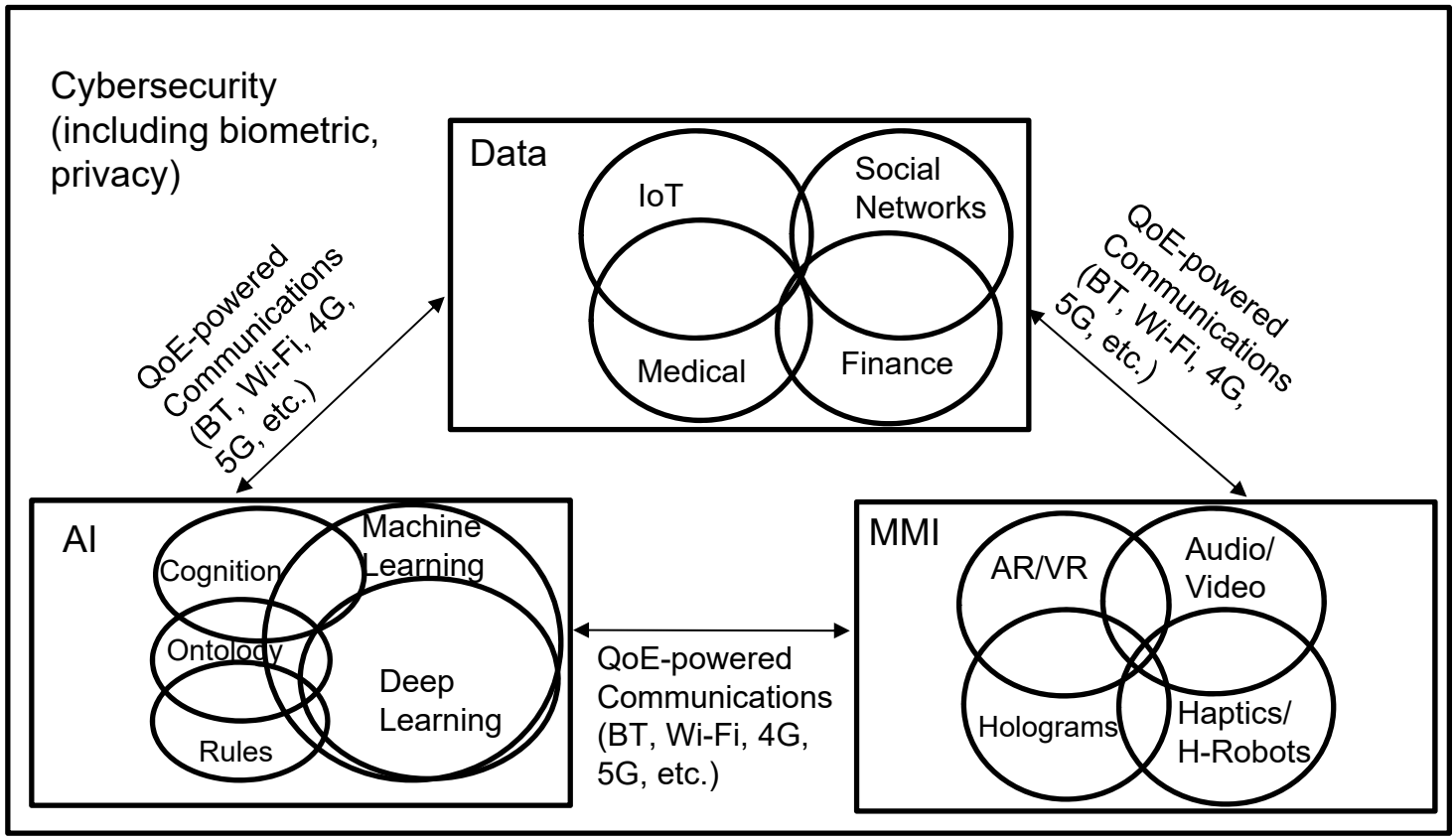
Fast feedback

Massive privacy

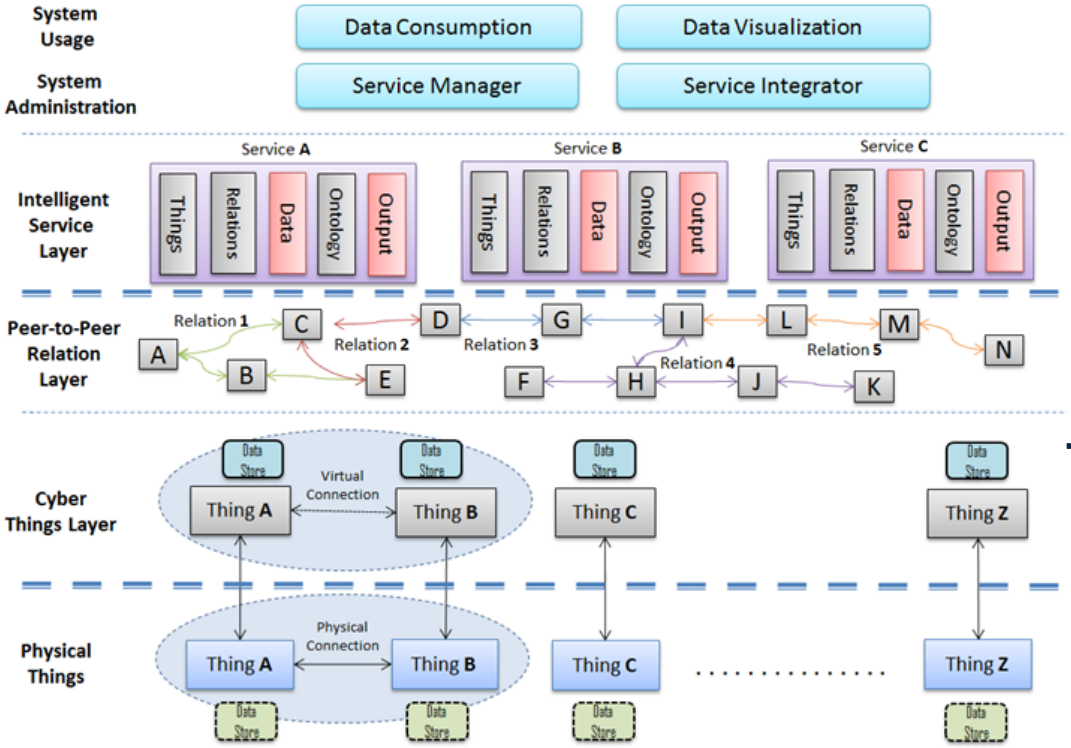
Security/Trust

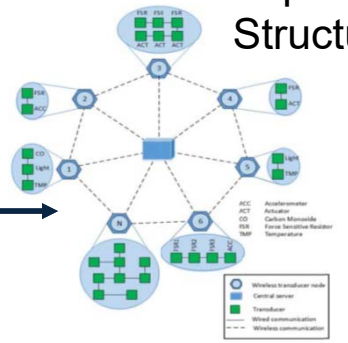
5G & Tactile Internet

Convergence of MM Tech



Digital Twin





Topological Structure

Plug & Play Transducer

ID	Transducer	Circuit	Remarks
	Wireless Node's Core (Mainboard)		Data collection, processing and communication
1-20	Pressure Sensor		I²C IDs 1-20 are reserved for pressure sensors (FSRs)
21-40	Vibrotactile Actuator		I²C IDs 21-40 are reserved for actuators
72-75	Temperature Sensor		I²C IDs 72-75 are reserved for Temperature Sensors (TMP102)
83-84	Accelerometer		I²C IDs 83-84 are reserved for accelerometer (ADXL345)
41,57	Light Sensor		I²C IDs 41, 57 are reserved for Light sensors (TSL2561)
76-78	CO Gas Sensor		I²C IDs 76-78 are reserved for Ambient Light sensors (TEMT6000)
85-90	Flex Sensor		I²C IDs 85-90 are reserved for flex sensors 4.5"
	Extension		

Kazi Masudul Alam and Abdulmotaleb El Saddik, "C2PS: A Digital Twin Architecture Reference Model for the Cloud-Based Cyber-Physical Systems", IEEE Access, vol. 5, pp. 2050–2062, 2017

Our journey with Digital Twins

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Canada's university

Intelligent 3D Avatar with Contactless Haptic Feedback


Lin Yang


Faisal Arafsha


Longyu Zhang


Basim Hafidh

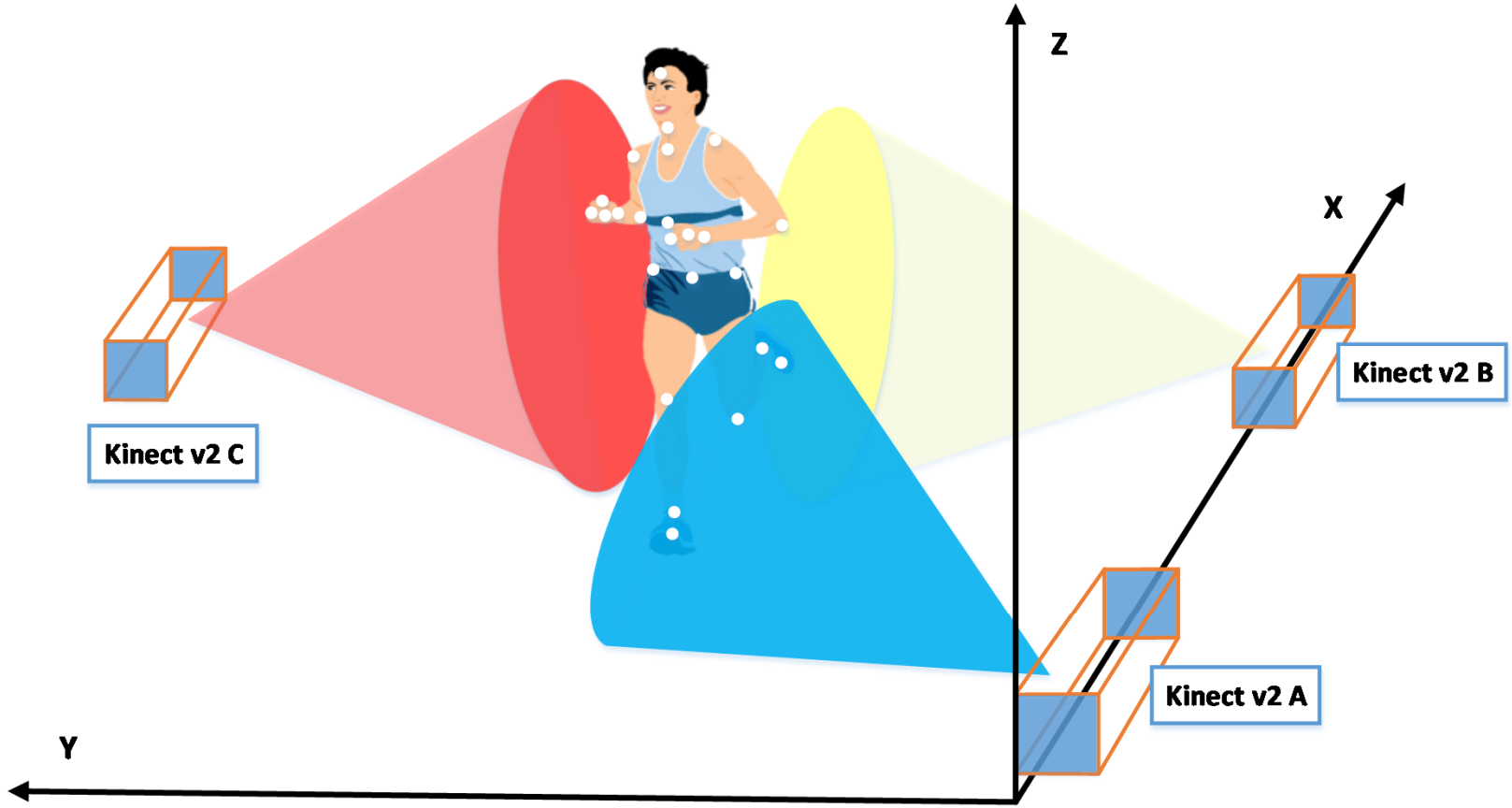

Amani Albraikan


Haiwei Dong


Abdulmotaleb El Saddik FIEEE, FCAE, FEIC

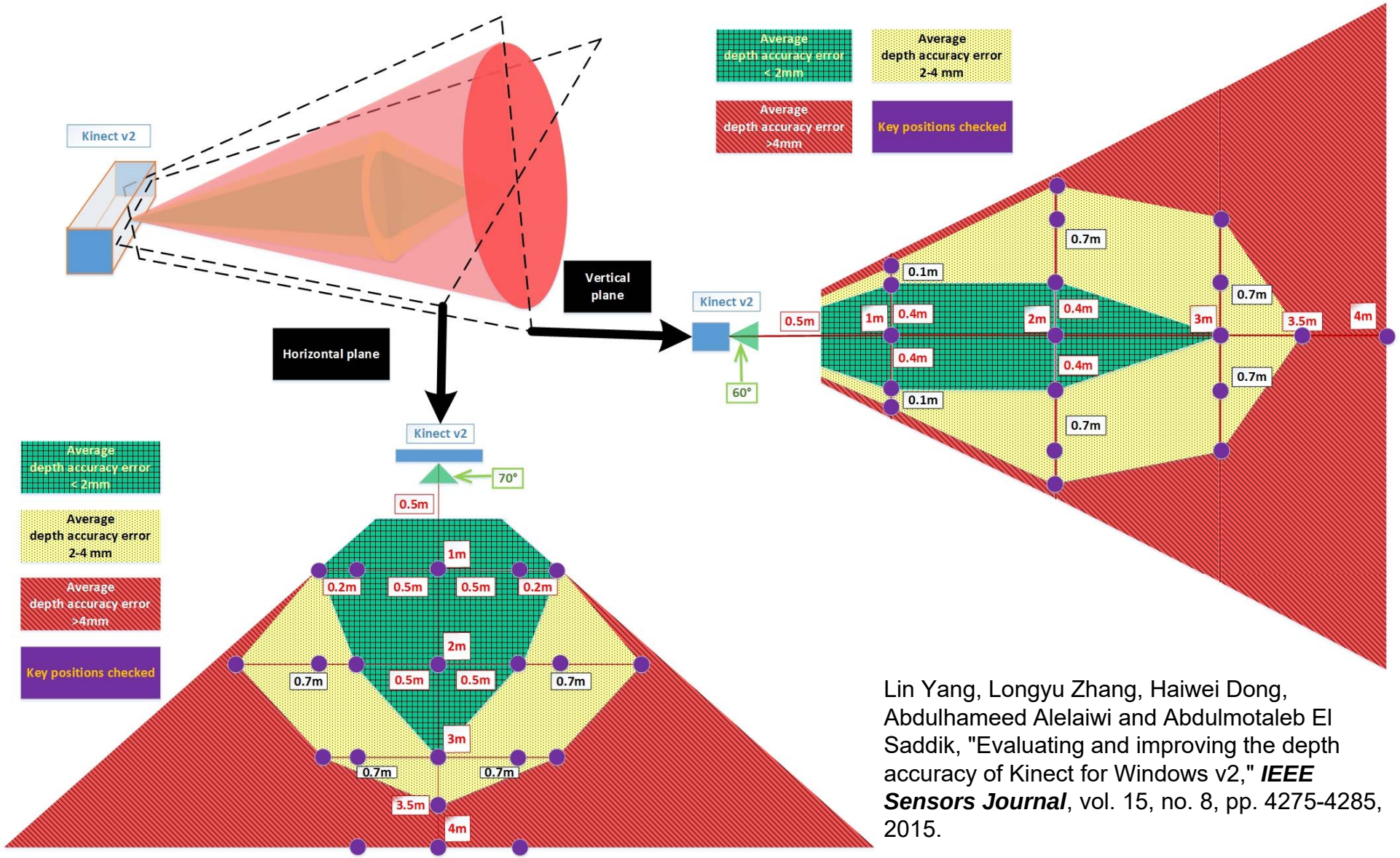
3D Motion Capture

By placing multiple 3D sensors around the measurement area and tracking simultaneously, we can obtain a more accurate result by applying trilateration method.



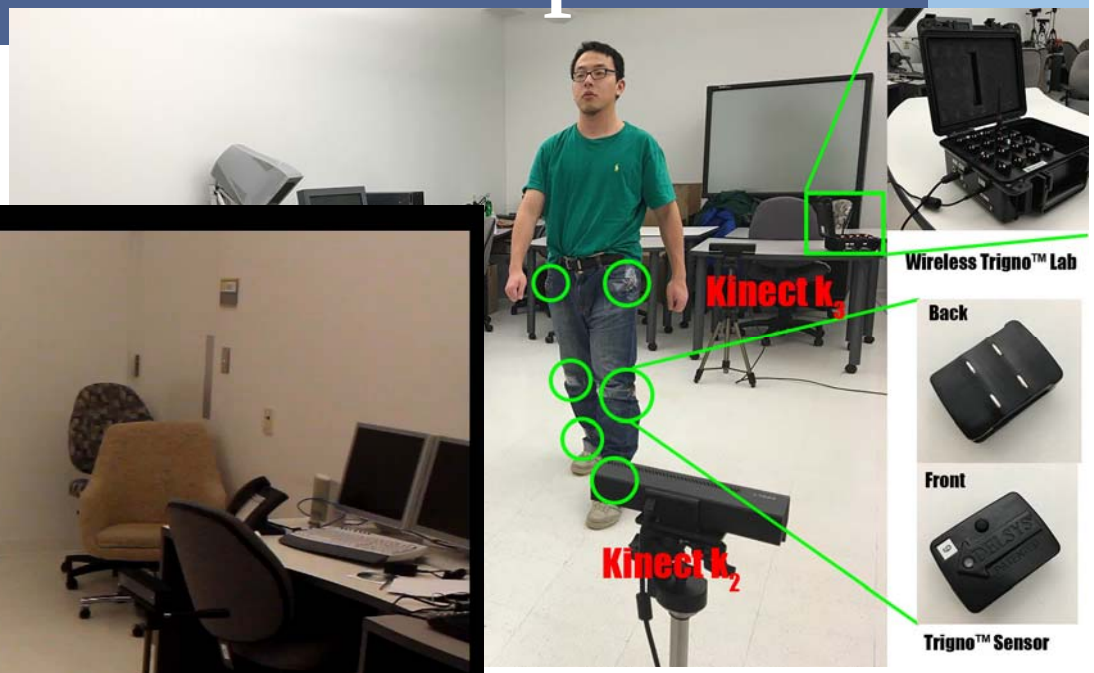
Depth image accuracy evaluation

Accuracy Distribution – Result : elliptical cone



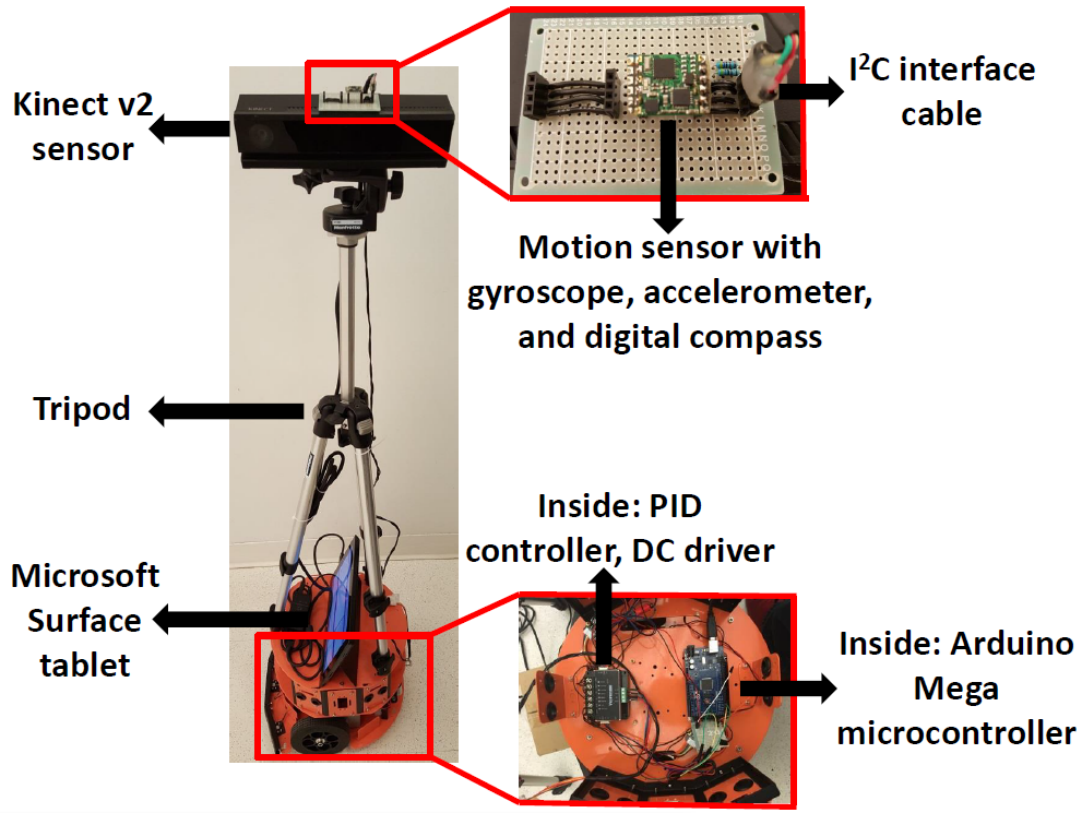
Lin Yang, Longyu Zhang, Haiwei Dong, Abdulhameed Alelaiwi and Abdulmotaleb El Saddik, "Evaluating and improving the depth accuracy of Kinect for Windows v2," ***IEEE Sensors Journal***, vol. 15, no. 8, pp. 4275-4285, 2015.

Self calibrating Motion Capture



Bowen Yang, Haiwei Dong, and **Abdulmotaleb El Saddik**, "Development of a Self-Calibrated Motion Capture System based on Nonlinear Trilateration of Multiple Kinect v2", IEEE Sensors Journal , pp: 2481 – 2491, Vol. 17(8), 2017

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

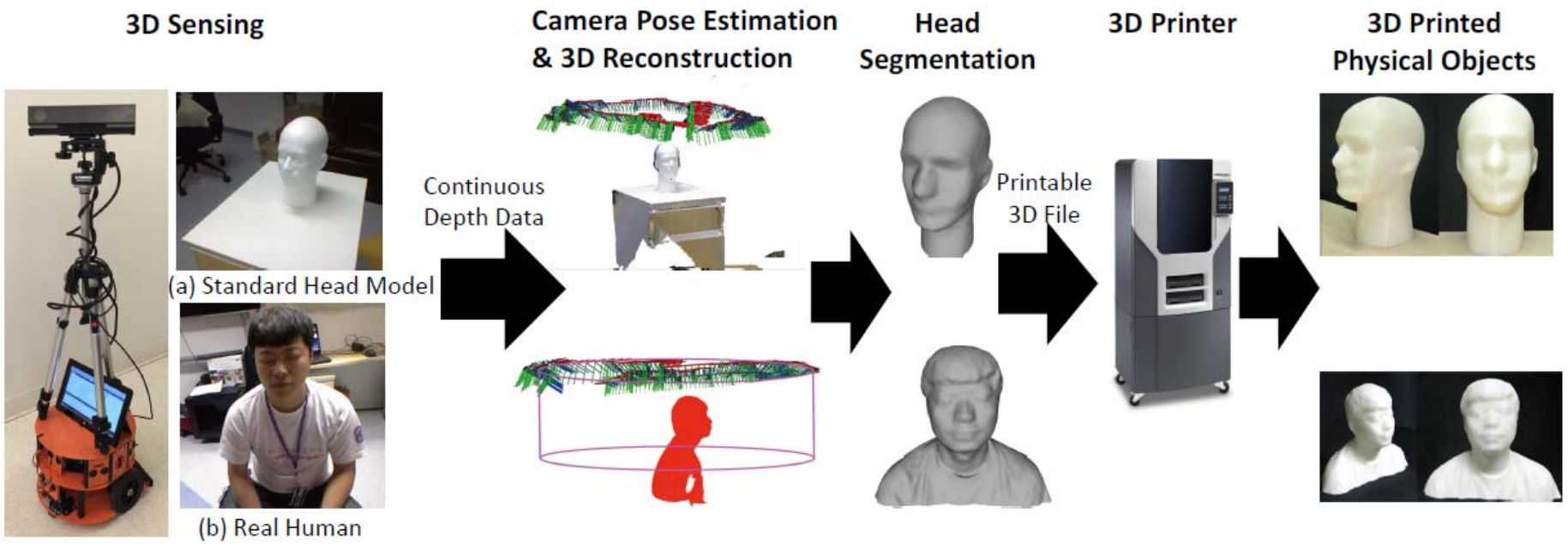


Proposed sensing device carried with a robot

Our sensing device is a consumer-grade composite sensor, including Kinect v2 sensor, gyroscope, digital compass, and accelerometer. The Kinect v2 sensor is used to capture depth data, while other sensors are mainly used to reduce accumulative errors of our system.

