ICT Virtual Organization of ASEAN Institutes and NICT
ASEAN IVO Forum 2016
Call for Presentations

Submission and Registration Form

Please enter the relevant information in the fields below, giving an appropriate explanation when necessary. You may add supplemental pages and supporting data. If necessary, you may be asked to provide additional documents.

I. Title—Title of presentation:

Transient wearable OS for healthcare solutions: 'Towards active healthy lifestyle'

II. Author(s)—Full name (First name family name):
(If you are already planning a project, please include the names of all team members)
SMN Arosha Senanayake[1], Abdul Ghani Naim[1], Daphne Teck Ching Lai [1], Owais A Malik[1] & Danish Zaheer[2]

III. Organization(s):
(If you are already planning a project, please include the institutions of all team members)
[1]Universiti Brunei Darussalam, [2]Sports Medicine & Research Centre (SMRC), Brunei Darussalam

IV. Topic selection:
(Select one from the topics listed in "Call for Presentations")

Smart Society

IV. Abstract:
(Describe the purpose, background, objectives, content, plans for connected projects, expected results/outcomes, etc.)

Purpose:
Gait abnormality and rehabilitation are major concerns on returning into daily active healthy lifestyle. In Brunei, 59.8% of Bruneians is overweight or obese and it is the highest indicator within ASEAN region. While eating habit is a major concern for overweight and obesity, cultural influence prevents taking precautions on the same. Hence, Brunei government started an initiative to closing down city center with no vehicles on the roads (in and out of city) every Sunday from 6AM – 10AM in order for its citizens to do walking, jogging, running and cycling on the roads which will allow not only healthy society as well as zero carbon emission from vehicles within this period. The purpose of this project is to examine and to provide transient wearable health OS solution such a way that each and every citizen is alerted on recovery status and recovery classification of gait abnormality and rehabilitation in real time.

Background:

Having done the extensive research on gait abnormality and rehabilitation of Brunei Soldiers and national athletes as reported in [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27], Industry Liaison Office of Universiti Brunei Darussalam has approved the university start-up IntelliHealth Solutions which covers comprehensive healthcare services for Brunei society: Reactive care services, clinic centric services and episodic response services. The details of the achievement shall be found in the websites; http://intelli-health.org/, https://www.researchgate.net/profile/Associate_Professor_Dr_S_M_N_Senanayake

This project is an extension to IntelliHealth Solutions focusing generalized solution for normal Brunei citizens. While IntelliHealth solutions has already achieved the establishment of reference standards of Brunei Citizens based on soldiers and national athletes (healthy citizens) using intelligent knowledge base formed (resident pattern storage in a centralized server), the goal of this project is to develop a transient wearable health OS solutions for transient pattern storage in real time with shared resource allocation for resident pattern storage already formed using intelligent knowledge base. This will allow real time monitoring of human test subject while performing real time walking, jogging, running and cycling. So far, resident pattern storage of soldiers and athletes has been established using smart data and decision fusion consisted of smart data analytics, ensemble learning, machine learning and AI techniques. The overall architecture of intelliHealth Solutions is illustrated in Figure 1 (refer annexure page 09).

Further real time gait abnormality and rehabilitation has been implemented using an Interactive Graphical User Interface (IGUI) based on case base reasoning as shown in Figure 2 (refer annexure page 10).

Objectives:

1. Design Hybrid Operating System architecture which allows the resource sharing of resident and transient pattern storage through smart device interfacing.
2. Design smart data interface using smart watch concept in order to acquire actual patter n set using smart sensing mechanisms (wearable sensors and vision) in real time. This will allow to create transient pattern storage.
3. Design 4GB memory storage, embed active RFID for clinical set up and interoperability of patient data within the hospital environment, in case of soldiers and athletes for their different training regimes at different locations (camps and stadiums) and data communication methods; wireless, Bluetooth and wireless mobile communication (3G, 4G) for transient pattern storage for data transmission/receive to/from the server.
4. Implement decision fusion techniques for transient pattern storage such a way that message is generated automatically to resident pattern storage once the temporary buffer/stack inside smart watch is full. This is the basis for discarding the transient pattern set if exists or/and will undergo case based reasoning to revise, to retrain and to repair resident pattern storage in order to update knowledge base using transient pattern storage.
5. Develop primary data visualization techniques to alert test subject on actual/current health (recovery) classification and health (recovery) status which are subject to three different criteria and protocols given by orthopedics', trainers/coaches, physiotherapists, etc; rehabilitation monitoring, injury prevention and performance enhancement. These protocols have been tested using IGUI already developed based on the so far published work by our research team.