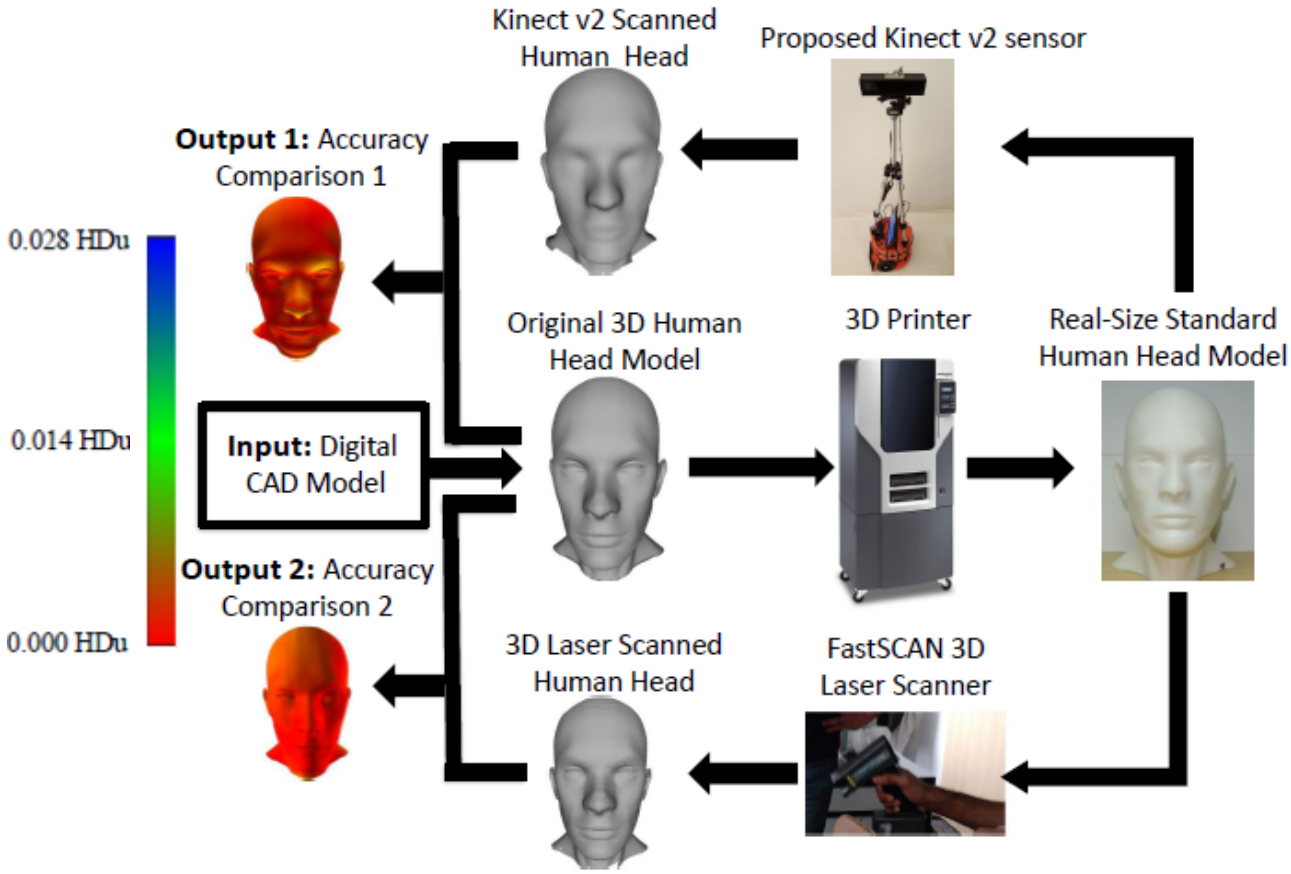
The composite sensor is fixed on a tripod, and mounted on a robot , which automatically rotates around the human subject with approximate 1-meter radius, to capture the full-view information.

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



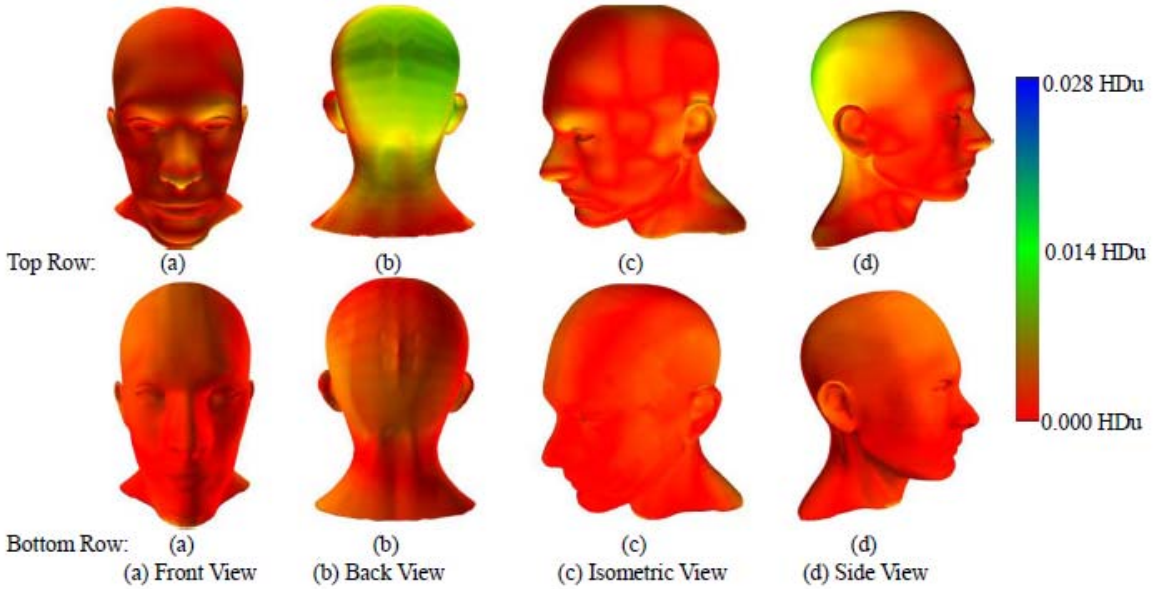
To validate the capabilities of our proposed scanning system, a visualized 3D CAD model of a standard human head model is prototyped, 3D printed and scanned separately by our proposed scanning system and by a commercial handheld 3D laser scanner FastSCAN. Furthermore, we computed the geometric differences (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

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

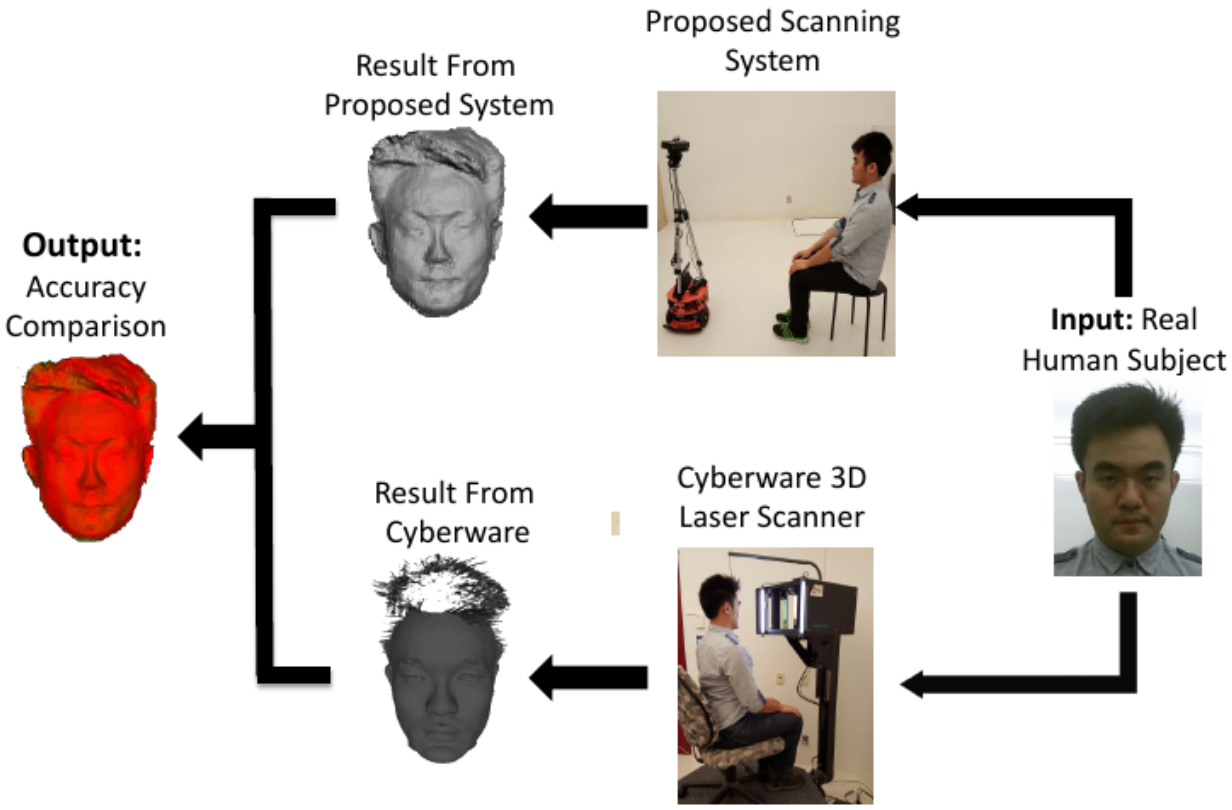
Hausdorff distance is the maximum value from Model_1 → Model_2 and Model_2 → Model_1 in the Euclidean space:

$$d_H(M_1, M_2) = \max\left\{ \sup_{m_1 \in M_1} \left(\inf_{m_2 \in M_2} d(m_1, m_2) \right), \sup_{m_2 \in M_2} \left(\inf_{m_1 \in M_1} d(m_1, m_2) \right) \right\}$$



Visualization of Hausdorff distance between scanned models and the ground-truth model separately. Top Row: Proposed system result. Bottom Row: FastSCAN scanner result.

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

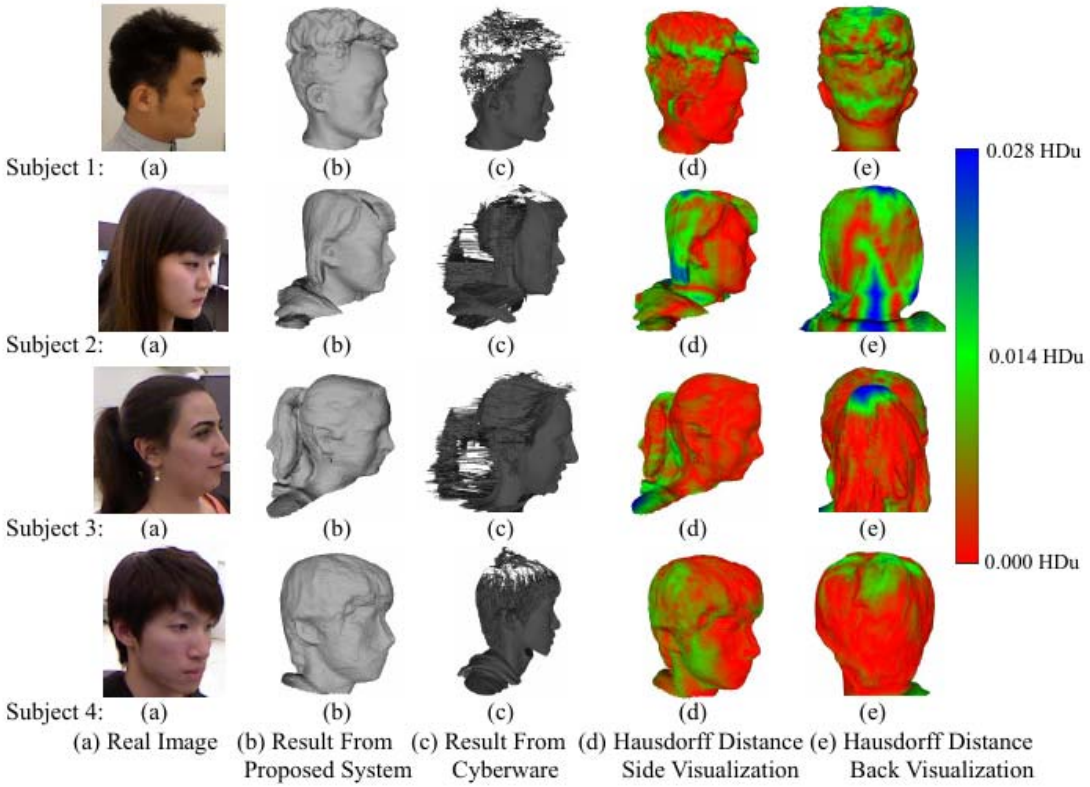


Experimental setup for the evaluation of real human scanning

To further validate our experimental results, we compared scanned real human models from our proposed system with the ones from commercial Cyberware laser scanning system on real-human subjects.

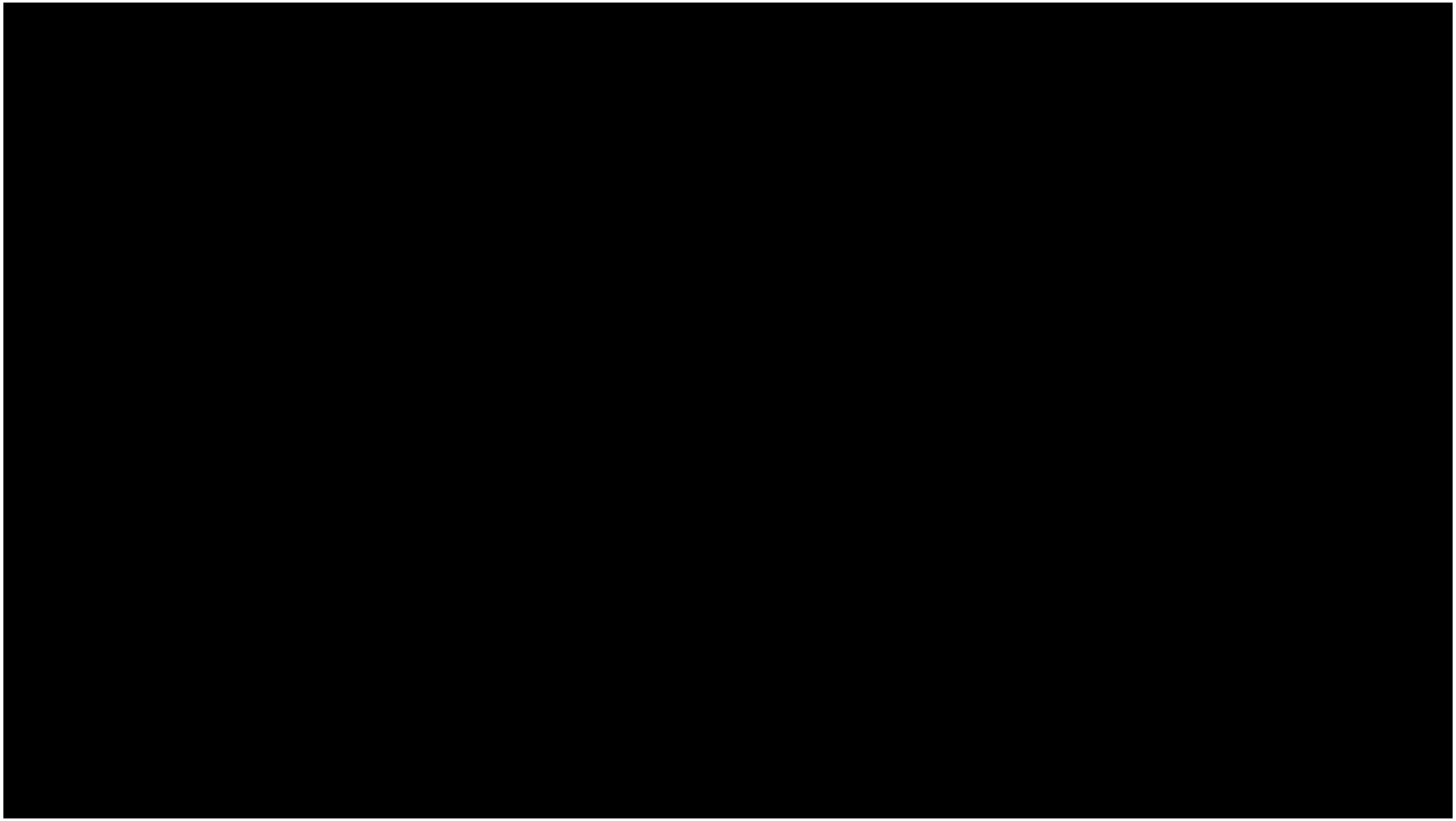
Development of an Automatic 3D Human Head Scanning-Printing System

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



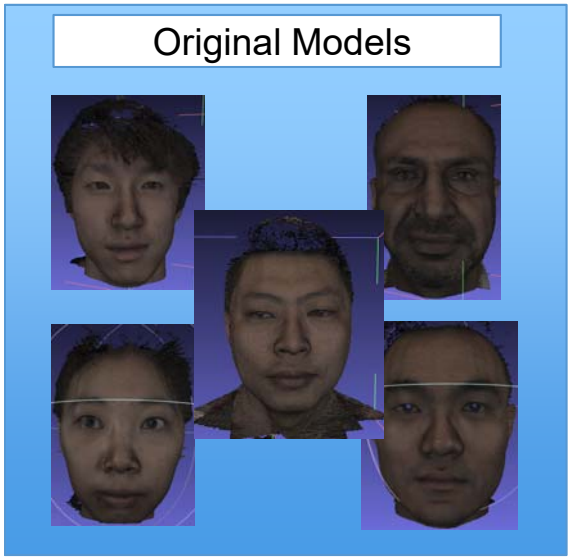
Experimental results of real human scanning

1 min scanner

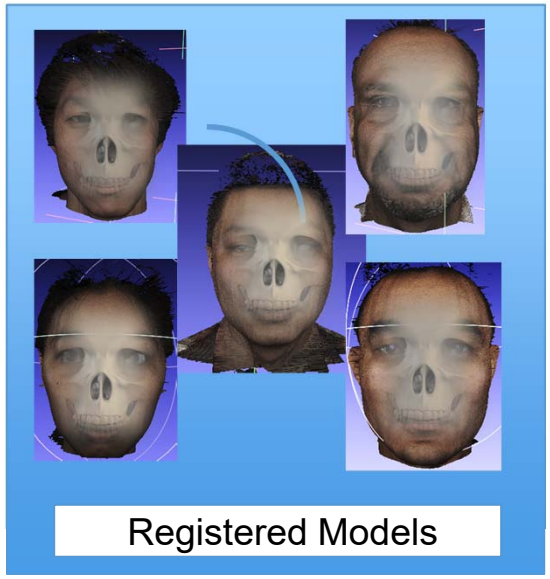


Longyu Zhang, Bote Han, Haiwei Dong and **Abdulmotaleb El Saddik**, “Development of an Automatic 3D Human Head Scanning-Printing System”, Springer Multimedia Tools and Applications (2016). doi:10.1007/s11042-016-3949-2

2) Head Stiffness Rendering



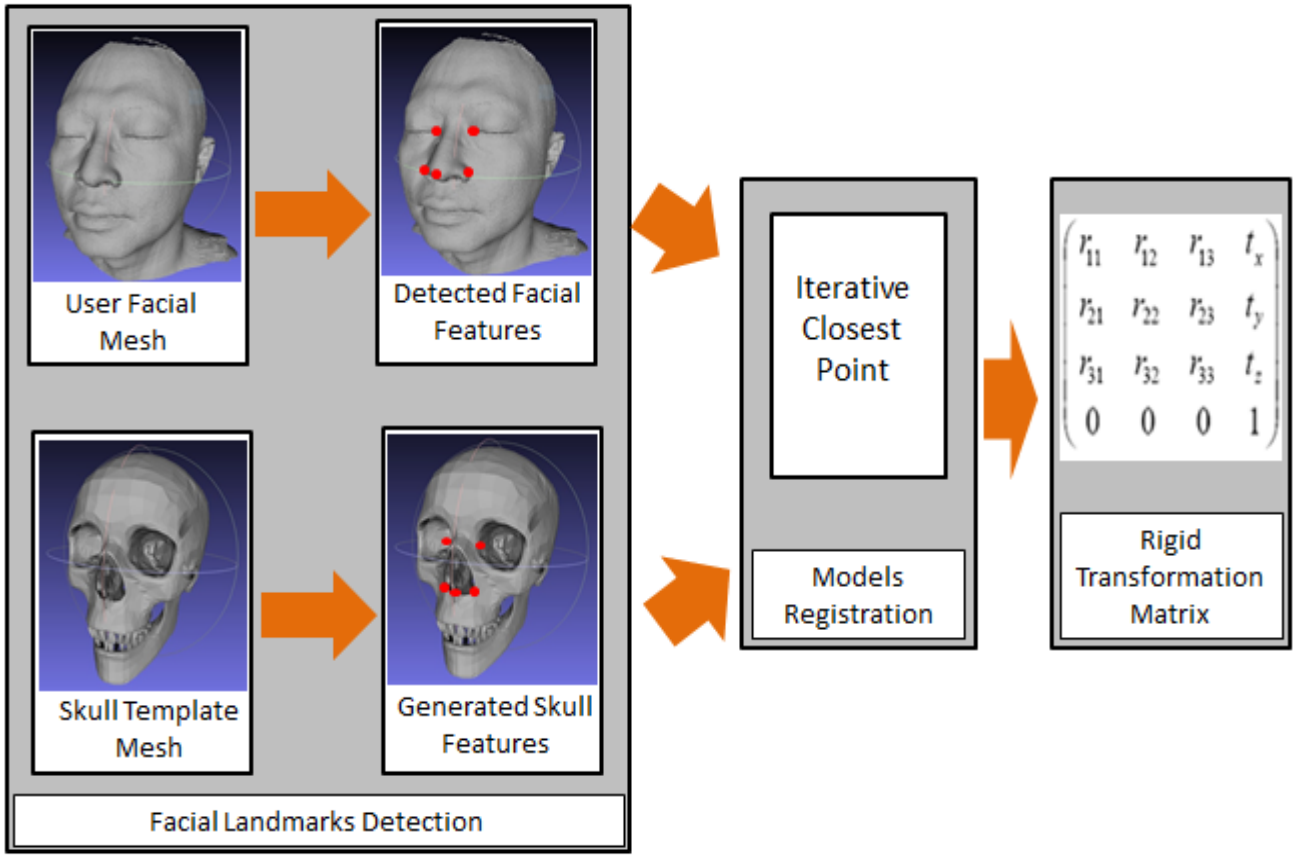
Semantic Alignment



Stiffness Rendering

2) Head Stiffness Rendering

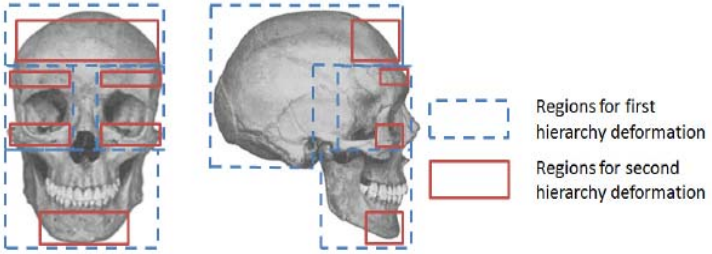
1. The head mesh and skull meshes are registered through ICP procedure by minimizing the correspondences between the facial features detected from both meshes.
   Features on skull mesh are generated with aesthetic proportions.