Content:

General system architecture is shown in Figure 3 (refer annexure page 11) taking into co nsideration next generation smart health devices that can be developed. The objectives ar e achieved using the critical stages described below;

- Patient/athlete/soldier health (recovery) classification and status (progress/recovery) are permanently stored using resident healthcare OS in a server subject to hybrid OS arc hitecture.
- Health (recovery) classification and status (progress/recovery) are based on pre-clinical, clinical/lab/center and post-clinical historical health pattern set stored in a knowledge base.
- While actual/current health (recovery) classification and status (progress/recovery) are temporarily stored using transient healthcare OS in transient Healthcare smart watch O S at a clinic/lab/center or/and at a given instance.
- Decision fusion for health (recovery) classification and status (progress/recovery) are i mplemented using hybrid intelligent mechanisms. While Knowledge base of historical p attern set is governed by various hybrid computational intelligent techniques, case bas e reasoning is applied for transient pattern storage.
- Resident pattern storage is based on all pre-clinical, clinical/lab/center and post-clinical historical health pattern set which are always incomplete pattern set of any test subj ect undergoing through decision fusion. Hence, updating knowledge base is a continuo us process based on the current (actual) pattern set generated in real time.
- Transient patter set is fully formed in real time, thus smart watch is used to store tra nsient pattern set temporarily which is subject to applying case base reasoning to revi se, to retrain and to repair resident pattern storage in order to update knowledge bas e using transient pattern storage.
- Smart watch is required to store transient pattern storage which generates a message automatically to resident pattern storage for the decision fusion on discarding the tra nsient pattern set generated using smart watch or/and will undergo case based reason ing to update the knowledge base
- Hence, smart watch is required to provide 4GB memory for transient pattern storage and flushing the transient pattern storage is subject to the above complete process, o therwise transient pattern set is permanently stored until new pattern set is generated or discarded the transient patter set subject to case base reasoning process applied above.
- In the hospital (clinical set up), sports medicine and research center and soldiers/polic e camps environment, smart watch must allow inter-operability among clinics, centers and labs with different specialists leading to different decision making processes. Thus, different transient pattern set will be generated which will undergo case base reasoni ng interfaced with decision fusion techniques in real time. Therefore, the inclusion of RFID is required to track transient pattern set IDs, usually based on patient, national athlete and soldier/police unique ID, but not necessary to be, as an example specific pool of national athletes' performance enhancement analysis; 6 national players of sho t put, javelin discuss, etc monitored by trainers, physiotherapists, physical strength con ditioning specialists, etc.
- Transient pattern set is generated via data communication methods; wireless, Bluetoot h, wireless mobile communication such as 3G, 4G etc subject to availability of integrat ed sensors during real time data acquisition such as vision, accelerometers, gyroscopes,

inertia or/and wearable sensors.

- Primary data visualization is health (recovery) classification and (progress/recovery) sta tus. Both health (recovery) classification and status (progress/recovery) is subject to t hree different criteria; rehabilitation monitoring, injury prevention and performance enh ancement. Example; Rehabilitation means, recovery classification and recovery status.

Thus, set of critical processes involved during the implementation is illustrated in the Figu re 4 (refer annexure page 12) and laboratory set up for prototype testing will be carried out in a clinical set up as shown in Figure 5 (refer annexure page 13).

Plans for Connected Projects:

Connected projects for this is IntelliHealth Solutions which was established as a UBD start -up in November 2015. Based on the invitation received from UMCH Technology Sdn Bhd, Malaysia, IntelliHealth Solutions signed the MoU during 1 ASEAN Entrepreneurship Summi t held Kuala Lumpur, Malaysia, December 2015 as per the website: (http://1aes.my/). Pri mary goal of this MoU is next generation smart health devices built under IntelliHealth sol utions reaching to ASEAN regional market jointly with UMCH Technology Sdn Bhd within n ext 5 years. The expectation of this proposal is to attract state-of-the-art Smart Watch co ncept in order to develop hybrid OS architecture which is novel and applicable in niche ar eas than the use of smart watch by general public with general applications developed an d available in the current market.

Further this project is partially supported by Human Performance of Lab (HPL) at the Perf ormance Optimization Centre of Ministry of Defense, Brunei, Sports Medicine and Research Centre, Brunei, Rehabilitation Centre of RIPAS Hospital in Brunei and Brunei Neuroscience, Stroke and Rehabilitation Centre (BNSRC), in particular soldiers, national athletes and pati ents.

All connected projects are also available in the following websites;

1. http://intelli-health.org/
2. https://www.researchgate.net/profile/Associate_Professor_Dr_S_M_N_Senanayake

Expected Results/Outcomes:

The overall outcome of this project is to develop transient wearable OS for healthcare of general public with its own vision 'towards active healthy lifestyle' during walking, jogging, running and cycling on each Sunday at the city center in order to monitor gait and reha bilitation of Brunei obese community the highest in the ASEAN region. Initially, within next two years, smart watch concept will be proven in the laboratory and clinical environment before being available for general public.

The results of this project reflects the following critical attributes which are the key durin g decision making processes of different specialists involved; trainers, coachers, physiother apists, physical strength and conditioning specialists, orthopedics, etc:

- Data with no human intervention
- Redundancy and reproducibility of data
- Access to most recently stored data
- Access to actual data with no transmission

References:

Patents:

1. TRANSIENT HEALTHCARE SMART WATCH OPERATING SYSTEM AND METHOD, BRUNEI PAT ENT NO: BN/N/2016/0065, Intellectual Property Office (IPO) Brunei Darussalam.
2. System and Method for Muscle Tracking and Detection, Brunei Patent Application No: BN/N /2016/0061, Intellectual Property Office (IPO) Brunei Darussalam.
3. REAL TIME BIOFEEDBACK MECHANISM AND DATA PRESENTATION FOR KNEE INJURY REH ABILITATION MONITORING AND A SOFT REAL TIME INTELLIGENT SYSTEM THEREOF, (Bru nei Patent filed with Patent Number: BN/N/2014/0036; PCT/IB2015/051510): https://patent scope.wipo.int/search/en/detail.jsf?docId=WO2015150931
4. FORCE SENSING DEVICE AND METHOD FOR REAL-TIME CONTROL AND VISUALISATION O F DATA FROM A FORCE SENSING DEVICE (Patent filed with Malaysian Patent number: PI 2008516)

Book Chapters – commercial publisher:

1. Dk Nurhayatul Filzah Pg Damit, **S. M. N. Arosha Senanayake**, Owais Malik and Pg Hj N or Jaidi Pg Tuah, "Pattern Recognition of Brunei Soldier's Based on 3-Dimensional Kinemati cs and Spatio-Temporal Parameters", N.T. Nguyen et al. (Eds.): Intelligent Information and Database Systems, part II, Lecture Notes in Artificial Intelligence (LNAI) 9622, Springer-Ver lag, Berlin Heidelberg, Vol. 9622, pp. 713-722, March 2016, DOI: 10.1007/978-3-662-49390 -8_69.
2. Putri Wulandari, **S. M. N. Arosha Senanayake,** Owais Ahmed Malik, "A Real-Time Intellig ent Biofeedback Gait Patterns Analysis System for Knee Injured Subjects", N.T. Nguyen et al. (Eds.): Intelligent Information and Database Systems, part II, Lecture Notes in Artificial Intelligence (LNAI) 9622, Springer-Verlag, Berlin Heidelberg, Vol. 9622, pp. 703-712, Marc h 2016, DOI: 10.1007/978-3-662-49390-8_68.
3. Joko Triloka, **S. M. N. Arosha Senanayake**, Daphne Lai "An Integrated Pattern Recogniti on System for Knee Flexion Analysis", N.T. Nguyen et al. (Eds.): Intelligent Information an d Database Systems, part II, Lecture Notes in Artificial Intelligence (LNAI) 9622, Springer-Verlag, Berlin Heidelberg, Vol. 9622, pp. 723-732, March 2016, DOI: 10.1007/978-3-662-4 9390-8_70.
4. Umar Yahya, **S. M. N. Arosha Senanayake**, Daphne Lai "An EMG Knowledge-Based Syst em for Leg Strength Classification and Vertical Jump Height Estimation of Female Netball P layers", N.T. Nguyen et al. (Eds.): Intelligent Information and Database Systems, part II, L ecture Notes in Artificial Intelligence (LNAI) 9622, Springer-Verlag, Berlin Heidelberg, Vol. 9 622, pp. 733-741, March 2016, DOI: 10.1007/978-3-662-49390-8_71.
5. Owais Ahmed Malik, **S. M. N. Arosha Senanayake**, "An Interval Type-2 Fuzzy Logic Base d Classification Model for Testing Single-Leg Balance Performance of Athletes after Knee Su rgery"**,** Proceedings of the 10th International Symposium on Computer Science in Sports (I SCSS), Volume 392 of the series Advances in Intelligent Systems and Computing pp 85-92, 2016.