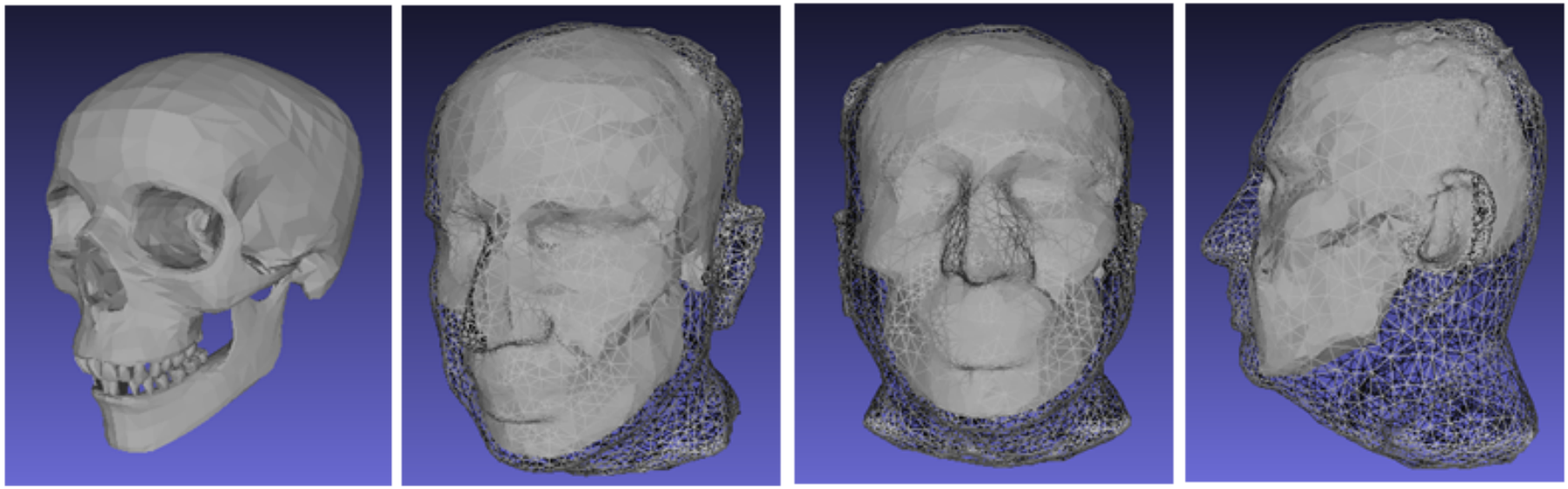
2) Head Stiffness Rendering

Fully processed approximation results

2. Hierarchical Region of Interest Process



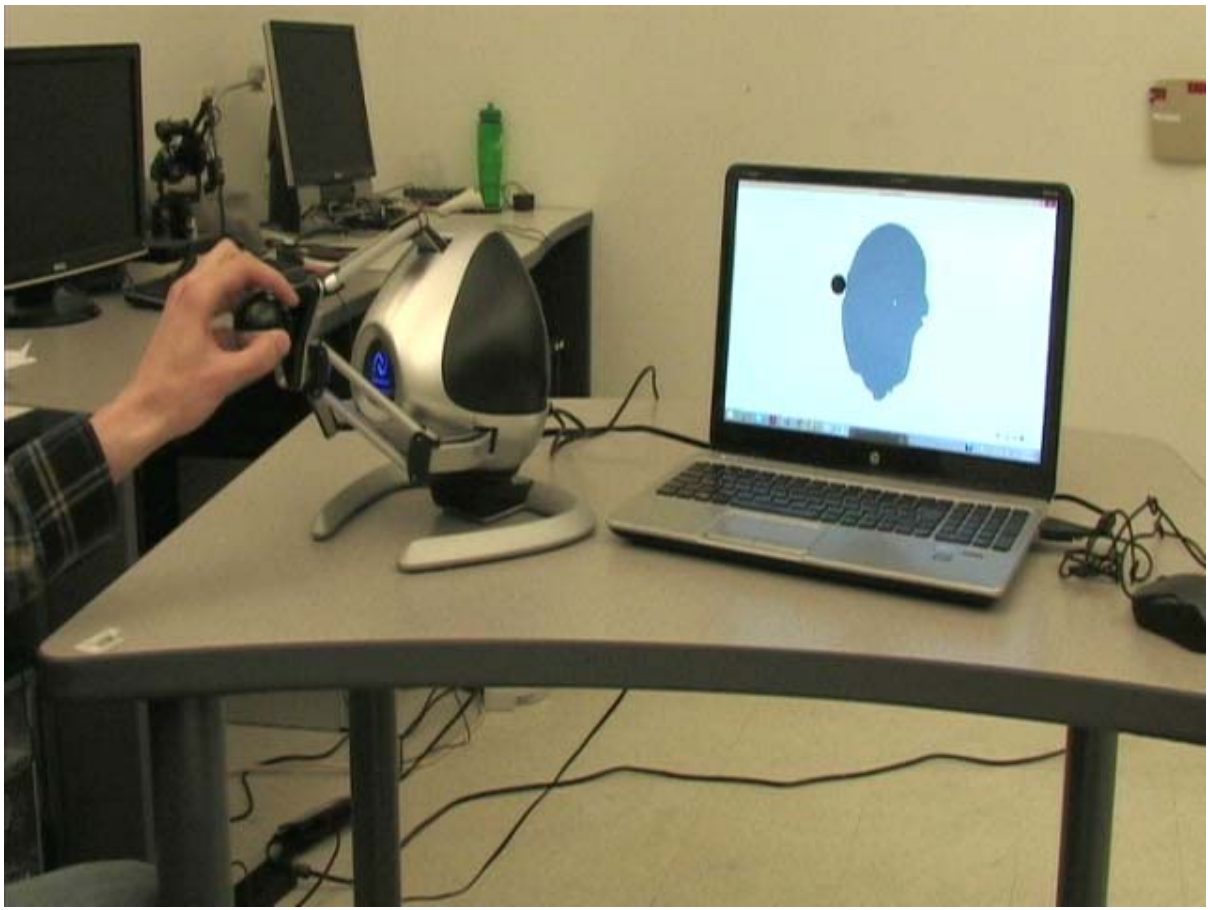
Deformed skull mesh of a male subject's head mesh:



a) b) c) d)

a) is the original skull template mesh and b), c) and d) are the fully deformed skull mesh of isometric, frontal and profiles view respectively.

2) Head Stiffness Rendering

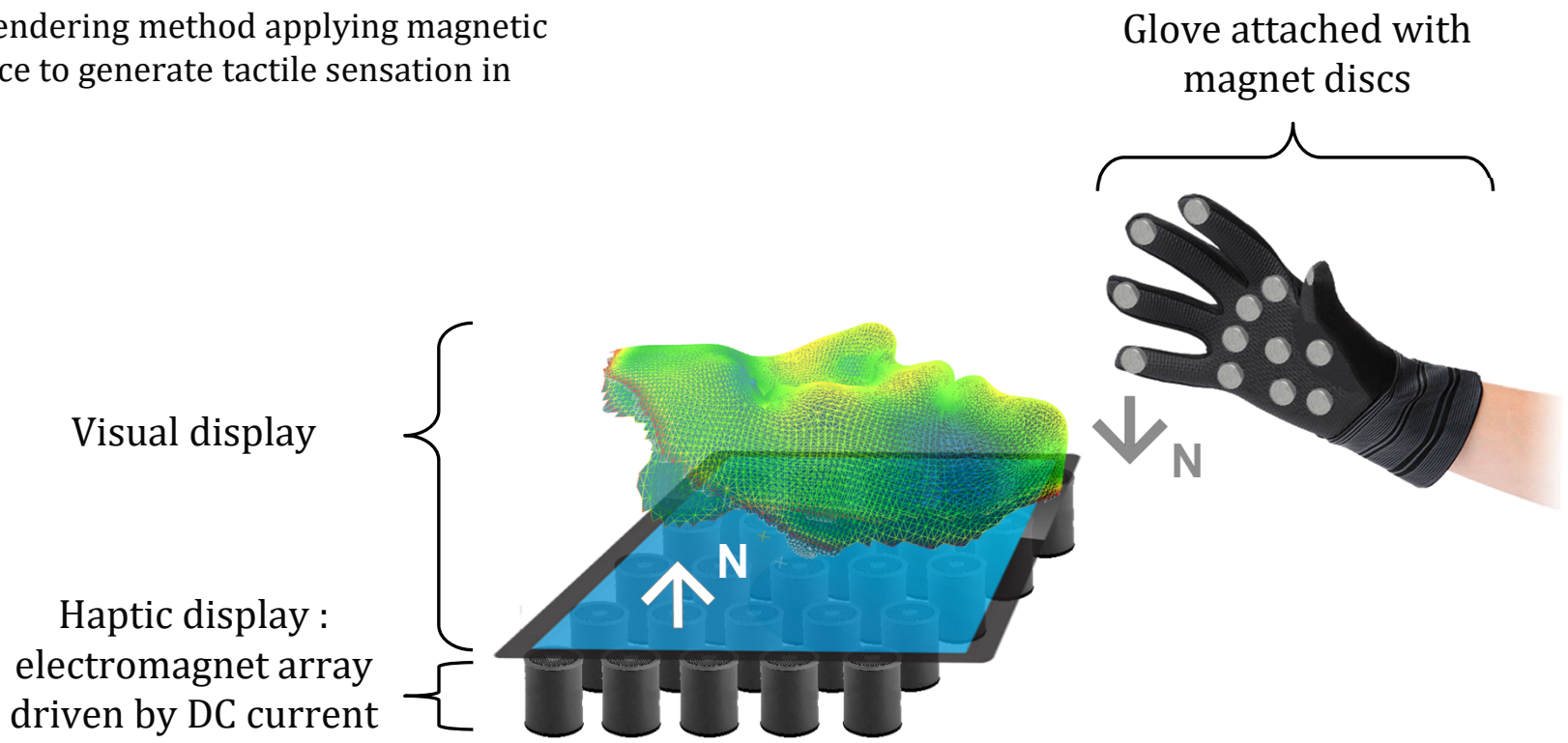


Minggao Wei, Yang Liu, Haiwei Dong, and **Abdulmotaleb El Saddik** "Human Head Stiffness Rendering", IEEE Transactions on Instrumentation & Measurement, Vol 66(8), pp: 2083-2096, DOI: : 10.1109/TIM.2017.2676258

3) Magnetic Rendering

Introducing a new way of haptic volumetric shape rendering

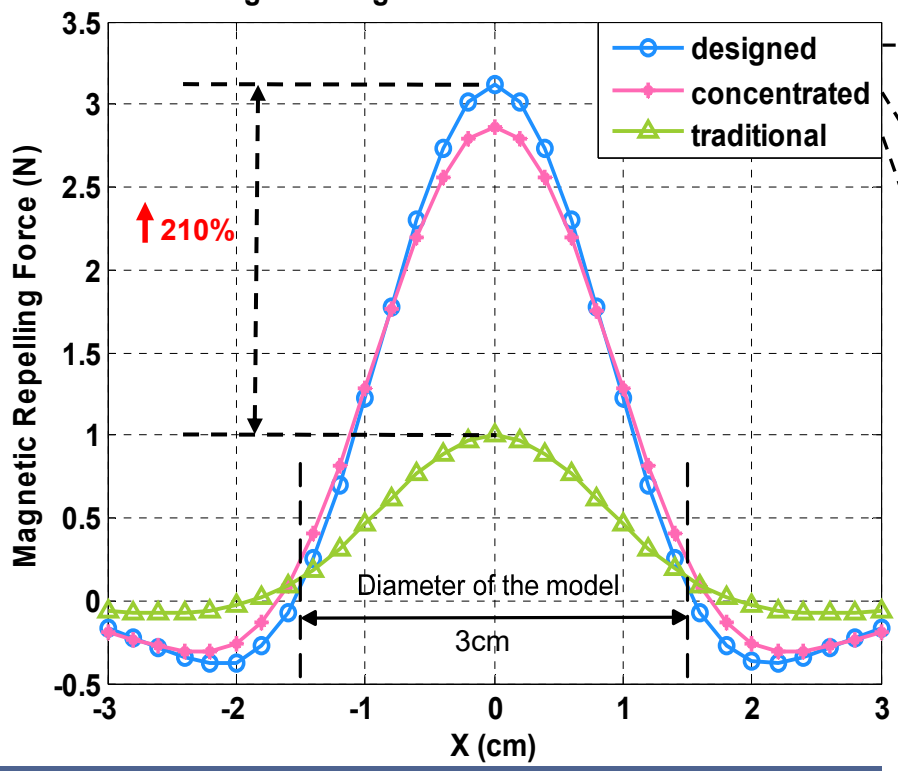
As a haptic rendering method applying magnetic repulsive force to generate tactile sensation in mid-air

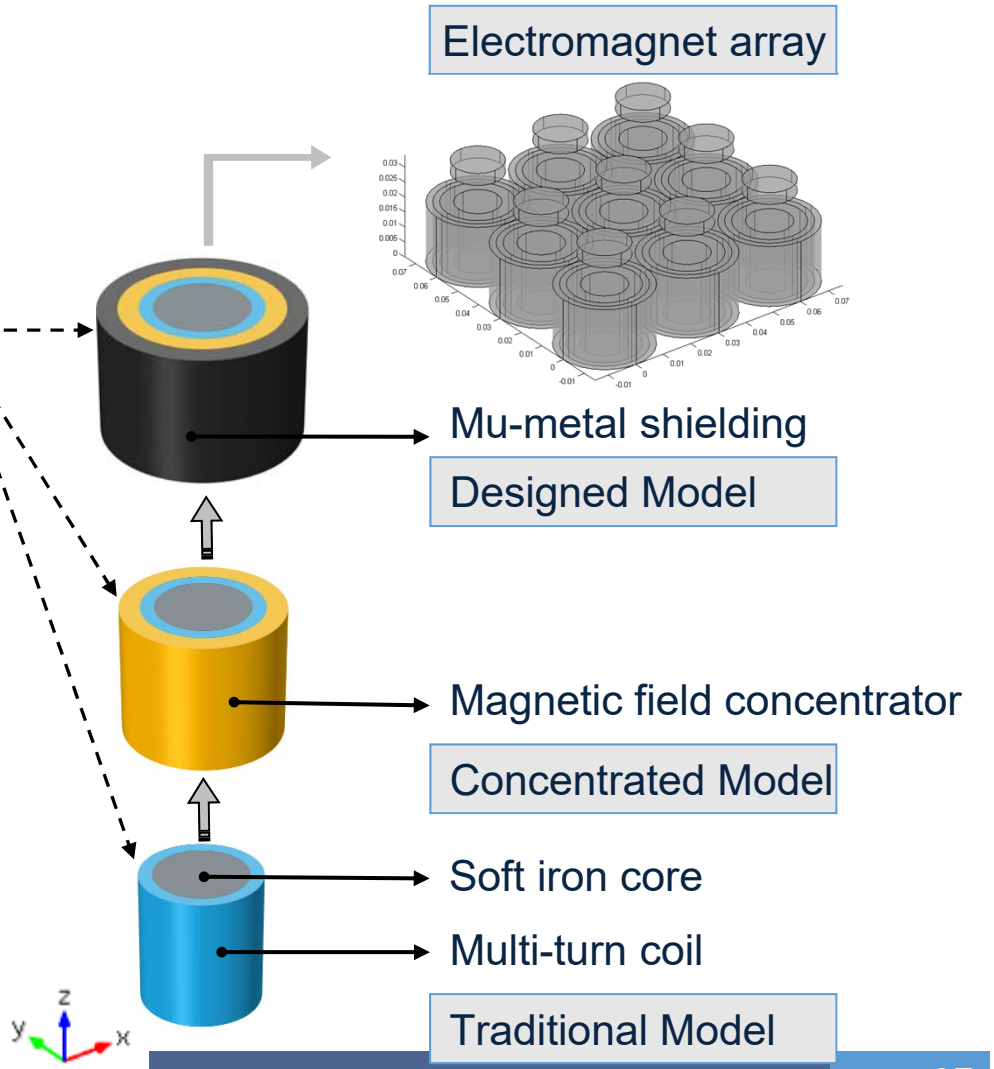


3) Magnetic Rendering

Design of a powerful electromagnet model

Magnetic Field Concentrate Electromagnet





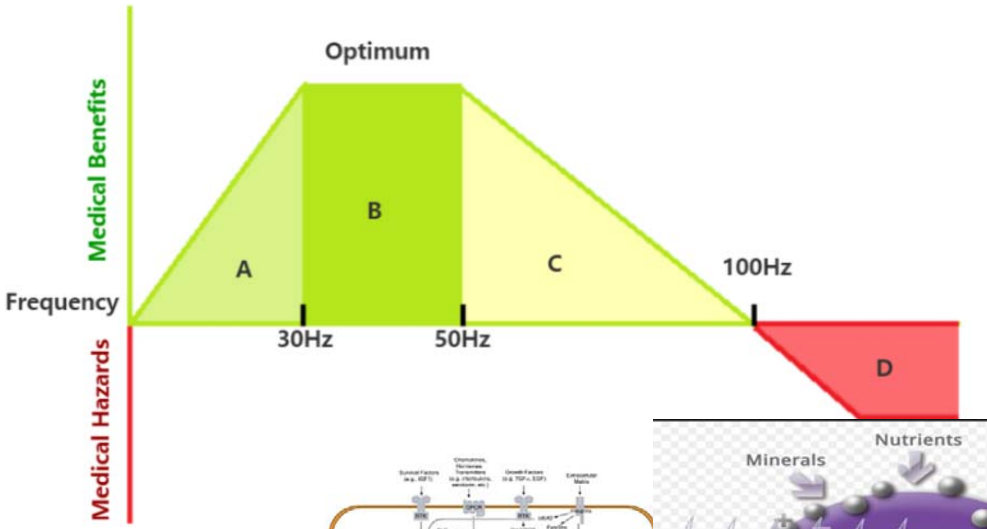
3) Magnetic Rendering

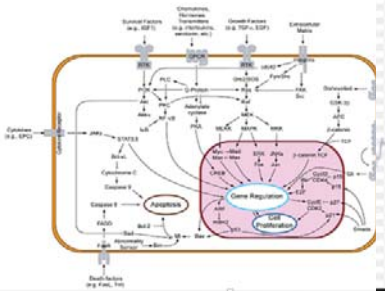
Qi Zhang, Haiwei Dong, and **Abdulmotaleb El Saddik**, “Magnetic Field Control for Haptic Display: System Design and Simulation” IEEE Access , Vol 4, 2016, pp 299-311, DOI: 10.1109/ACCESS.2016.2514978

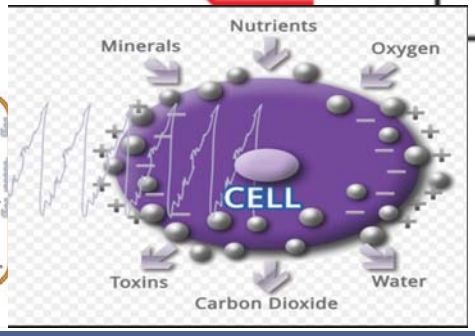
Design Requirements

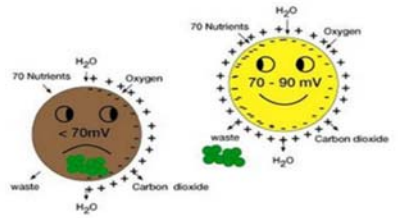
Define the desired waveform

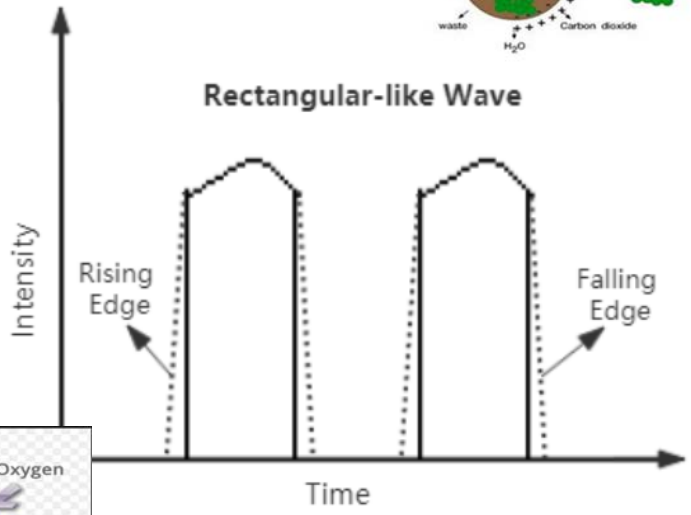
- Frequency of the UPEMF wave (30Hz)
- Shape of the UPEMF wave (Rectangular)
- Intensity of the UPEMF wave (0.12T)