Peer Review Journal Publications:

6. D. N. Filzah Pg Damit, **S. M. N. Arosha Senanayake**, Owais Malik and Pg Hj Nor Jaidi Pg Tuah," Instrumented measurement analysis system for soldiers' load carriage movement

using 3-D kinematics and spatio-temporal features", Measurement, Elsevier, pp. 230-238, Vol. 95, January 2017, First Online: 16 October 2016, http://dx.doi.org/10.1016/j.measurement.2016.10.017

7. Joko Triloka, **SMN Arosha Senanayake**, Daphne Lai "Neural computing for walking gait pattern identification based on multi-sensor data fusion of lower limb muscles", Neural Computing and Applications, Springer London, pp 1-13, First Online: 20 April 2016, 10.1007/s00521-016-2312-x.
8. **SMN Arosha Senanayake**, Joko Triloka, Daphne Lai, "Influence of Knee Flexion during Squat with and without Load using an integrated Knee-flexion Analysis System", Journal of Musculoskeletal Research, Vol. 18, No. 3 (2015) 1550014 (19 pages), © World Scientific Publishing Company, DOI: 10.1142/S0218957715500141.
9. **SMN Arosha Senanayake**, Owais Ahmed Malik, Danish Zaheer, "A Multi-Sensor Integration Based Complementary Tool for Monitoring Recovery Progress of Anterior Cruciate Ligament Reconstructed Subjects", IEEE/ASME Transactions on Mechatronics, IEEE, USA Oct. 2015 issue, vol. 20, issue 5, pp. 2328-2339; DOI:10.1109/TMECH.2014.2376199.
10. Owais A Malik, **S M N Arosha Senanayake**, Danish Zaheer, "An Intelligent Recovery Progress Evaluation System for ACL Reconstructed Subjects Using Integrated 3-D Kinematics and EMG Features", IEEE Journal of Biomedical and Health Informatics (IEEE J-BHI), ISSN 2168-2194, Vol. 19, Issue 2, pp. 453-463, March 2015; DOI: 10.1109/JBHI.2014.2320408.
11. Arunie Upeksha .Alahakone, **S. M. N. Arosha Senanayake,** "Improving lower extremity joint kinematics during jump landing using an automated vibrotactile biofeedback system", International Journal of Autonomic Computing, Inderscience Publishers, Vol. 2, No. 1, pp. 39-53, February 2014, **DOI**: 10.1504/IJAC.2014.059110.
12. **SMN Arosha Senanayake**, Owais Ahmed Malik, Pg. Mohammad Iskandar, Danish Zaheer, "A Knowledge-Based Intelligent Framework for Anterior Cruciate Ligament Rehabilitation Monitoring", *Journal of Applied Soft Computing (impact factor 2.140), Elsevier,* ISSN 1568-4946, Vol. 20, pp. 127 -141, July 2014, http://dx.doi.org/10.1016/j.asoc.2013.11.010.
13. **SMN Arosha Senanayake**, Owais Ahmed Malik, Danish Zaheer,"An Intelligent Recovery Progress Evaluation System for ACL Reconstructed Subjects Using Integrated 3-D Kinematics and EMG Features", IEEE Journal of Biomedical and Health Informatics, IEEE, USA (accepted), 2014.
14. **SMN Arosha Senanayake**, Owais Ahmed Malik, and Pg. Mohammad Iskandar , Assessing post anterior cruciate ligament reconstruction ambulation using wireless wearable integrated sensors, Journal of Medical Engineering and Technology, Vol. 37, No. 8, pp. 498-510, November 2013; Early Online: 1–13 ©2013 Informa UK Ltd. DOI: 10.3109/03091902.2013.837529, ISSN: 0309-1902, October, 2013**.**
15. **S. M. N. Arosha Senanayake**, Owais Ahmed Malik, Pg. Mohammad Iskandar, Dansih Zaheer: Anterior cruciate ligament recovery monitoring system using hybrid computational intelligent techniques. Int. J. Hybrid Intelligent Systems. 10(4): 215-235 (2013), ISSN 1448-5869, DOI: 10.3233/HIS-130178.
16. **SMN Arosha Senanayake**, Owais Ahmed Malik, and Pg. Mohammad Iskandar , Integrating Multi-Sensors for Observing Post ACL Reconstruction Recovery Progress, Transaction on Control and Mechanical Systems (TCMS), ID# 149, Vol. 2, No. 4, April 2013.