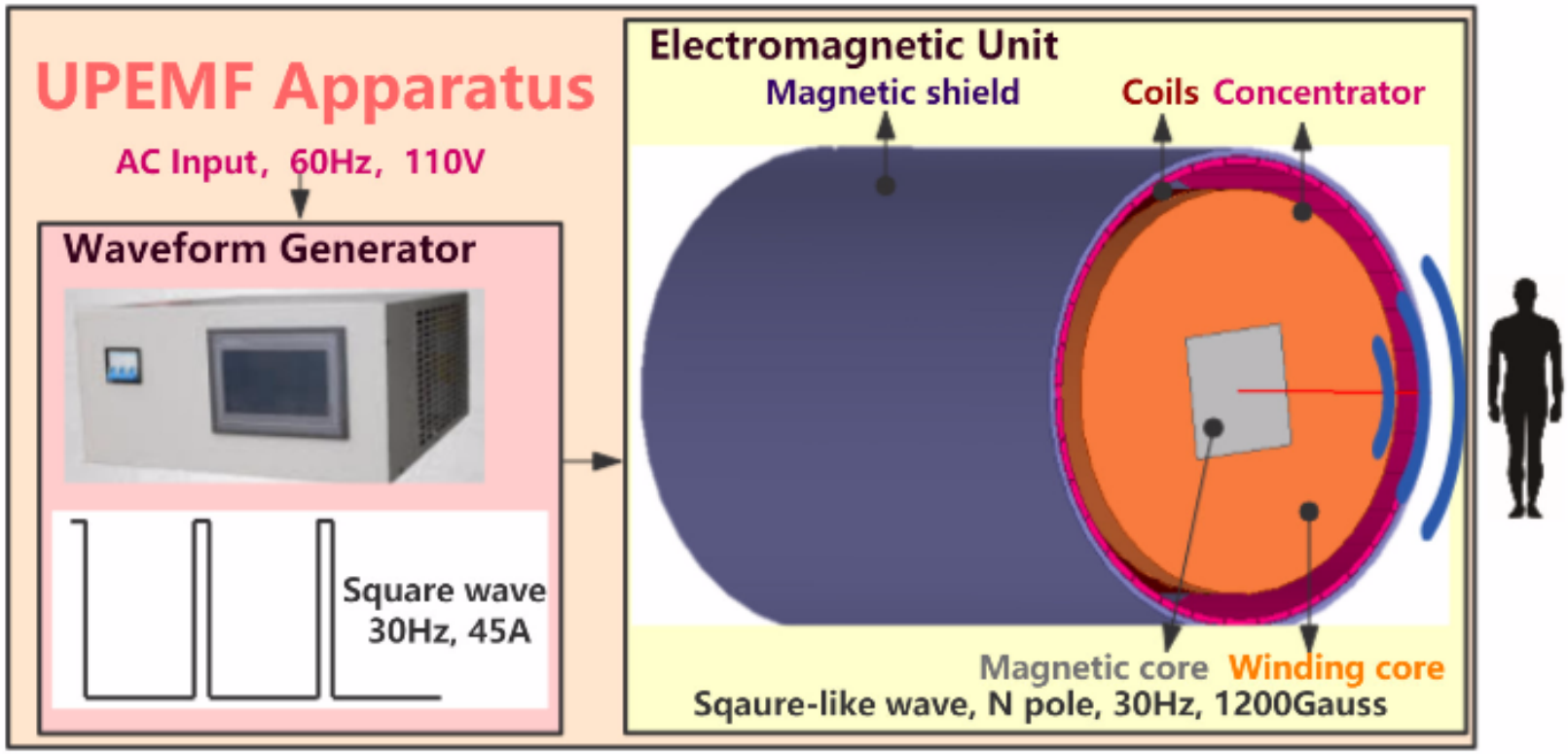




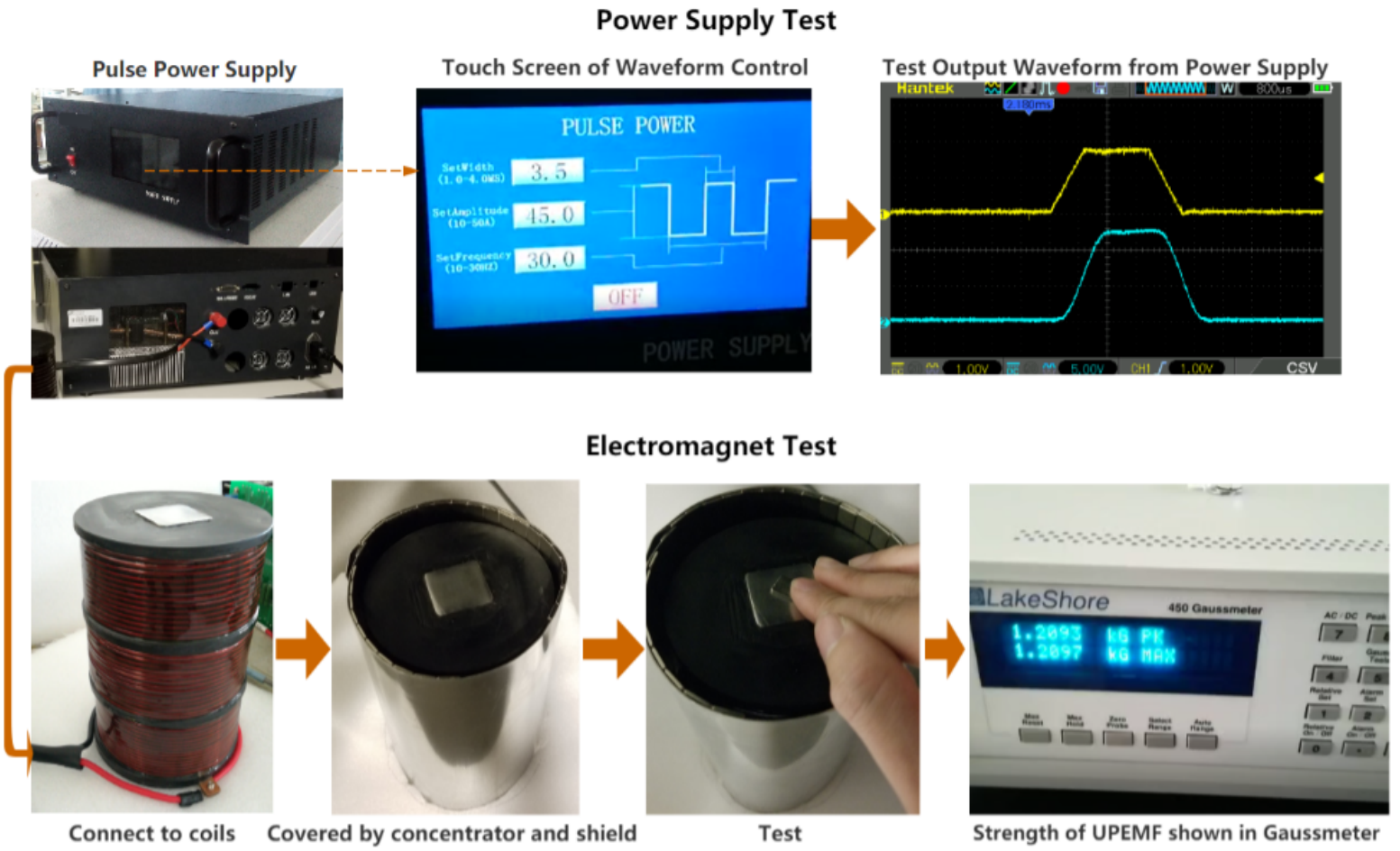


System Design

- Proposed UPEMF system



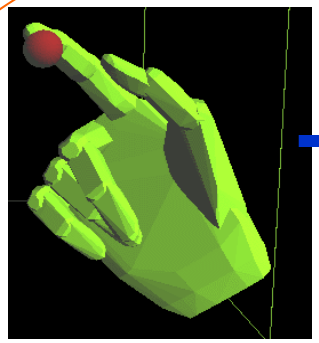
Test

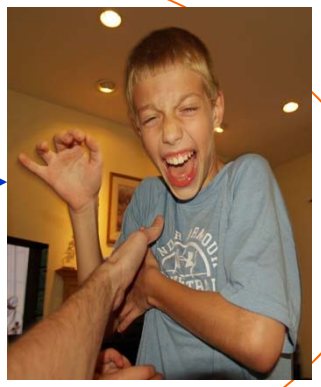


Yuxiang Jiang, Haiwei Dong, Abdulmotaleb El Saddik, “A Unipolar Pulse Electromagnetic Field Apparatus for Magnetic Therapy” IEEE Instrumentation & Measurement Magazine (to appear)

Why Haptics – Biometrics?

Haptic Systems



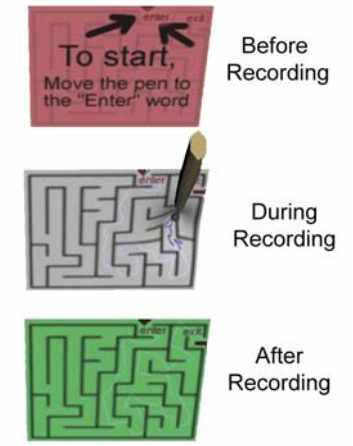


The problem with Biometrics without Haptics (movie)

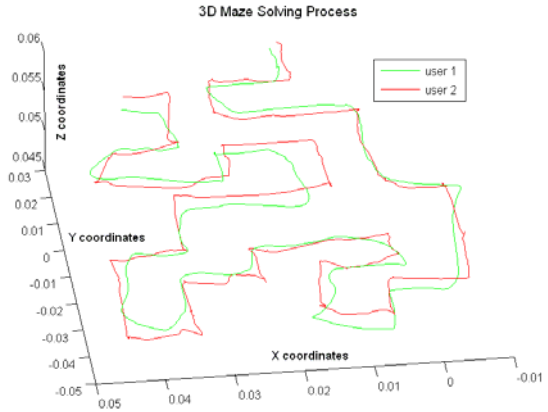
Biometrics Systems

Case Study: Identifying Human

The Experiment



Graphic Representation



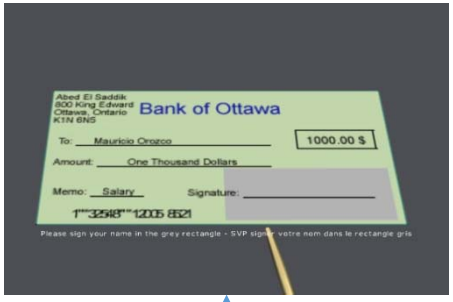
$$MS = \sum_{c=1}^{3} \sum_{i=1}^{N} \left(d_{c,i}^{1} - I_{c,i}^{2}\left(t^{p}\right) \right)^{2}$$

Methodology

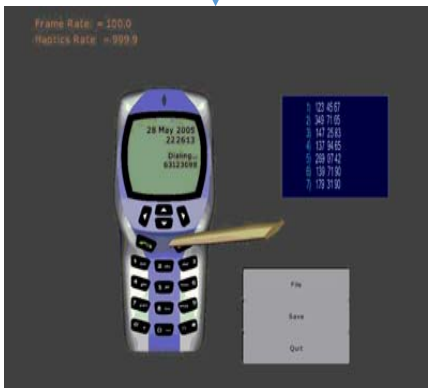
- **Dynamic Time Warping :**
  - **+ Nelder-Mead non-linear minimization**
- **Spectral analysis: Fast Fourier Transform**
- **Unsupervised Method: K-Means**

Verifying such feasibility

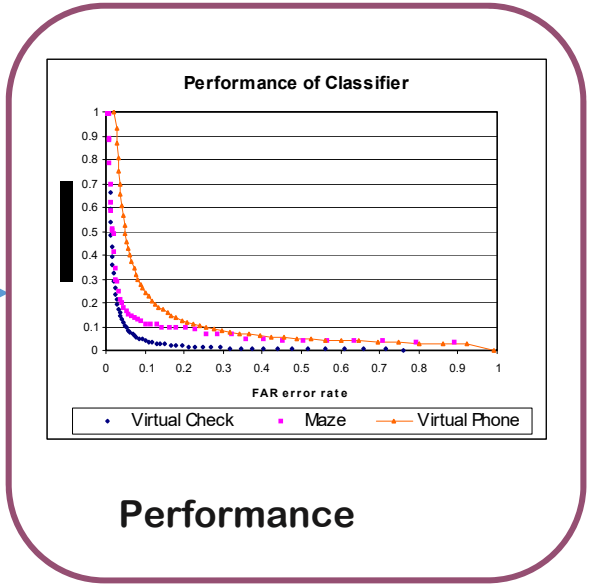
Virtual Check



Ambient Intelligent Engine



Virtual Mobile Phone



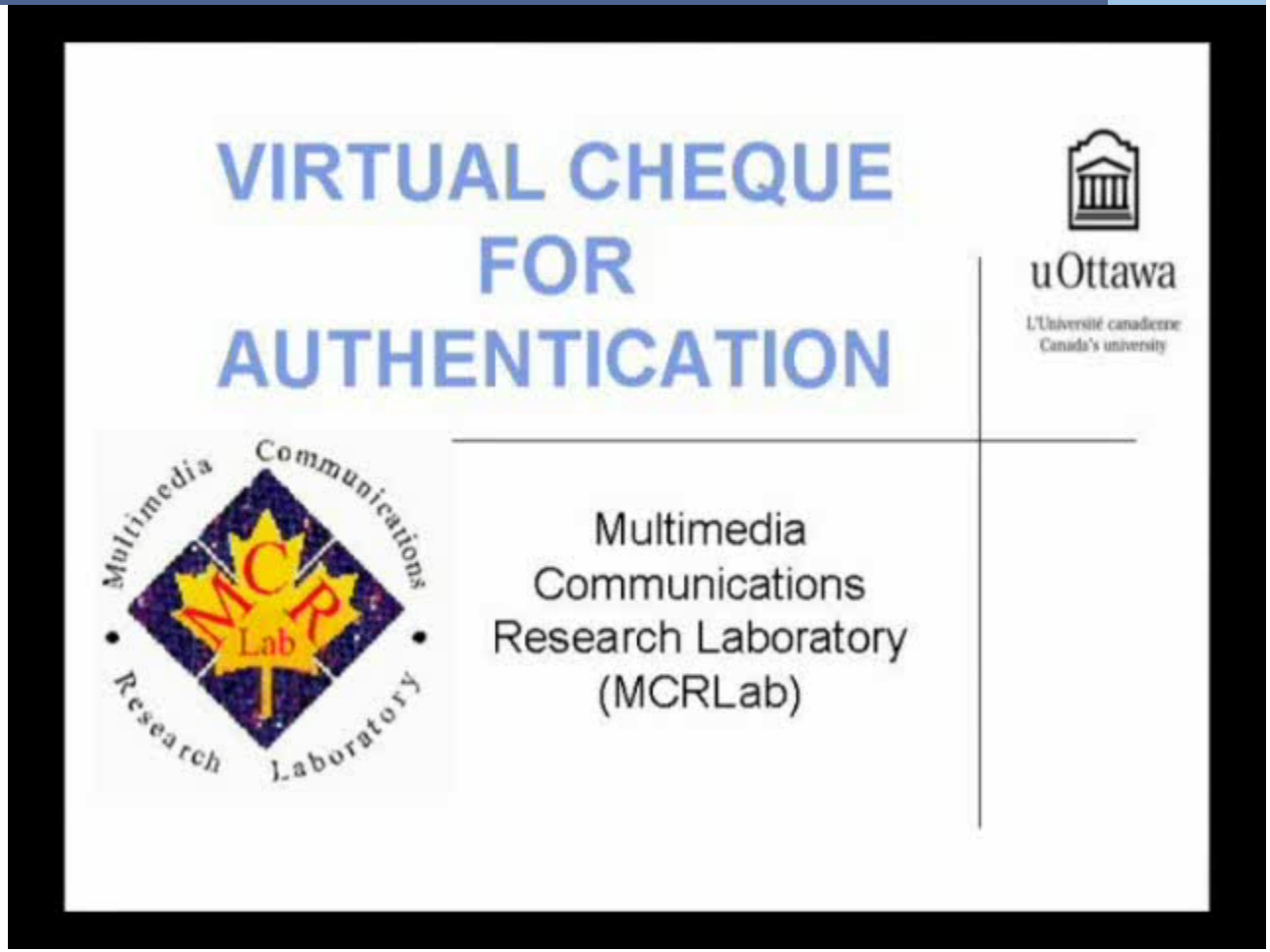
El Saddik et al., "A Novel Biometric System for Identification and Verification of Haptic Users", IEEE Transactions on Instrumentation and Measurement, Vol.56, No. 3 (2007), pp: 895 – 906.

Experimental Results

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%

Virtual Check

FAR = ~7%
FRR = ~12%

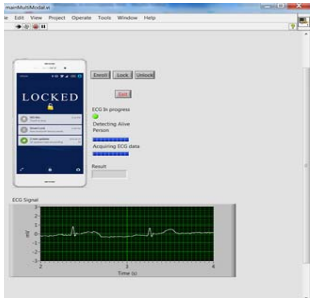


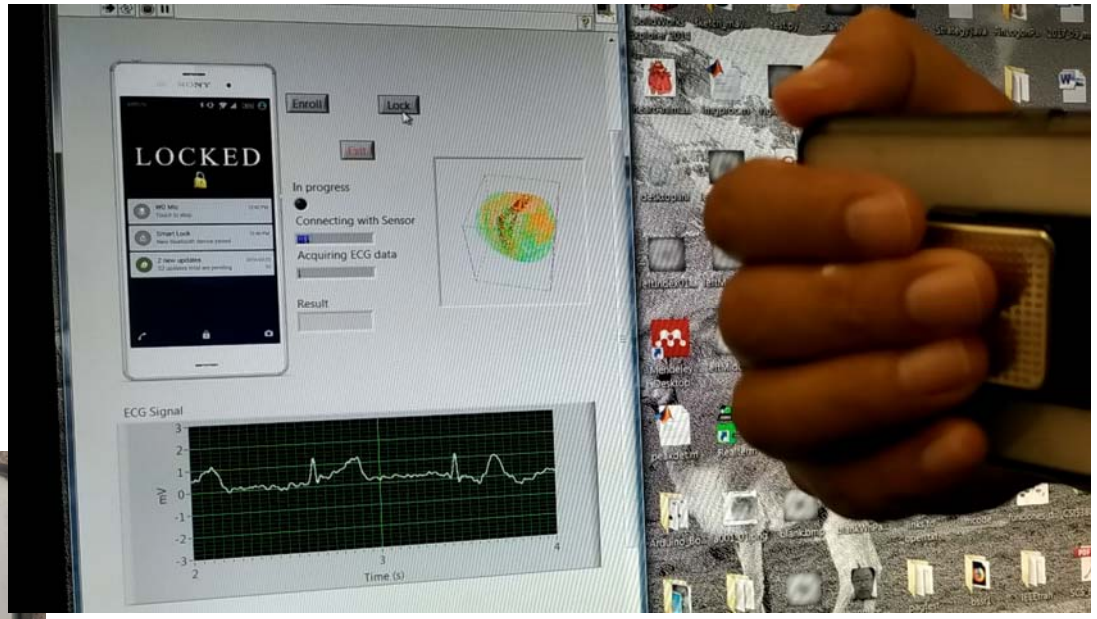
Nizar Sakr, Fawaz Alsulaiman, Julio J. Valdes and Abdulmotaleb El Saddik, "Identity Verification based on Haptic Handwritten Signatures using Genetic Programming" ACM Transactions on Multimedia Computing Communications and Applications Vol 9(2), 2013

Multibiometrics

ECG + Fingerprint

ECG Biometrics



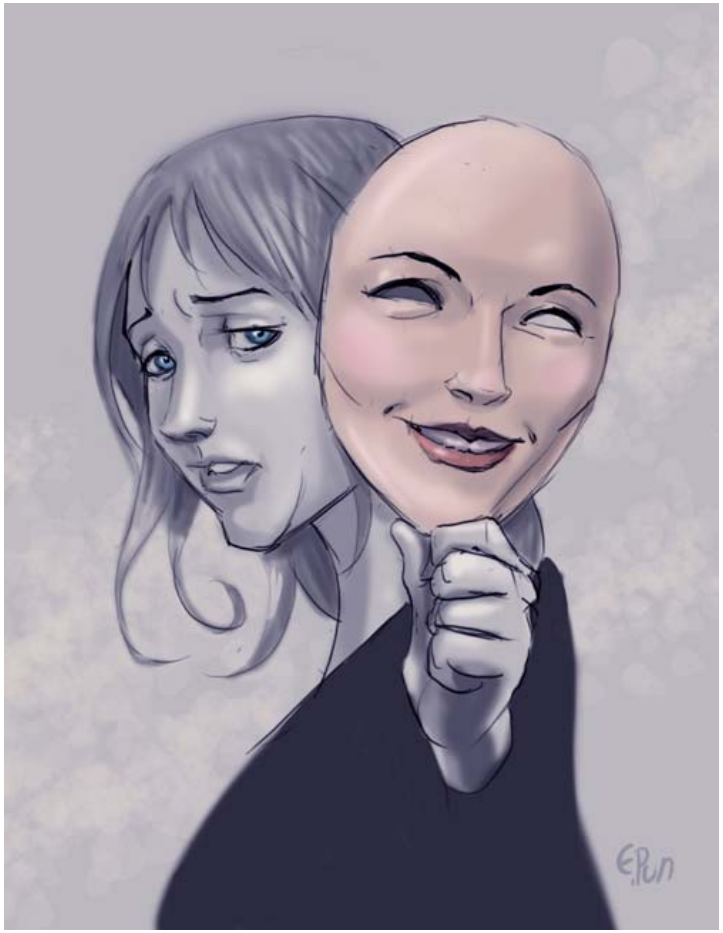


- We obtained 84.93% for TAR and 1.29% for FAR, with the advantage that the required time to perform the authentication with our proposed algorithm is 4 seconds only.

- 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

Emotion

What is behind your facial features ?

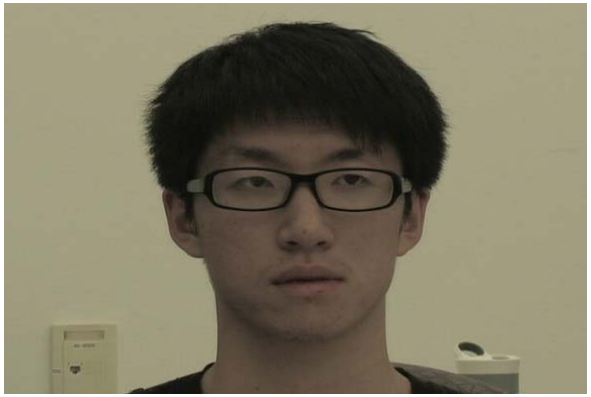


Is the **Medical Field** the only place for HRV analysis ?

What about Affective Computing ?

Picture from: http://edwardpun.blogspot.ca/2006_12_01_archive.html

Proposed System



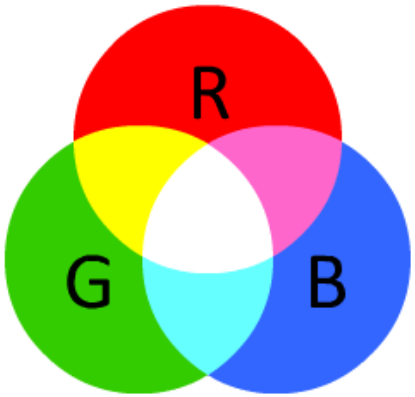
One input frame from the video

Amplitude mapping

Phase mapping

Blood flow intensity

Blood flow direction



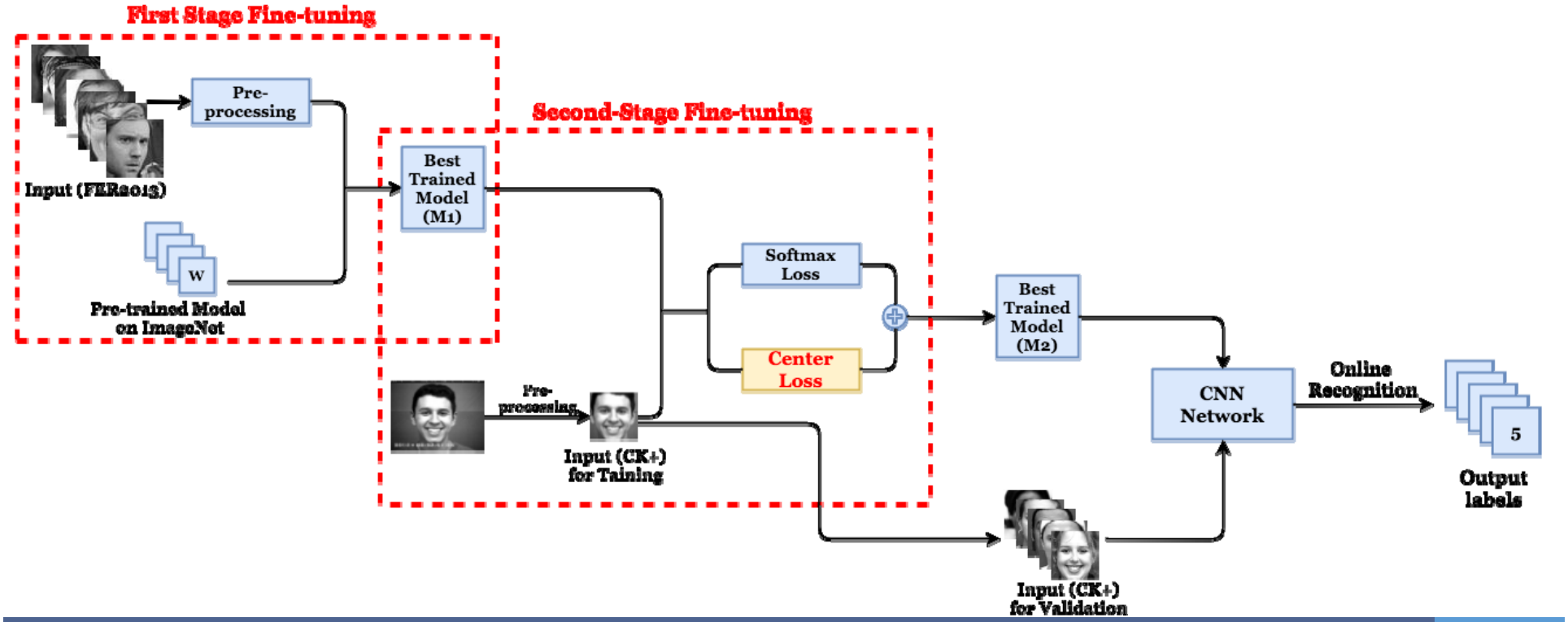
Compared with the red and blue channel, the green channel contains the strongest color variation due to blood circulation.

HRV parameters

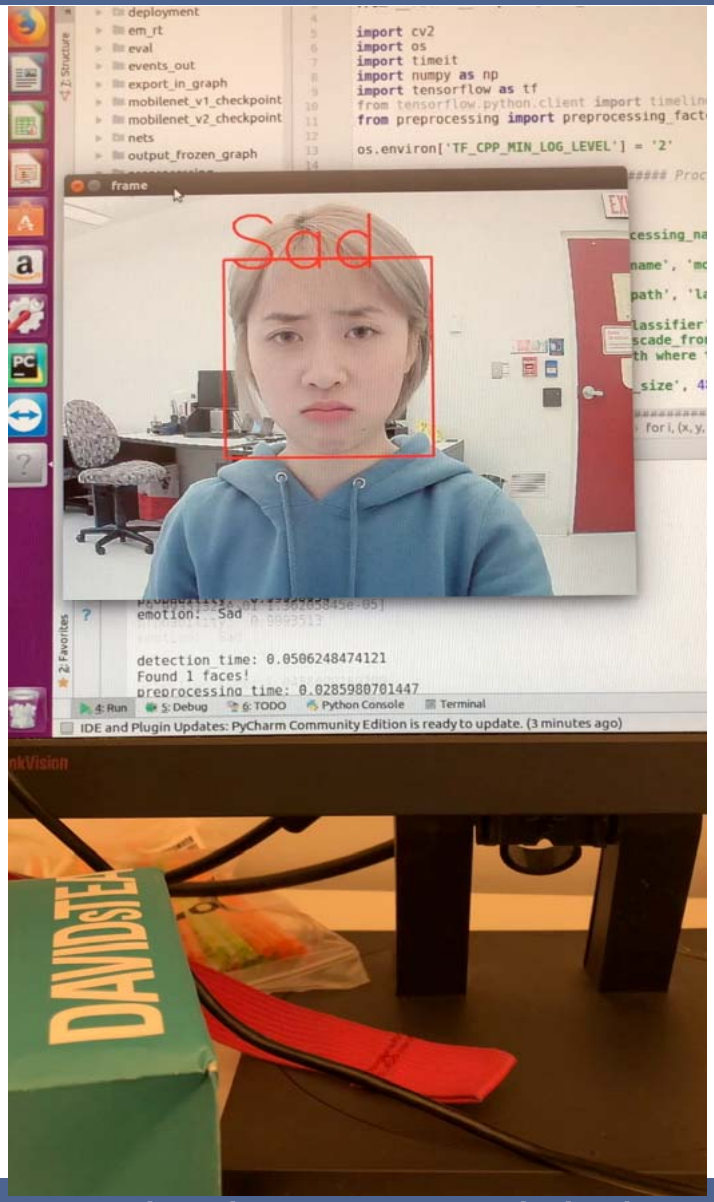
	Parameter	Description
Time Domain	**HR**	The heart rate (bpm)
	$\overline{RR}$	The mean of RR intervals
	SDNN	The standard deviation of RR intervals
	RMSSD	the root mean square of successive RR intervals difference
	NN50	Number of RR intervals pairs differing more than 50 ms
	pNN50	The division of NN50 over total number of RR intervals (%)
Frequency Domain	**LF**	The low frequency extracted from RR intervals after applying PSD
	HF	The high frequency extracted from RR intervals after applying PSD
	LF/HF	The LF frequency value divided by the HF value

Capturing Emotions

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

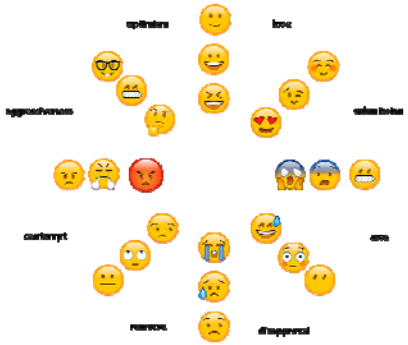


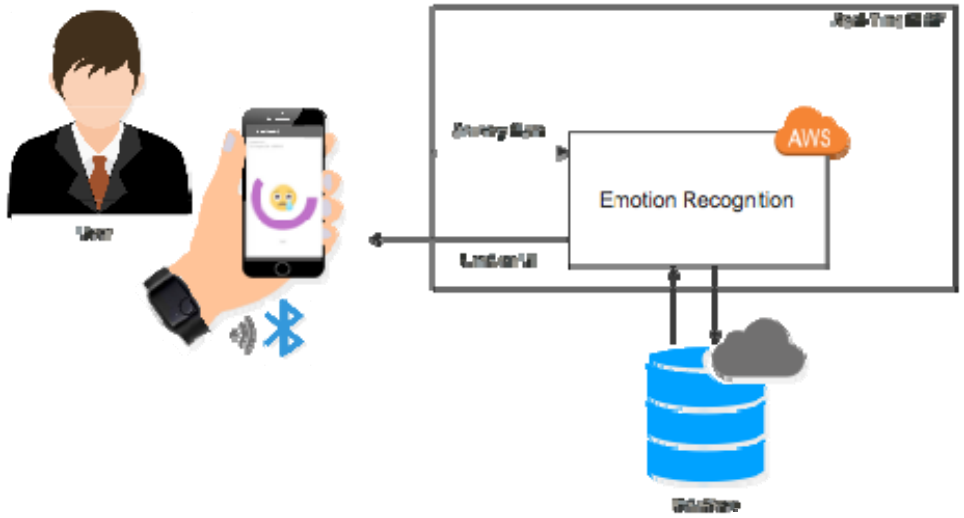
Real-time Experiments



iAware

Emoji-based version of the emotion wheel



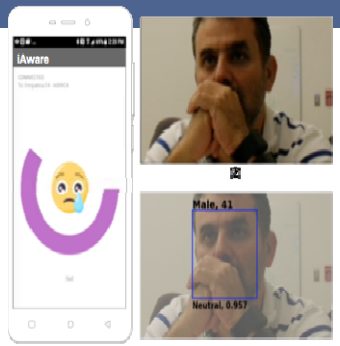


The iAware emotion monitoring system

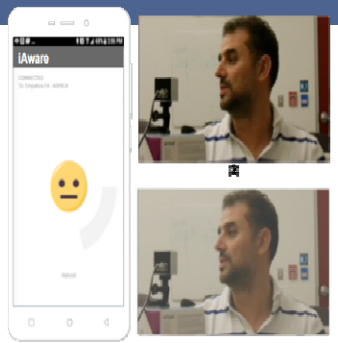
iAware visual feedback: (a) for natural, (b) happy, (c) sad, (d) love, and (e) fear emotions}

Real-time Emotion (DL) and Feedback

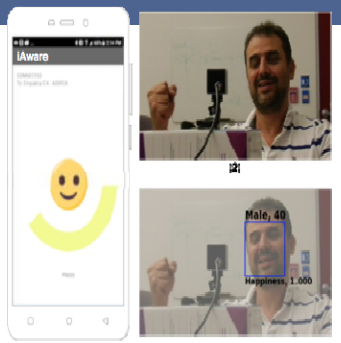
Stimuli: Argentina's player injured



Stimuli: Conversations with a friend

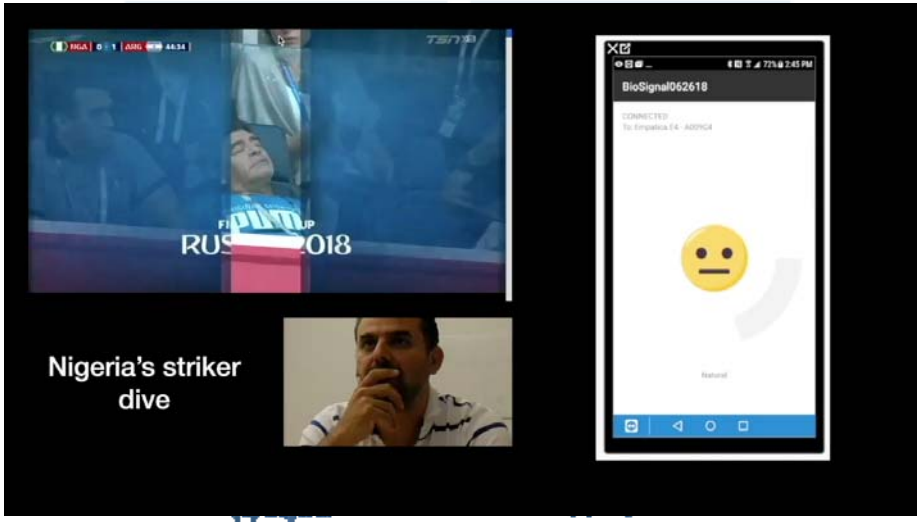


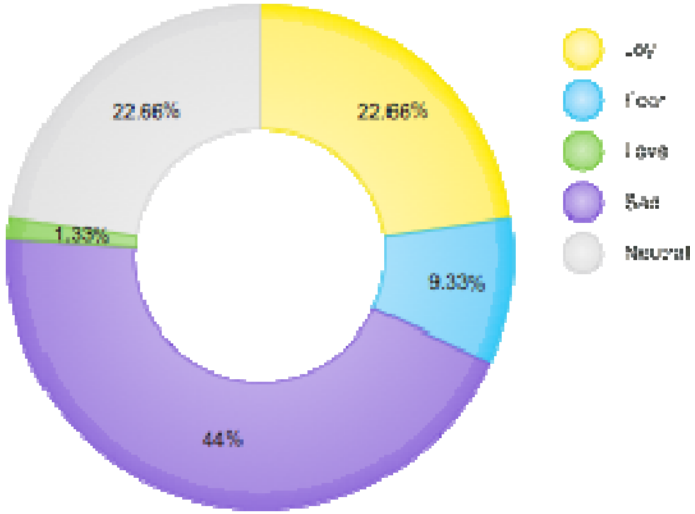
Stimuli: Argentina scored the first goal



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

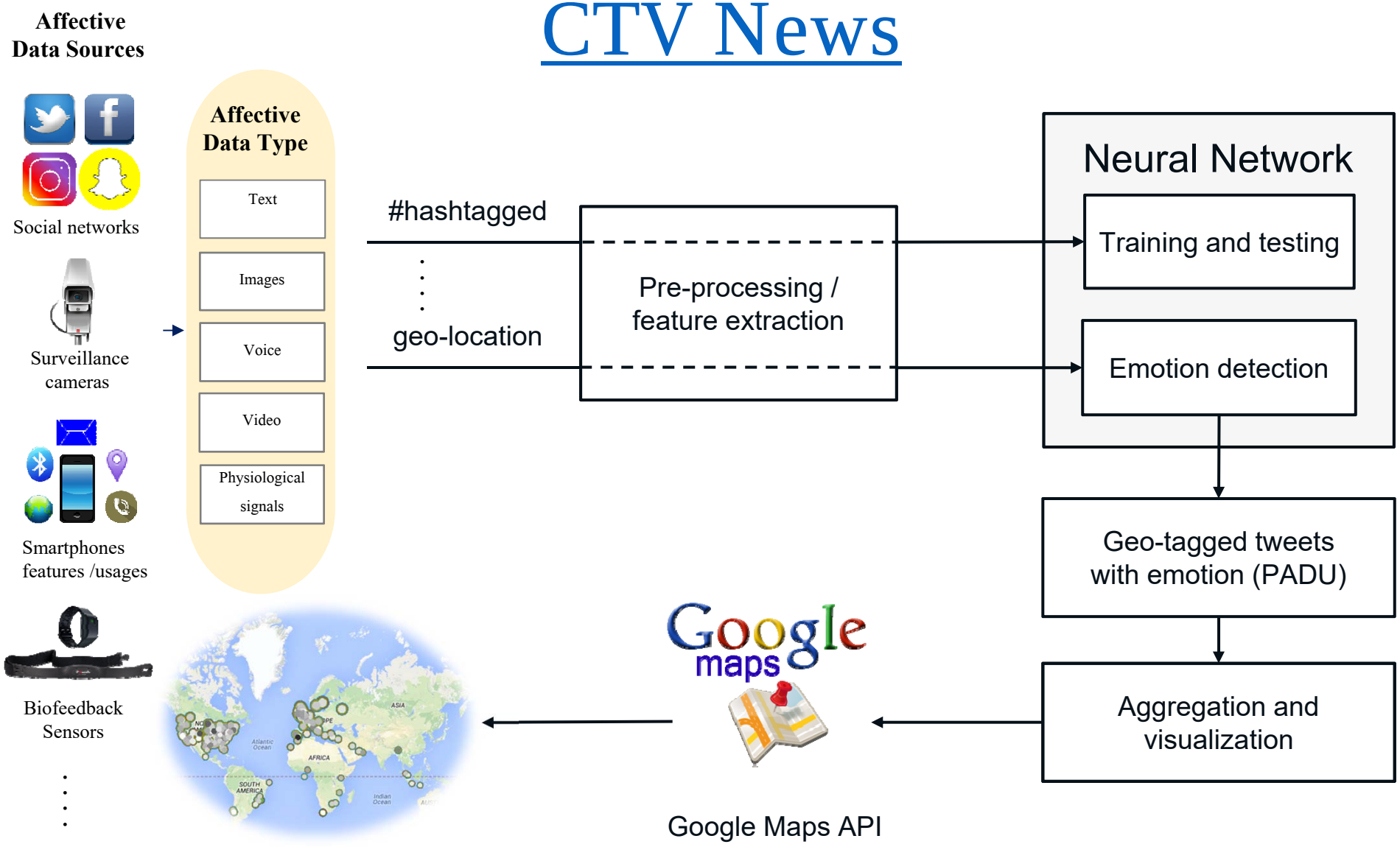
Direct Feedback



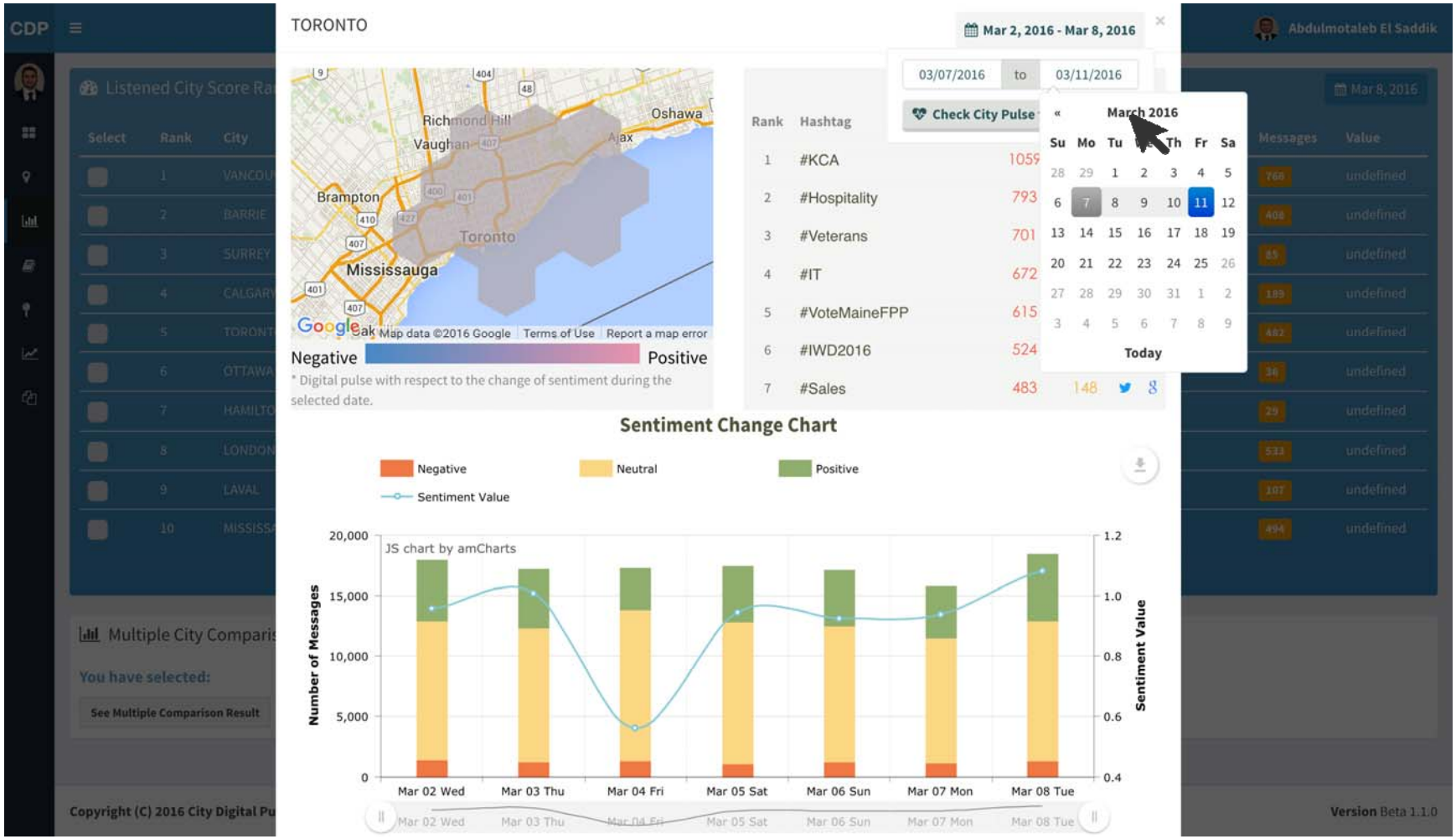


Emotional Cities

CTV News



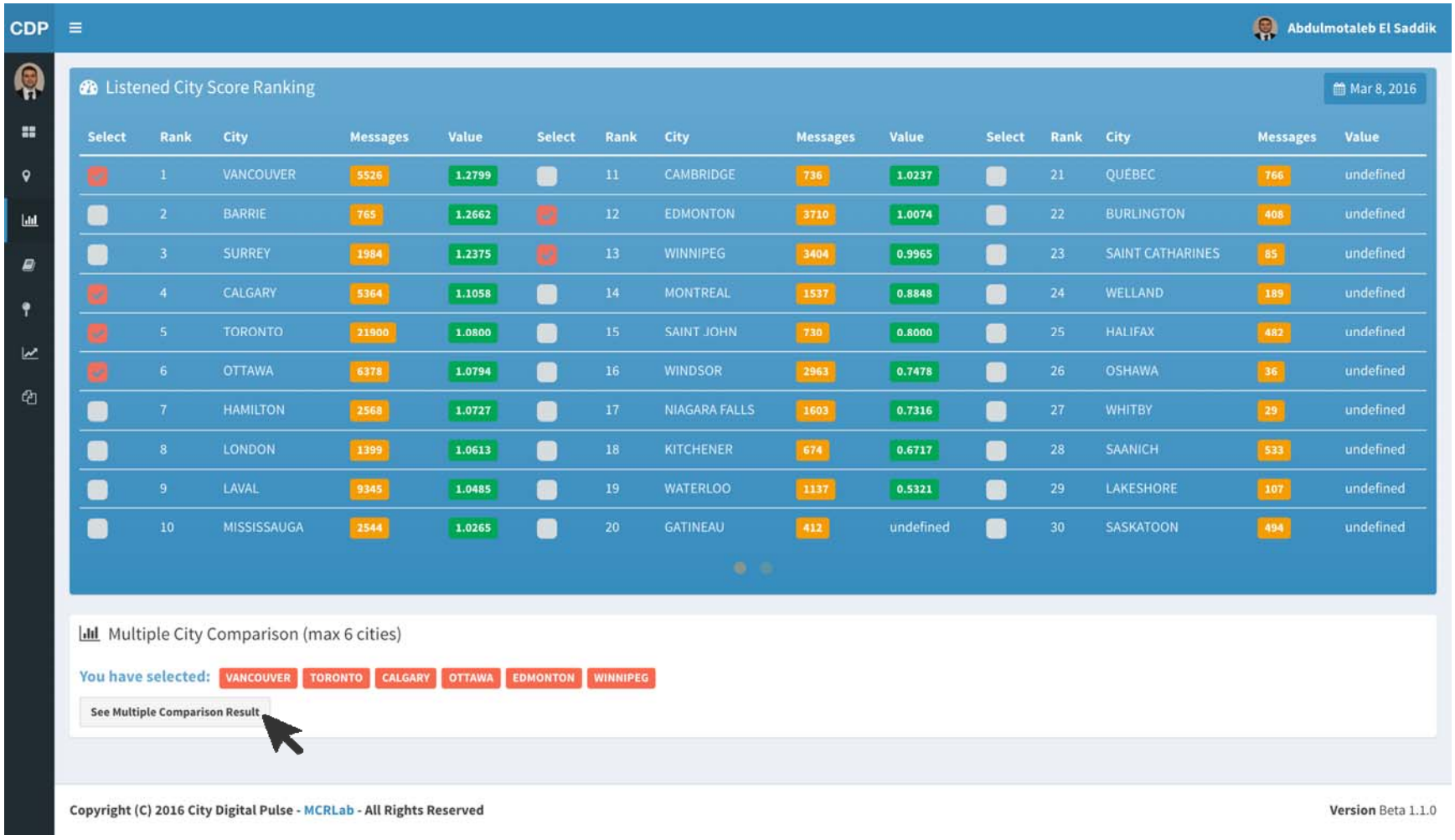
Single City Analysis



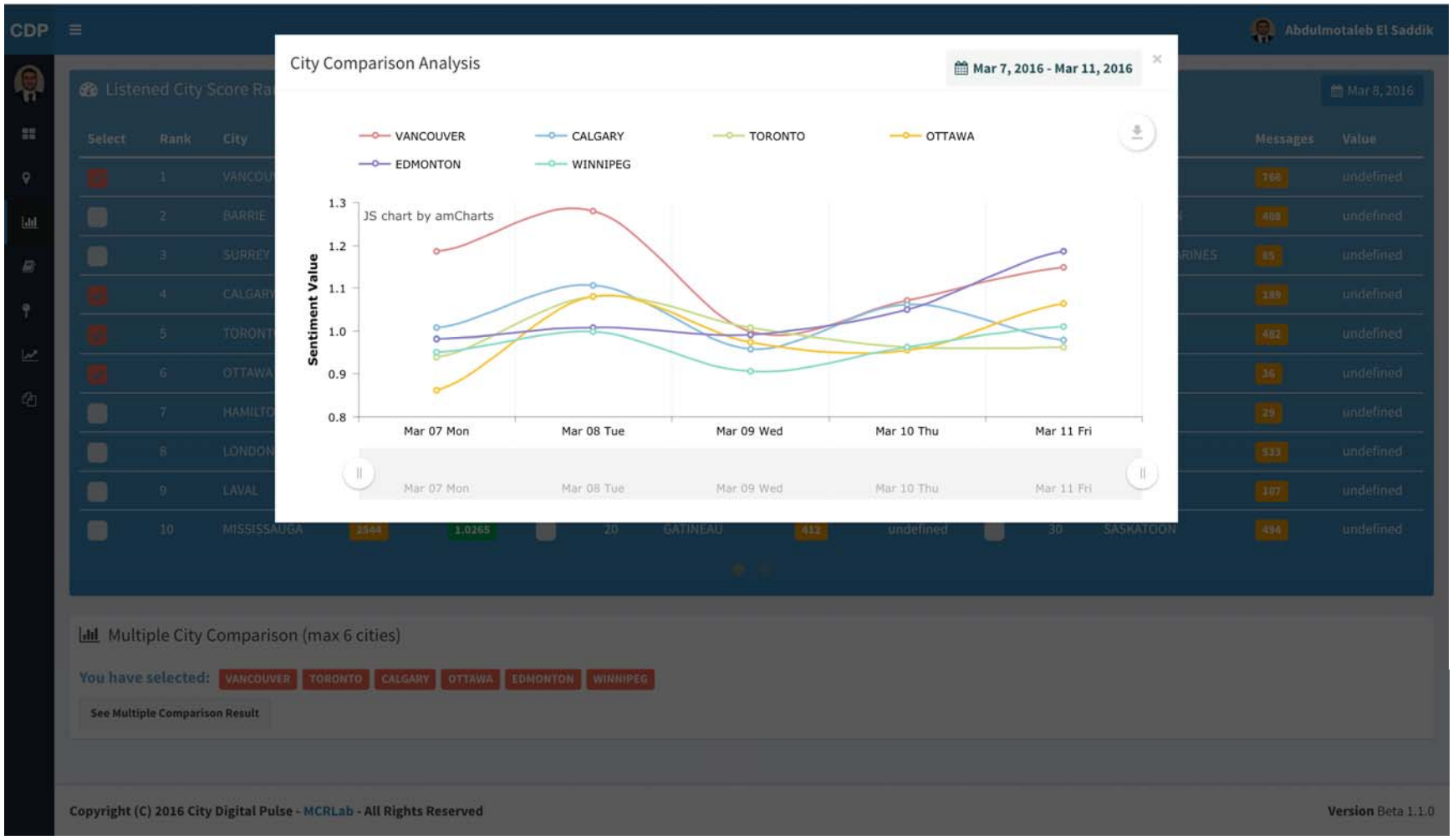
Zhongli Li, Shiai Zhu, Huiwen Hong, Yuanyuan Li, and **Abdulmotaleb El Saddik** "City Digital Pulse: A Cloud Based Heterogeneous Data Analysis Platform", Springer Multimedia Tools and Applications 76 (8), 10893-10916, 2017

Hashtag Img and Sentiment Change

Multiple City Comparison



Multiple City Comparison

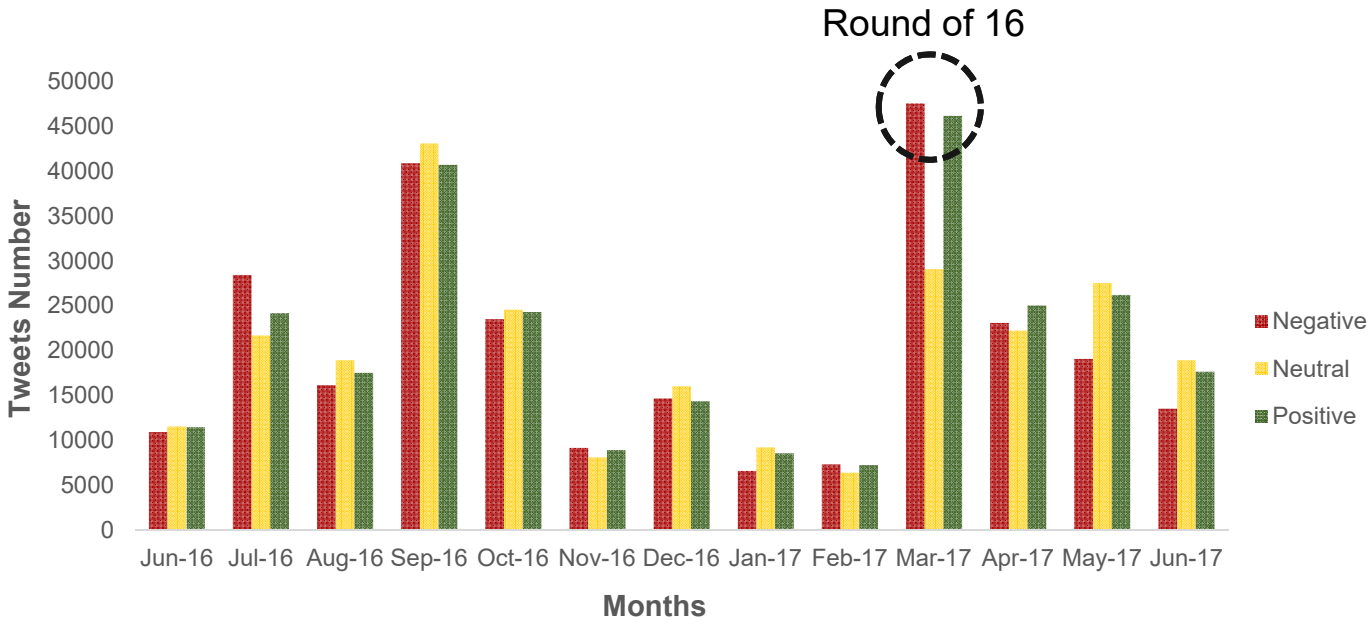


Champions League Analysis

" The long **bomb** was **sick** "

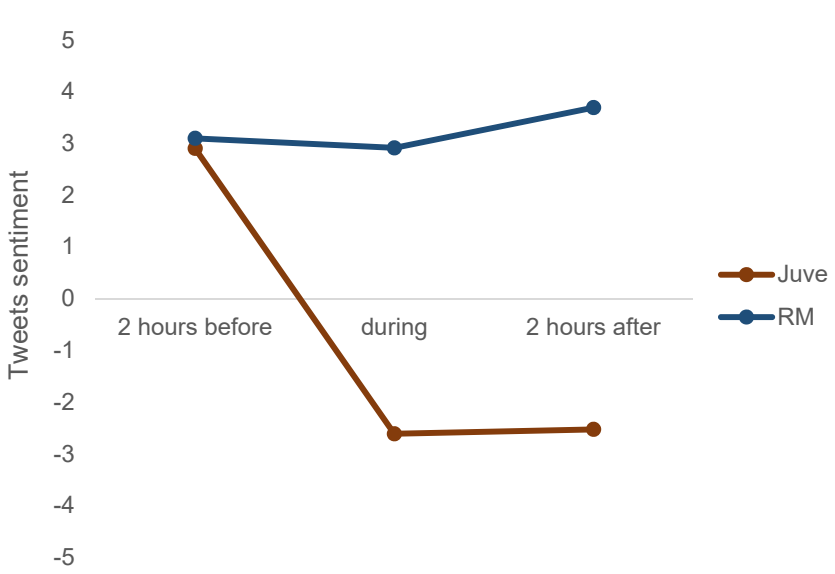
Negative words

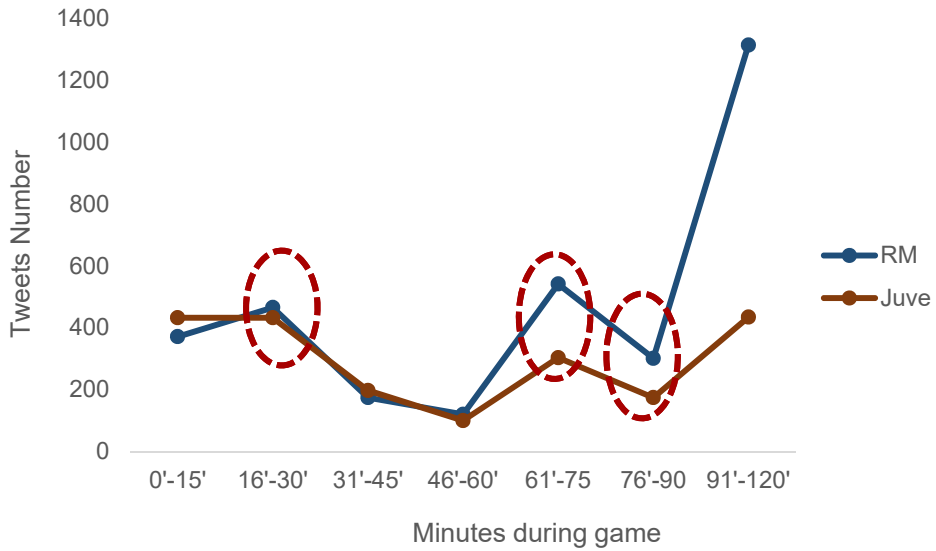
" Luis. F***. Suarez. Again "



Champions League Analysis

- **The Final Game**

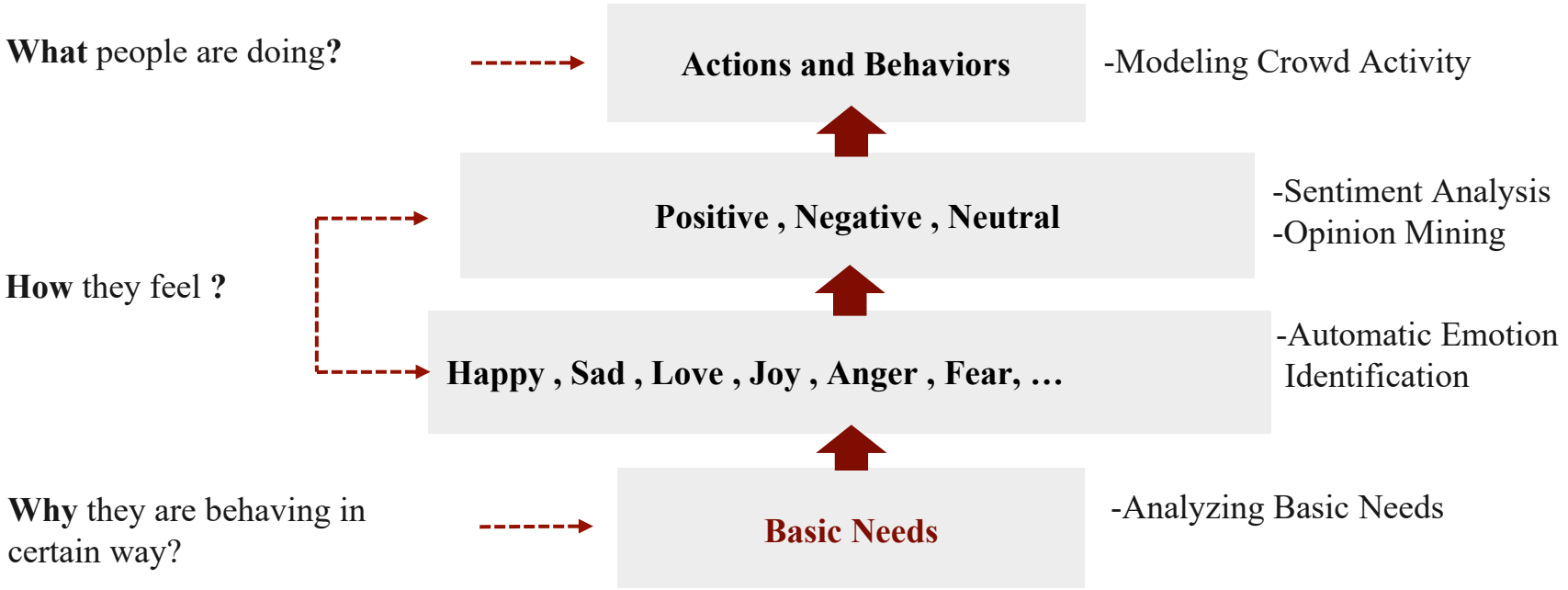




Samah Aloufi; Fatimah Alzamzami; Mohamad Hoda; Abdulmotaleb EI Saddik, "Soccer Fans Sentiment Through The Eye of Big Data: The UEFA Champions League as a Case Study", in Proceedings of the 1st IEEE International Conference on Multimedia Information Processing and Retrieval. Venue Pullman Airport Hotel, Miami, FL, USA, April 10-12, 2018

Human Needs in Affect-Aware City

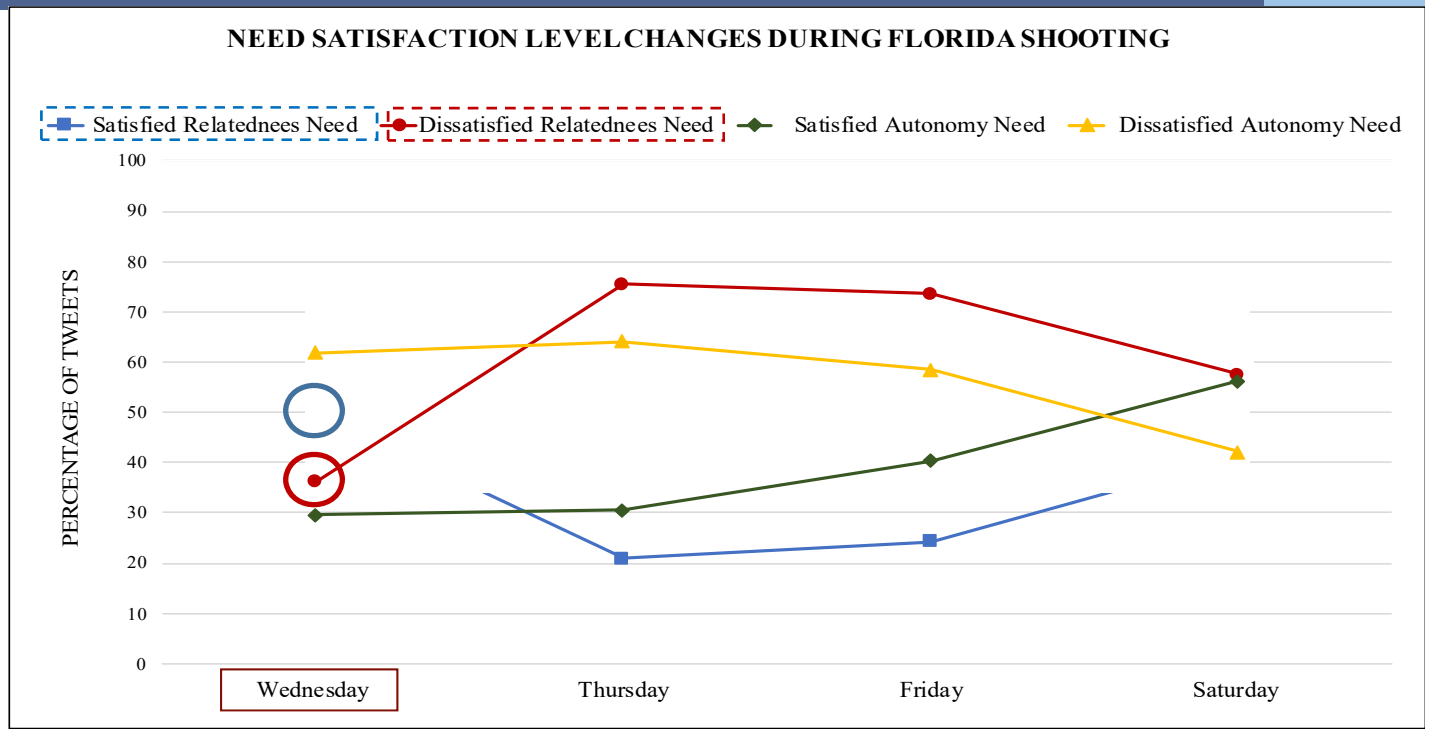
- Understand the affective states of the citizen
  - Provide a form of implicit feedback.
- The interpretation of the analyzed affective states can guide authorities in improving situational awareness and quality of life.

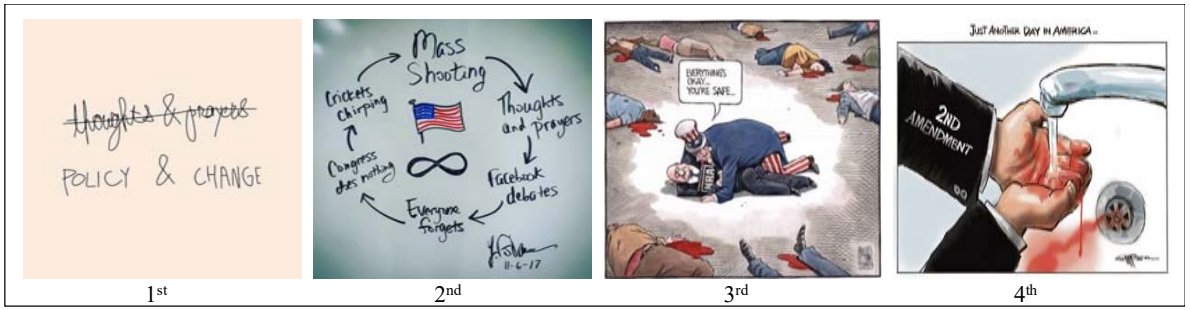


Rajwa Alharthi, Benjamin Guthier, Camille Guertin, Abdulmotaleb El Saddik, "A dataset for psychological human needs detection from social networks", IEEE Access, 10.1109/ACCESS.2017.2706084, 2017

Case Study: Florida Shooting

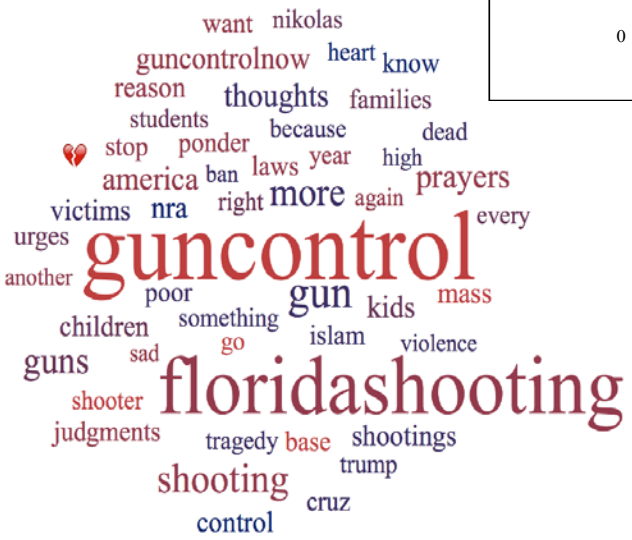
1.#TalkAboutItNow
2.#GunControl
~~1.#TalkAboutItNow~~
~~3.#Broward~~
~~2.#GunControl~~
~~4.#GunControlNow~~
~~3.#Broward~~
~~5.#LoveisLouder~~
~~4.#GunControlNow~~
~~6.#Prayers~~
5.#LoveisLouder
~~7.#MassShooting~~
6.#Prayers
~~8.#RIP~~
~~7.#MassShooting~~
~~9.#ThoughtsandPrayer~~
8.#RIP
~~10.#Condolences~~
9.#ThoughtsandPrayer
10.#Condolences

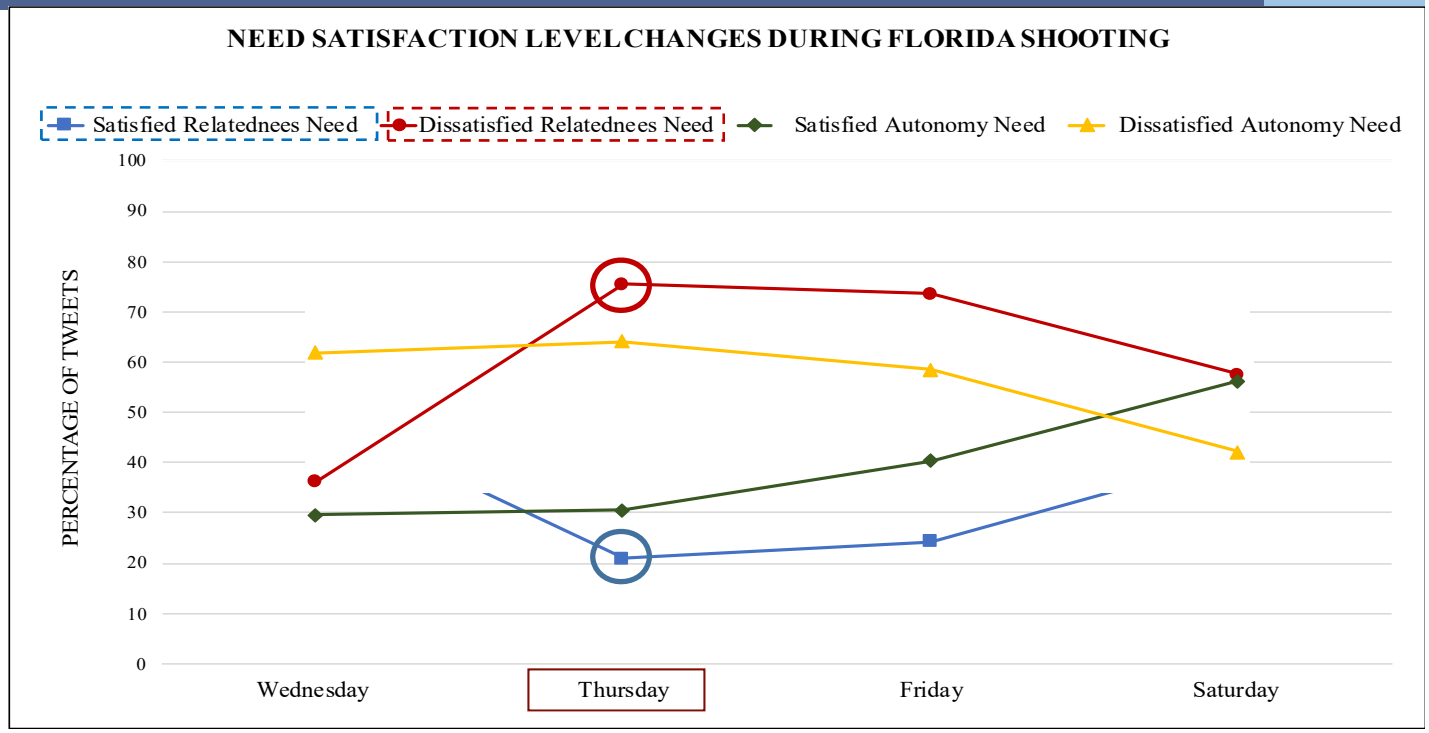


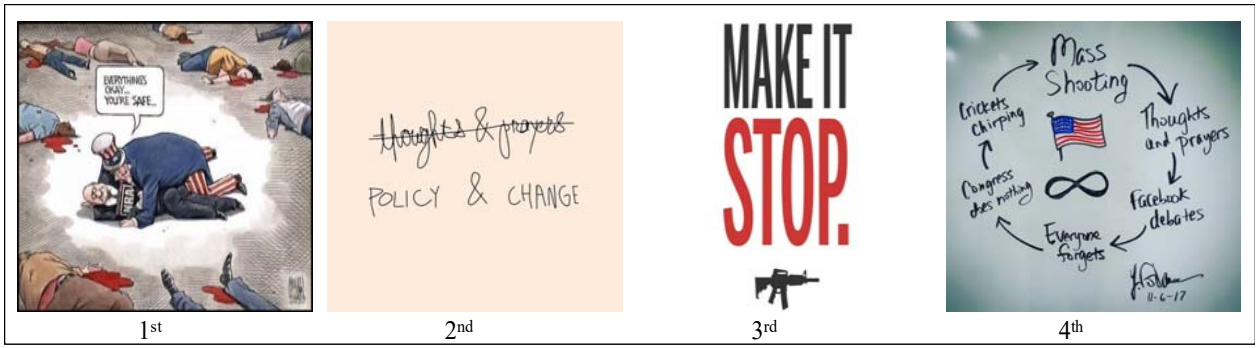


Florida Shooting

1.#GunControl
2.#GunControlNow
3.#Islam
4.#Poor
5.#NRA
6.#PrayForDouglas
7.#America
8.#PolicyandChange
9.#GunReformNow
10.#NRABloodMoney



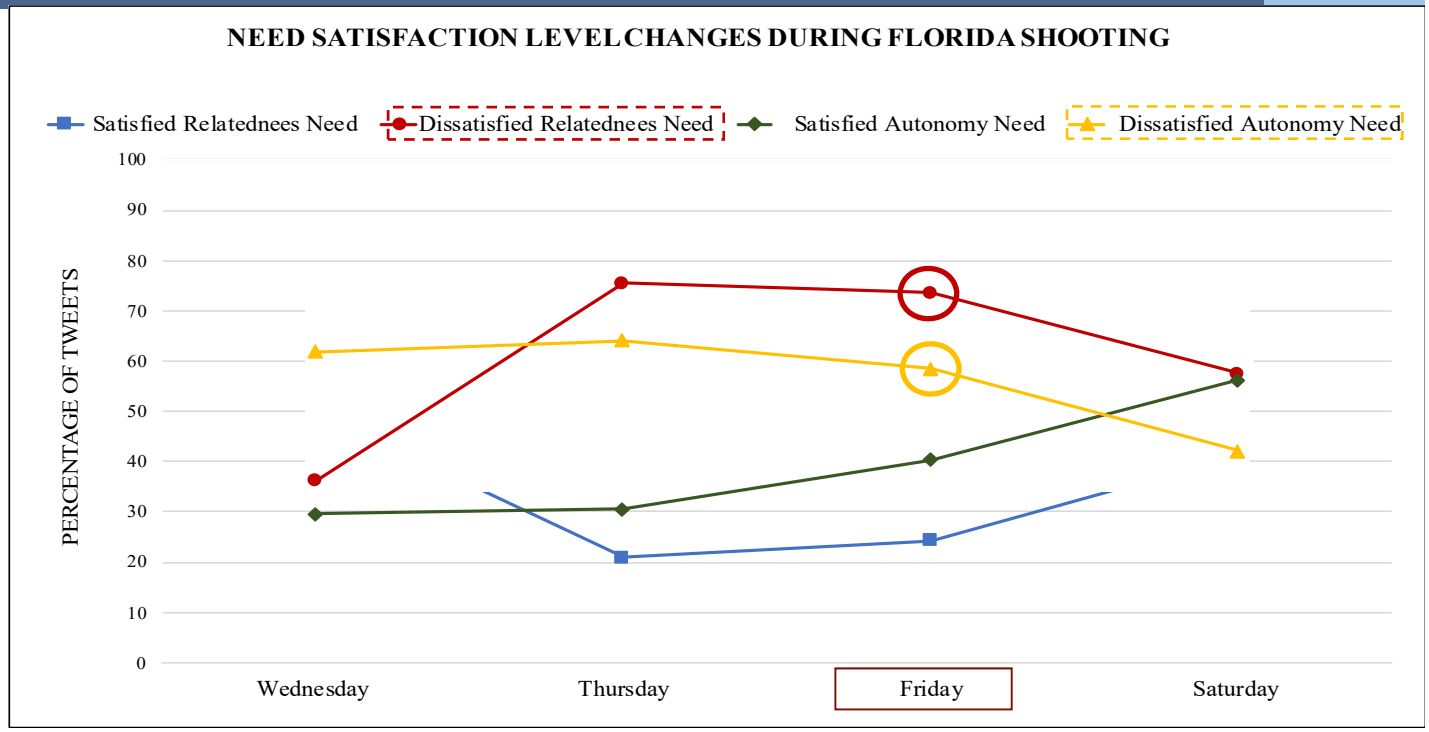


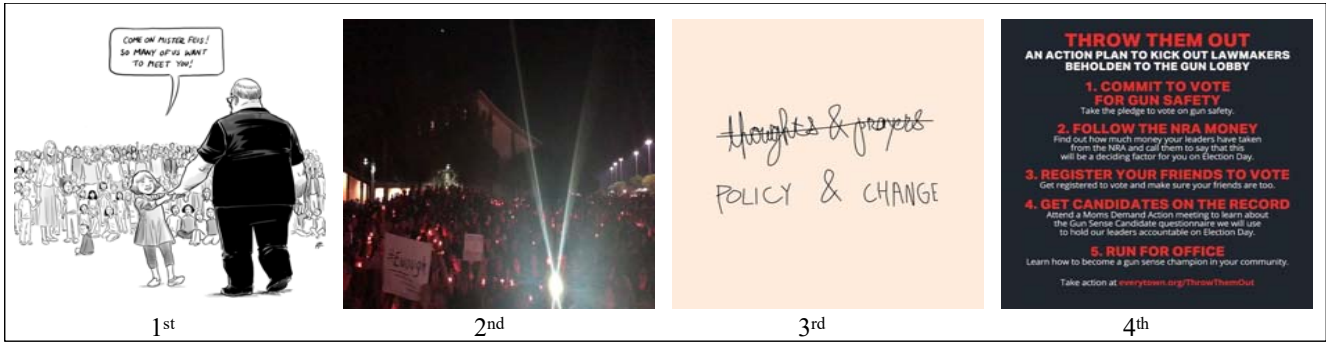


1st 2nd 3rd 4th

Florida Shooting

1.#GunControl
2.#FBI
3.#GunReformNow
4.#GunControlNow
5.#MAGA
6.#NikolasCruz
7.#Trump
8.#SecondAmendment
9.#StandYourGround
10. #NRA

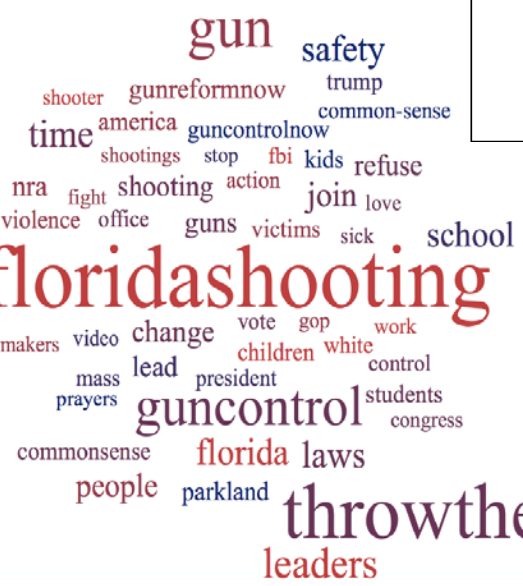


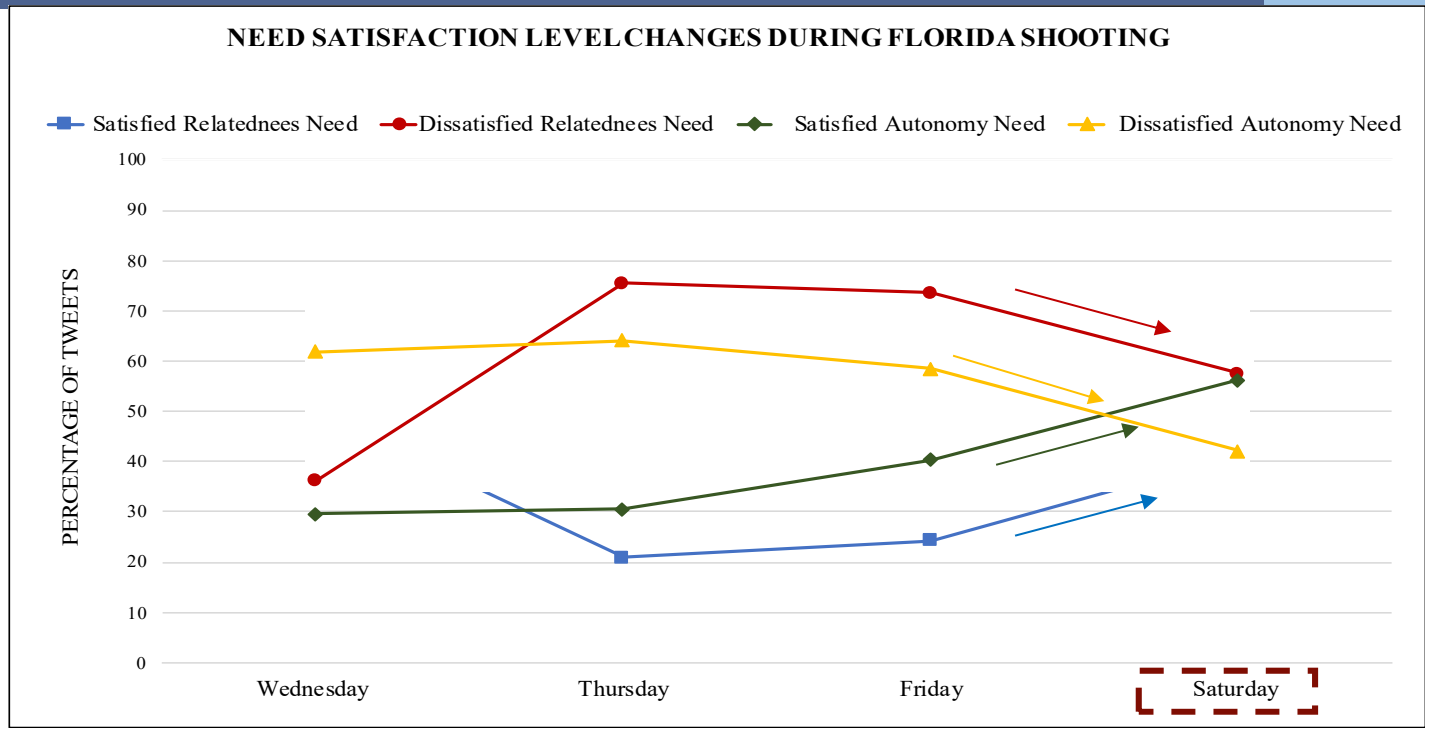


1st 2nd 3rd 4th

Florida Shooting

1.#ThrowThemOut
2.#GunControl
3.#GunReformNow
4.#GunControlNow
5.#NRA
6.#NikolasCruz
7.#GunReform
8.#FBI
9.#StudentsDemandAction
10.#EndGunViolence





1st

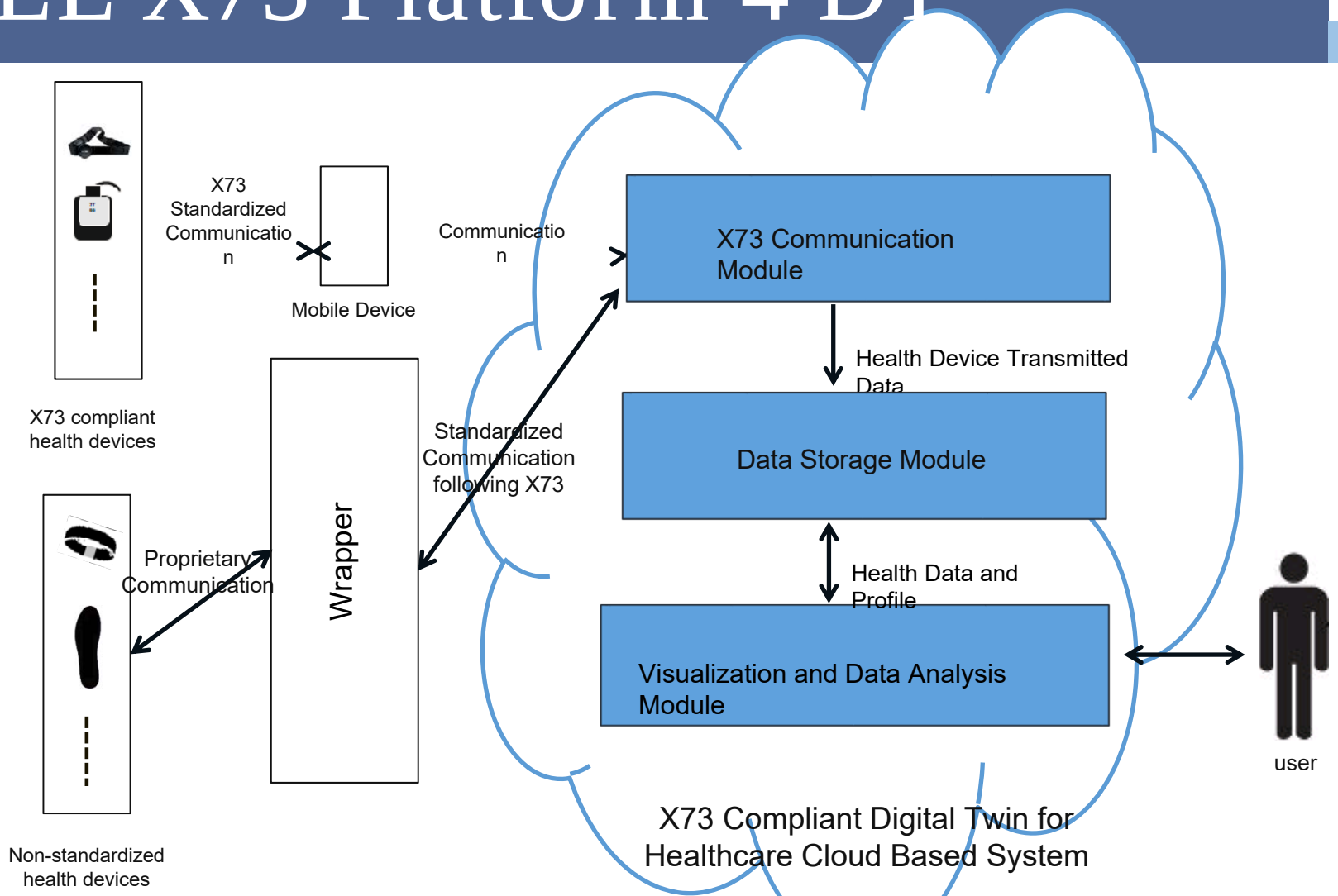
2nd

3rd

4th

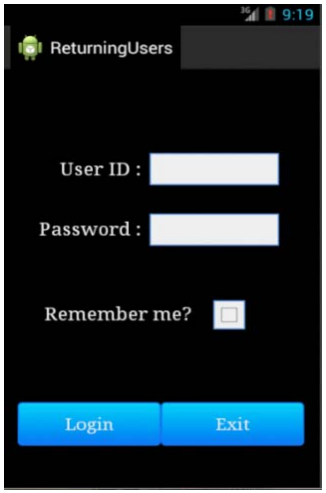
Digital Twin
4
Health and Well-being

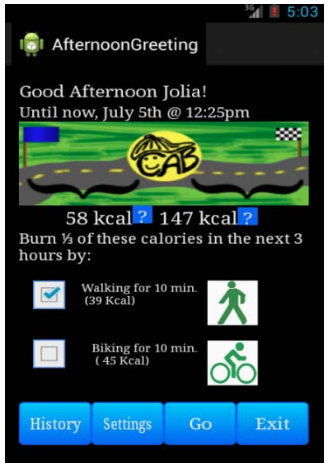
IEEE X73 Platform 4 DT

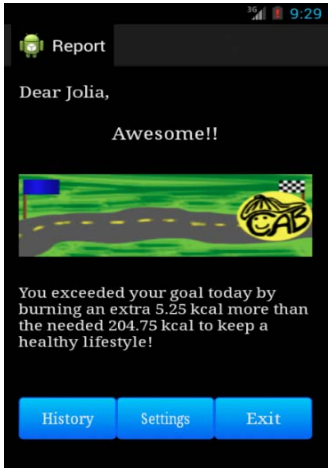


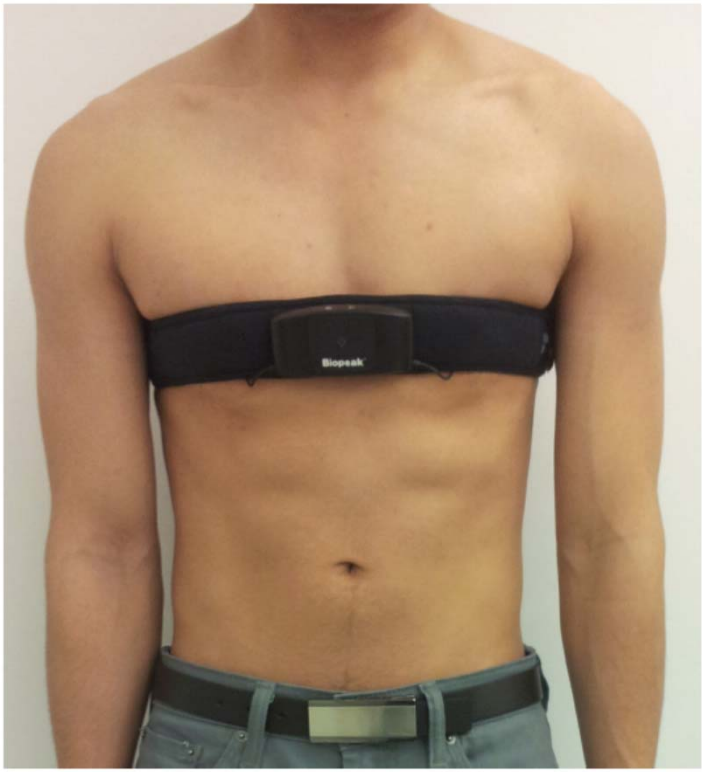
H. Badawi, F. Lamarti, F. Arafsh, and A. El Saddik, “Standardizing a Shoe Insole as a Personal Health Device (PHD) Based on ISO/IEEE 11073 (X73)” In Proceeding of the 2019 International Conference on Information Technology & Systems - ICITS'19 (Feb. 6-8, 2019) Ecuador

Physical Activity Advisory System









[Mobile cloud-based physical activity advisory system using biofeedback sensors](#)HF Badawi, H Dong, A El Saddik, Future Generation Computer Systems 66, 59-70

Collect data about Mobile usage

5 student-athletes from the University of Ottawa install app on their personal smartphone

Smartphone usage is tracked automatically, remotely, and in real-time via the mobile app

Participants complete **self-report surveys** pertaining to:
a) key psychosocial variables
b) perceived smartphone usage
c) perceived sport performance

All surveys are collected via the mobile app

Usage data is subjected to algorithms to extract **detailed statistical information.** All data is used to create preliminary participant profiles

15-days

Poppy DesClouds, Fedwa Laamarti, Natalie Durand-Bush, Abdulmotaleb El Saddik, “Developing and testing an application to assess the impact of smartphone usage on well-being and performance outcomes of student-athletes”, in Proceedings of the 2018 International Conference on Information Technology & Systems

Results

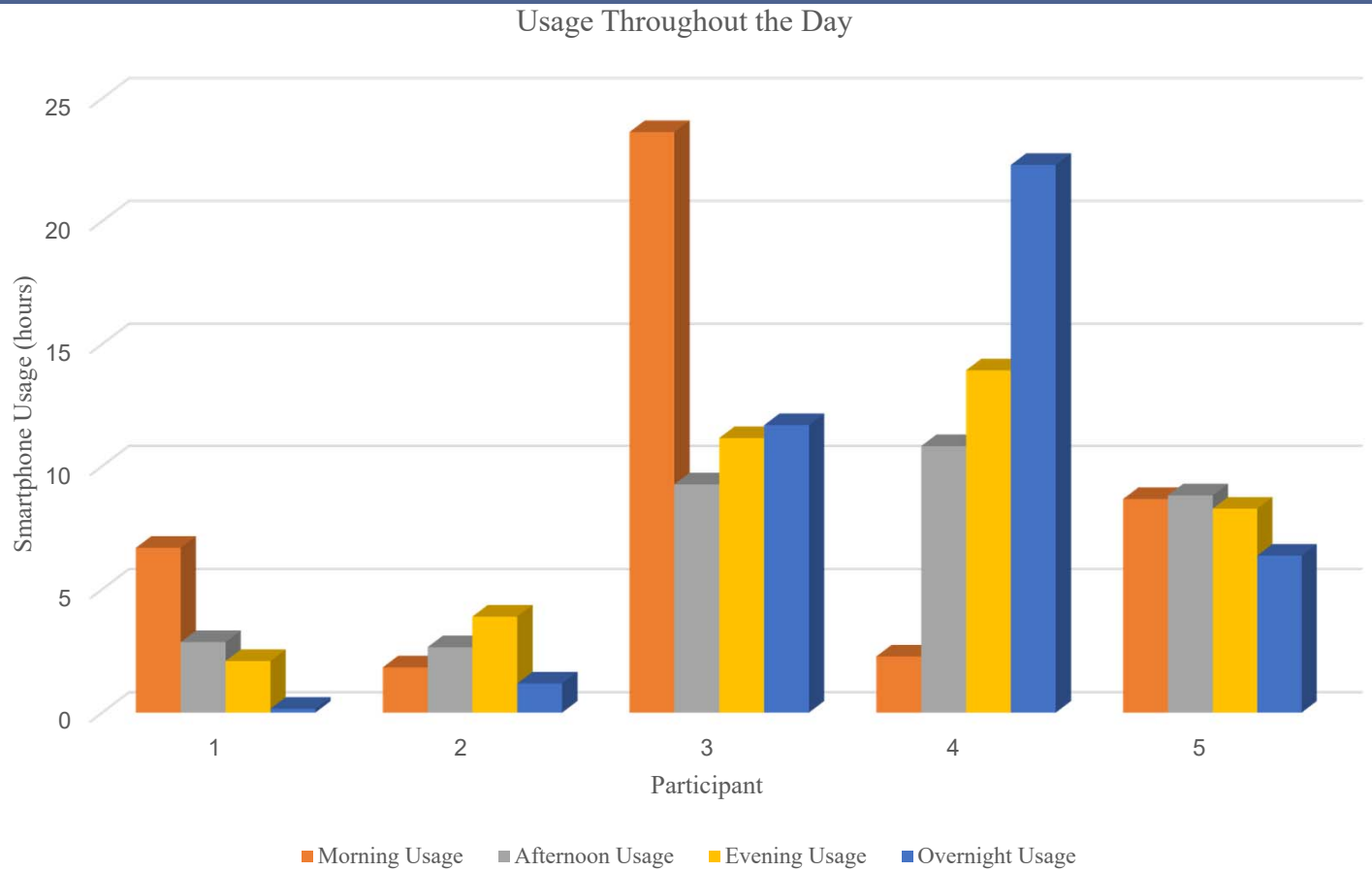
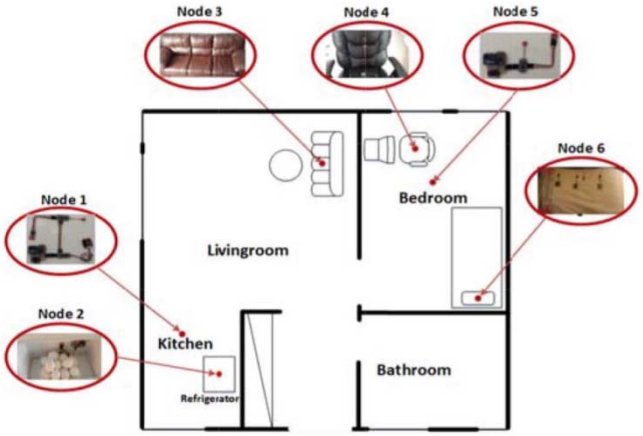


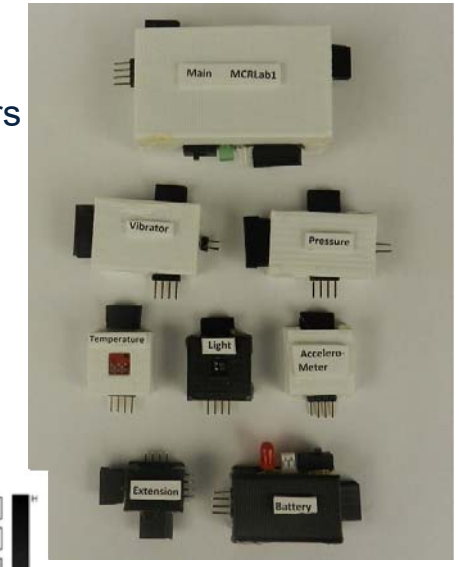
Fig. 1. Prevalence of smartphone usage throughout four periods of the day, morning (6am-12pm), afternoon (12pm-6pm), evening (6pm-12am), and overnight (12am-6am).

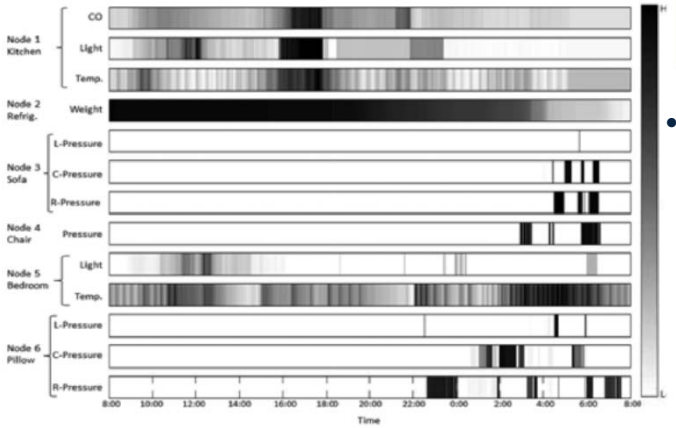
- Participants total smartphone usage ranged from 20.5 hours to 119.4 hours
- Average usage of 4.5 hours per day (31.7 hours per week)

Reconfigurable Transducer Network



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



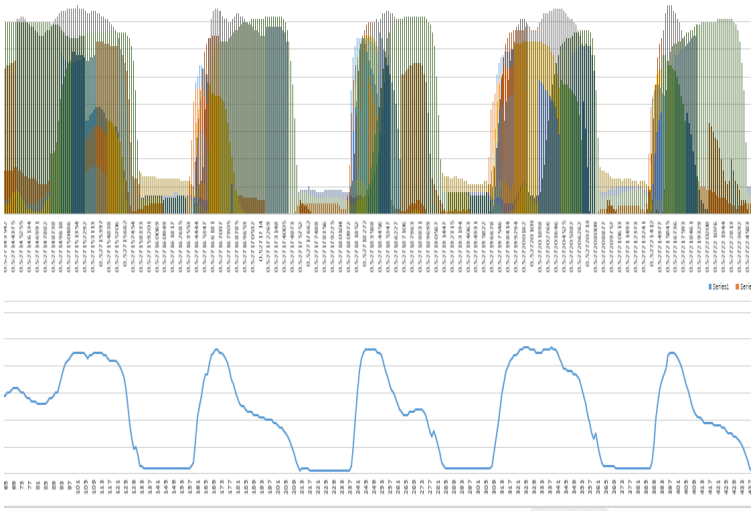


- The dynamic condition of a multiple rooms during a period of 24 hours is monitored. Recommendations are given by fuzzy logic.

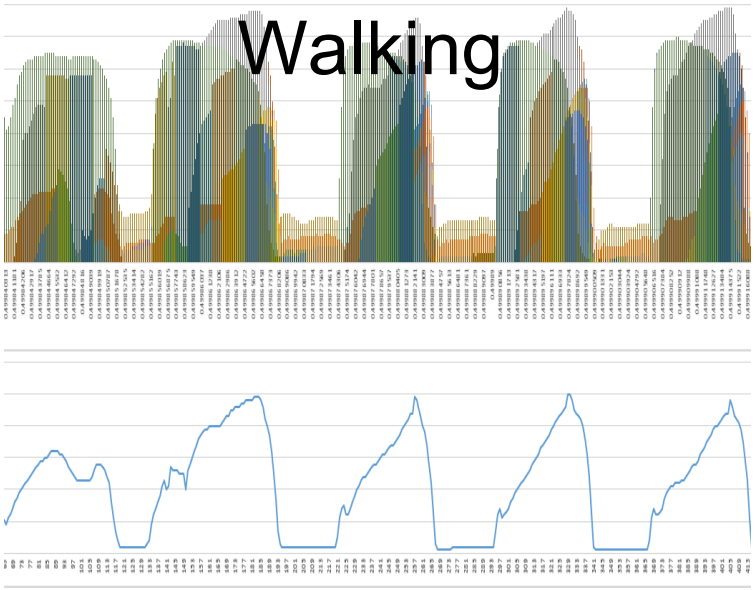
Basim Hafidh, Hussein Al Osman, Haiwei Dong and Abdulmotaleb El Saddik ,“A framework of reconfigurable transducer networks and its XML-based communication,” ***IEEE Embedded Systems Letters***, vol. 7, no. 3, pp. 81-84, 2015.

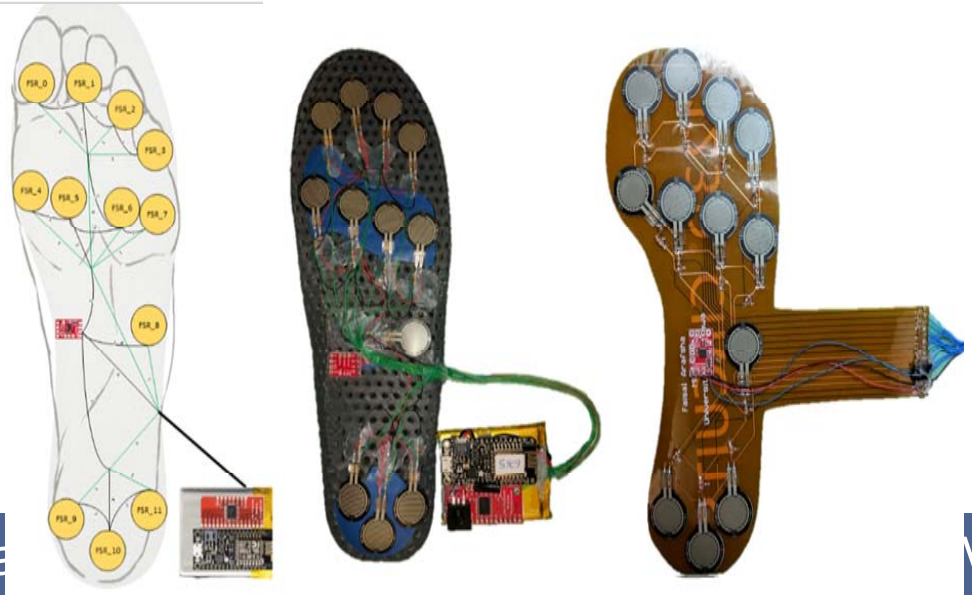
Smart Insole

Forward Walking

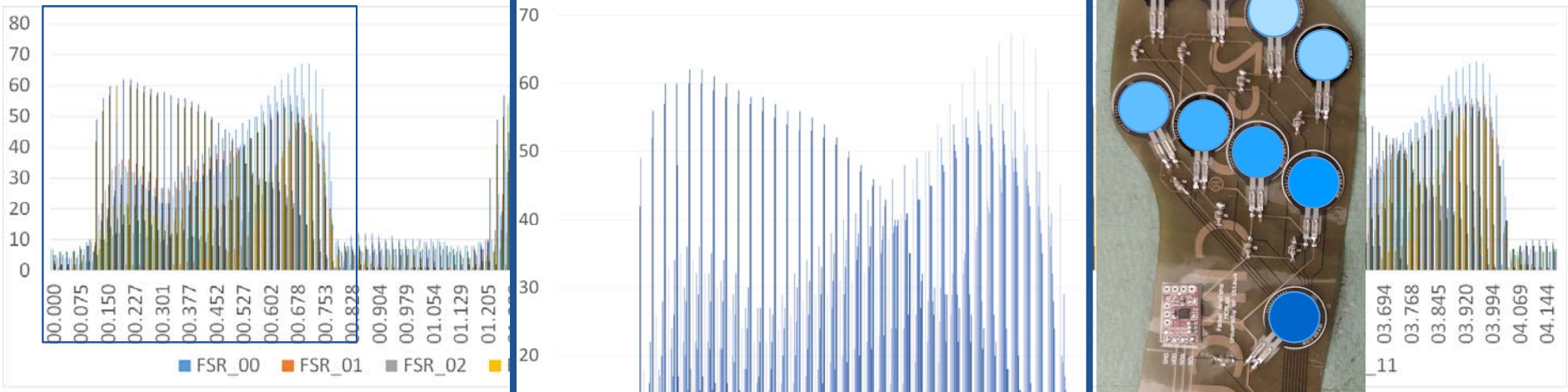


Backward Walking

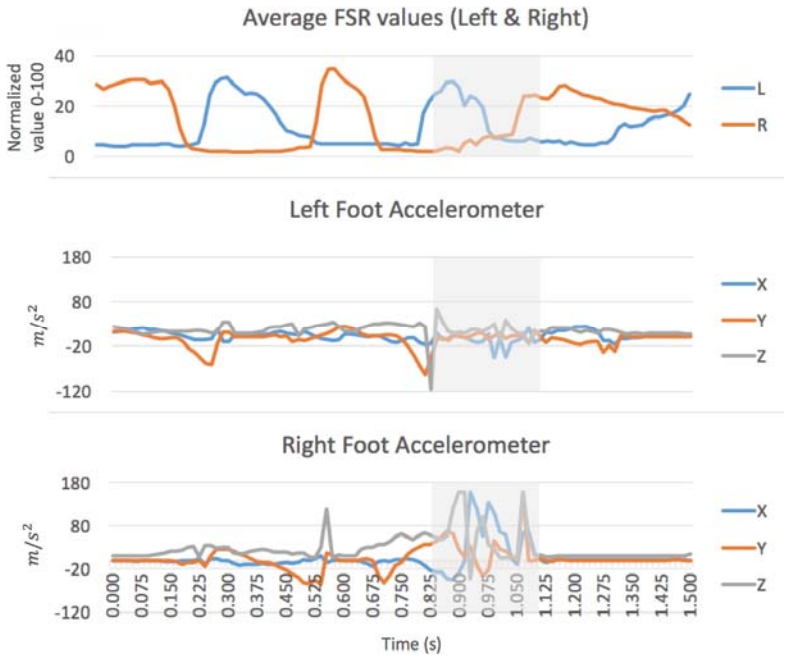


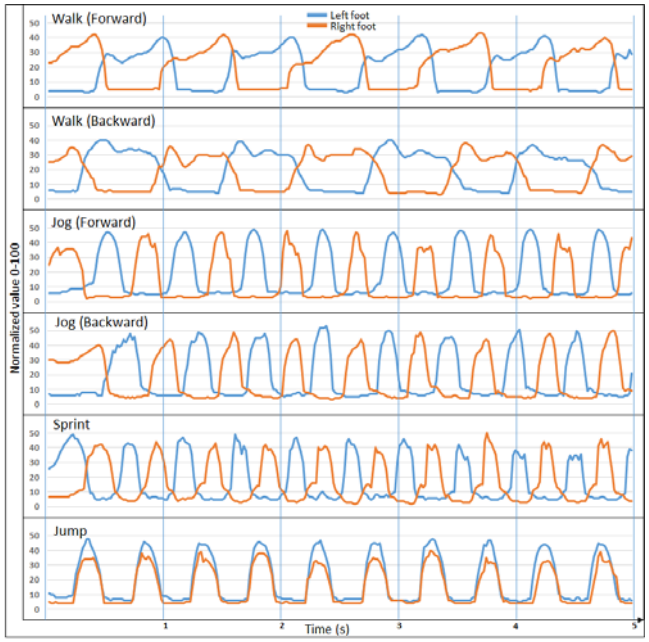


Results



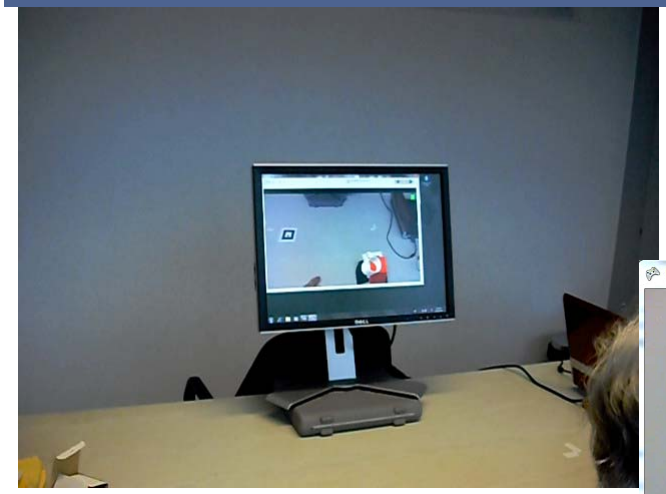
Results

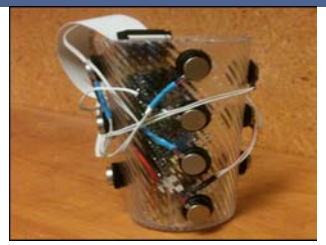


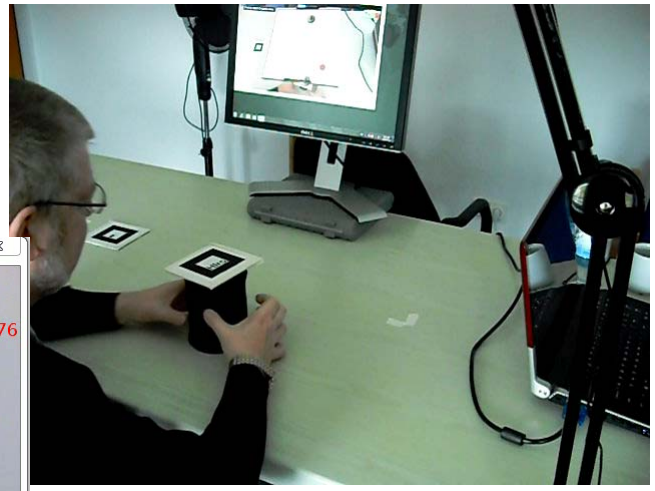


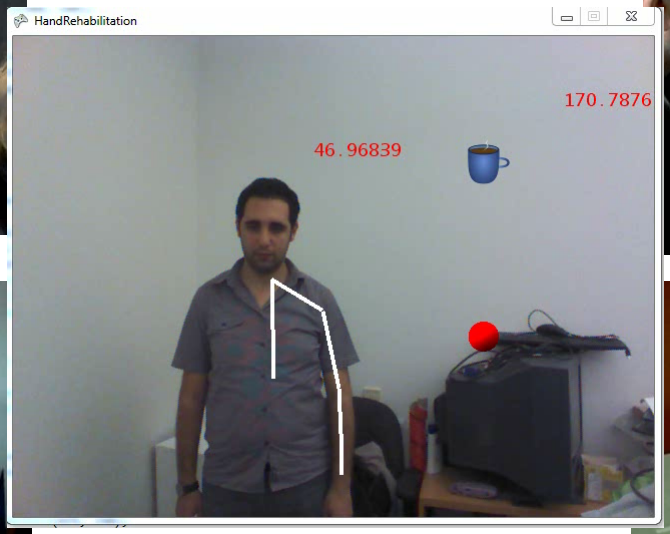
Faisal Arafsha , Christina Hanna, Ahmed Aboualmagd, Sarah Fraser and Abdulmotaleb El Saddik, “Instrumented Wireless SmartInsole System for Mobile Gait Analysis: A Validation Pilot Study with Tekscan Strideway”, J. Sens. Actuator Netw. 2018, 7(3), 36; doi:10.3390/jsan7030036

Post Stroke rehabilitation









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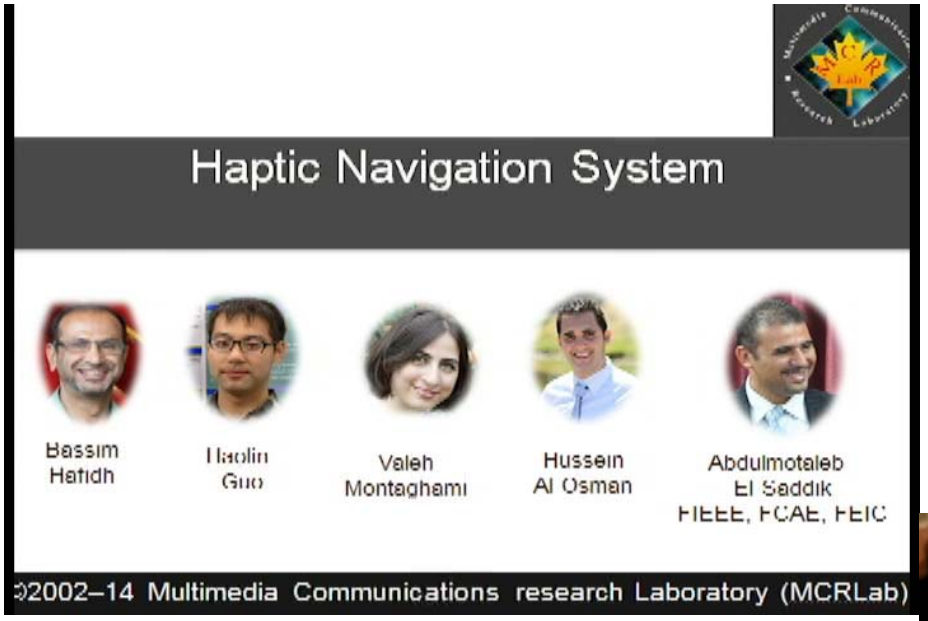
Elderly


Haptic Navigation System
Bassim Hafidh
Haolin Guo
Valeh Montaghami
Hussein Al Osman
Abdulmotaleb El Saddik
FIEEE, FCAE, FEIC
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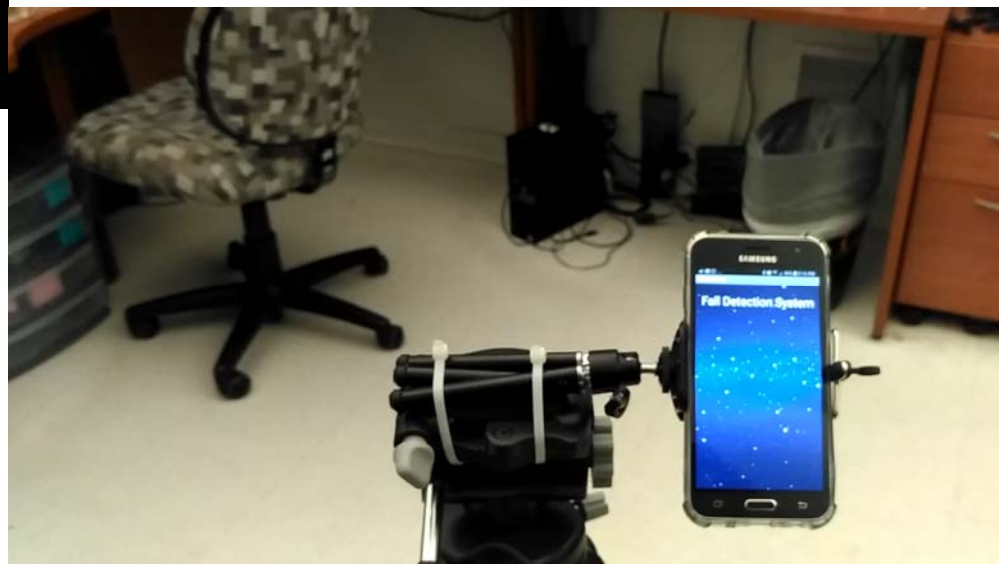
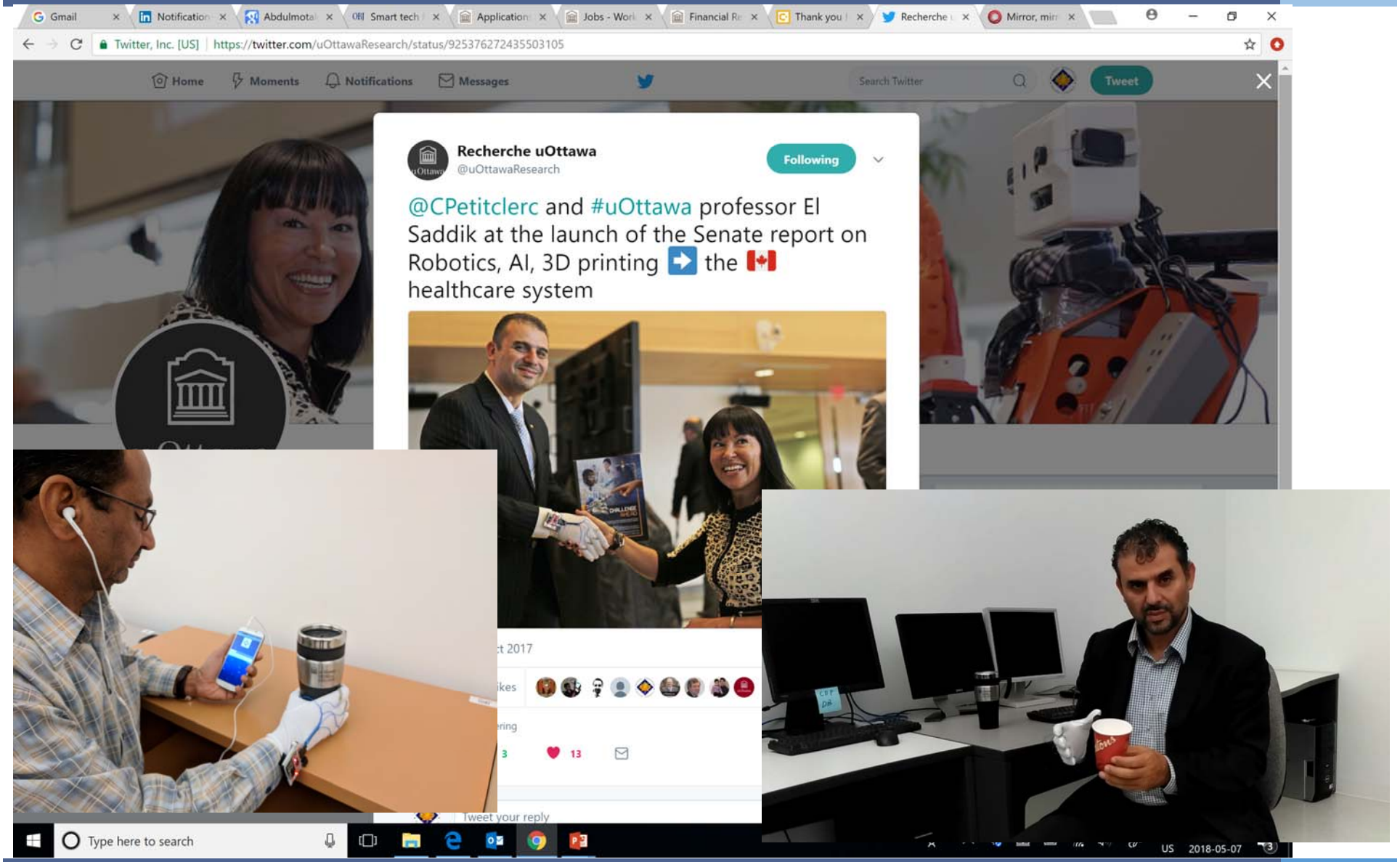
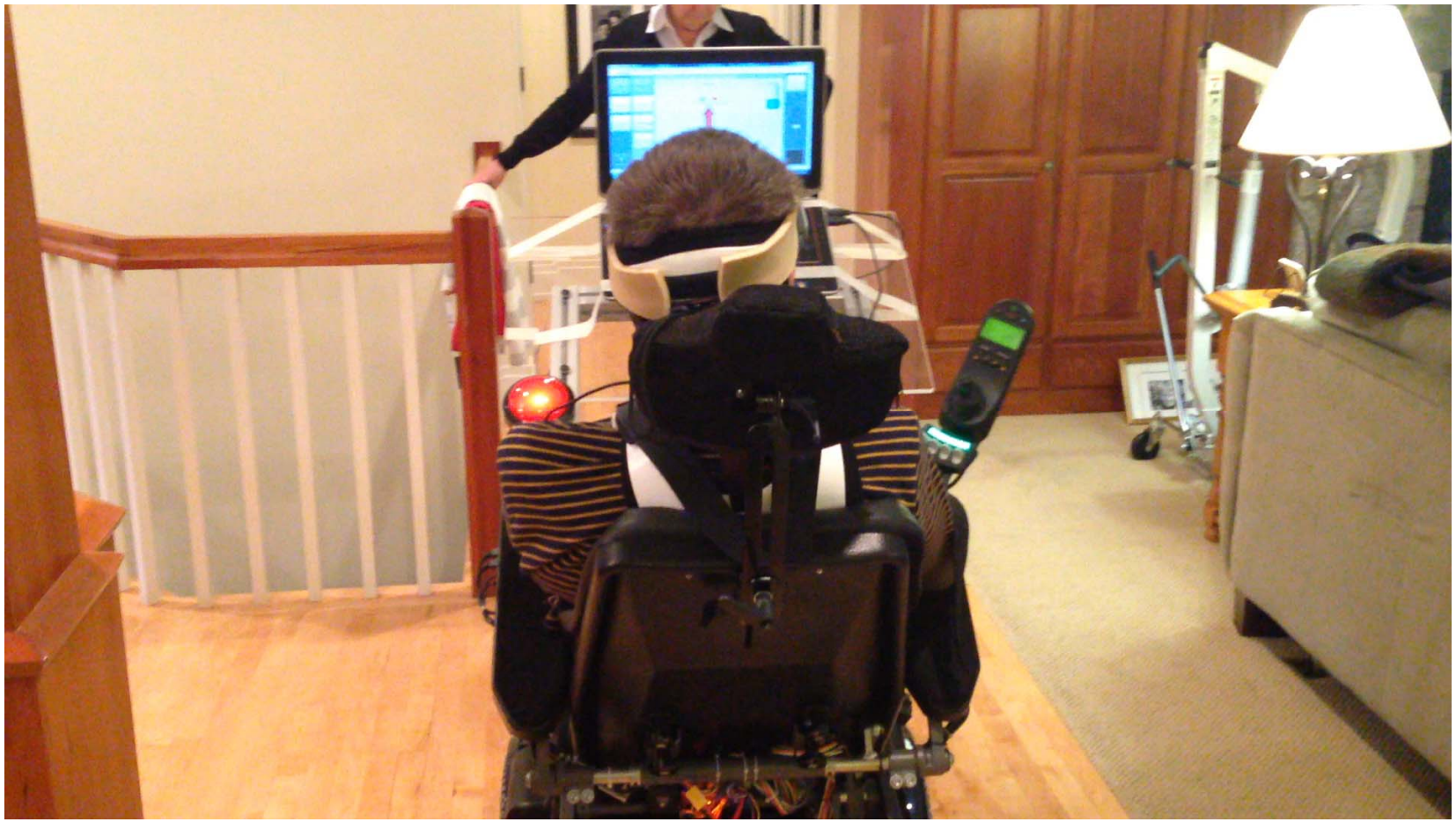

Fall Detection System

Smart gloves for diabetics



ALS – Eye Gaze, Sensors



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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

Final Thoughts

- Digital twin can act as a tool to remove the gender biases we see today in some domains
  - It gives hope for an inclusive society
- It will definitely challenge the existing power structures .
- Like we have the feminist movement,
  - we will soon have **anti-technology** movements on a grand and serious scale

Thank you for your attention!

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