Invited Talks

17. Invited to organize special session on Smart Pattern Processing for Sports (SP^2S), at the 8th Asian Conference on Intelligent Information and Database Systems (ACIIDS 2016), March 14-16, 2016, Da Nang, Vietnam, https://aciids.pwr.edu.pl/2016/src/ACIIDS_2016_Special_Se

ssion_(SP2S_2016)_CFP_v.3.0.pdf

18. Fourth International Conference on Eco-friendly Computing and Communication Systems (IC ECCS – 2015), "IntelliHealth (Intelligent Digital Healthcare Services)", December 6-8, 2015, National Institute of Technology, Kurukshetra, India, http://iceccs.in/Plenary.asp
19. 1 ASEAN Entrepreneurship Summit – 2015: U-Start Tigers Roar IV , "IntelliHealth Solution s", November 16-22, 2015, Kuala Lumpur, Malaysia, http://1aes.my/
20. Forum Panelist of the Humanity Forum for Movement Impaired Children, in conjunction wit h IECBES2014 (2014 IEEE Conference on Biomedical Engineering and Sciences) under IEEE motto "Advancing Technology for Humanity", December 7-11, 2014, Miri, Malaysia, http://w ww.ieee.org/conferences_events/conferences/conferencedetails/index.html?Conf_ID=32297
21. The 1st International Joint Meeting among Partner Universities, "UBD Sciences", December 17-18, 2014, Gifu University, Japan, http://www.eng.gifu-u.ac.jp/news_en/2015/04/ijmdec201 4.html
22. Invited Speaker: S. M. N. Arosha Senanayake for invited session, Wearable Sensors and Bo dy Area Sensor Networks for Activity Monitoring: Advances in Understanding of Human Acti vity, 35th Annual International IEEE Electronics in Medicine and Biology Society (EMBS) Co nference, pp. 7221 – 7225, ISBN 978-1-4577-0216-7/13/$26.00 ©2013 IEEE,, Osaka Intern ational Convention Center, July 3-7, 2013 Osaka, Japan, http://embc2013.embs.org/
23. General Chair of 4th International Conference on Soft Computing and Pattern Recognition (SoCPaR 2012), Institute of Electrical and Electronics Engineers (IEEE), USA, ISBN 978-1-4 673-5118-8;2012 IEEE, December 10-13, 2012, The Core, UBD, http://www.mirlabs.org/soc par12/

International Peer Review Referred Conference Publications:

24. Owais A. Malik, **S. M. N. Arosha Senanayake, *Senior Member, IEEE*** , Danish Zaheer, "An Adaptive Interval Type-2 Fuzzy Logic Framework for Classification of Gait Patterns of Anterior Cruciate Ligament Reconstructed Subjects", Proceedings of 2014 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) : World Congress on Computational Intelligence, pp. 1068-1075, ISBN 978-1-4799-2072-3/14/$31.00 ©2014 IEEE, July 6-11, 2014, Beijing, China.
25. **S. M. N. Arosha Senanayake, *Senior Member, IEEE*** , Joko Triloka, Owais A. Malik, M ohammad Iskandar, Pg, "Artificial Neural Network Based Gait Patterns Identification Using Neuromuscular Signals and Soft Tissue Deformation Analysis of Lower Limbs Muscles", Proc eedings of 2014 International Joint Conference on Neural Networks (IJCNN) : World Congr ess on Computational Intelligence, pp. 3503-3510, ISBN 978-1-4799-1484-5/14/$31.00 ©20 14 IEEE, July 6-11, 2014, Beijing, China.
26. **S. M. N. Arosha Senanayake, *Senior Member, IEEE*** , Owais A. Malik, Mohammad Isk andar, Pg., and Danish Zaheer, "3-D Kinematics and Neuromuscular Signals' Integration for Post ACL Reconstruction Recovery Assessment", **Invited Speaker: S. M. N. Arosha Sen anayake for invited session, Wearable Sensors and Body Area Sensor Networks for Activity Monitoring: Advances in Understanding of Human Activity, 35th Ann ual International IEEE Electronics in Medicine and Biology Society (EMBS) Confe rence, pp. 7221 – 7225, ISBN 978-1-4577-0216-7/13/$26.00 ©2013 IEEE,, Osa ka International Convention Center, in Osaka, Japan**.
27. **Senanayke, SMN Arosha** , Malik, Owais Ahmed, Iskandar, Pg. Mohammad, Zaheer, Dan sih, "A Hybrid Intelligent System for Recovery and Performance Evaluation After Anterior Cr uciate Ligament Injury", Intelligent Systems Design and Applications (ISDA), 2012 12th IEE E International Conference on, November 2012, **ISBN:** 978-1-4673-5117-1, pp. 986-991.

V. Speaker information:

Full name: SMN Arosha Senanayake
Institute: Universiti Brunei Darussalam
Address: C2-17, Motion Analysis Lab, Integrated Science, Universiti Brunei Darussalam, Jalan Tungku Link, Gadong, BE-1410, Brunei-Maura, Brunei Darussalam
Telephone: 6737148124
E-mail: arosha.senanayake@ubd.edu.bn

VI. Support for speaker—circle or underline any that you wish to request:

- ⊙ Round trip fare at discount economy class
- ⊙ Accommodation




Layer 9 — Smart Data Interface

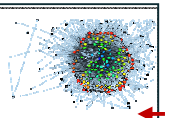
Layer 8 — Smart Device Interfacing

Layer 7 — Transient Pattern Storage

Layer 6 — Smart Data and Fusion

Smart Data Analytics

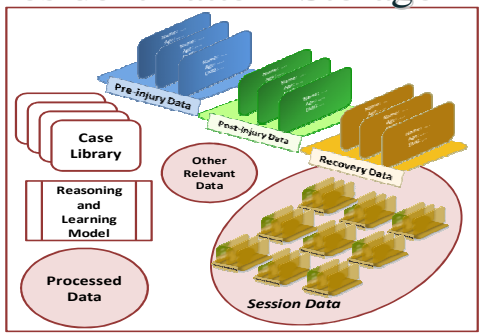
Clustering Techniques

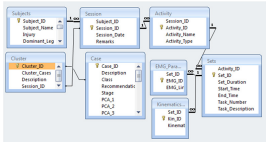


Machine Learning/AI Techniques

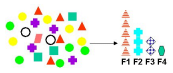
Ensemble Learning

Resident Pattern Storage

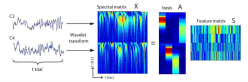




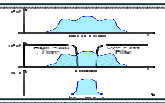
Layer 5 — Feature Selection and Transformation



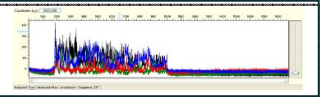
Layer 4 — Relevant Feature Extraction



Layer 3 — Signals' Filtering and Pre-Processing



Layer 2 — Raw Signal Collection

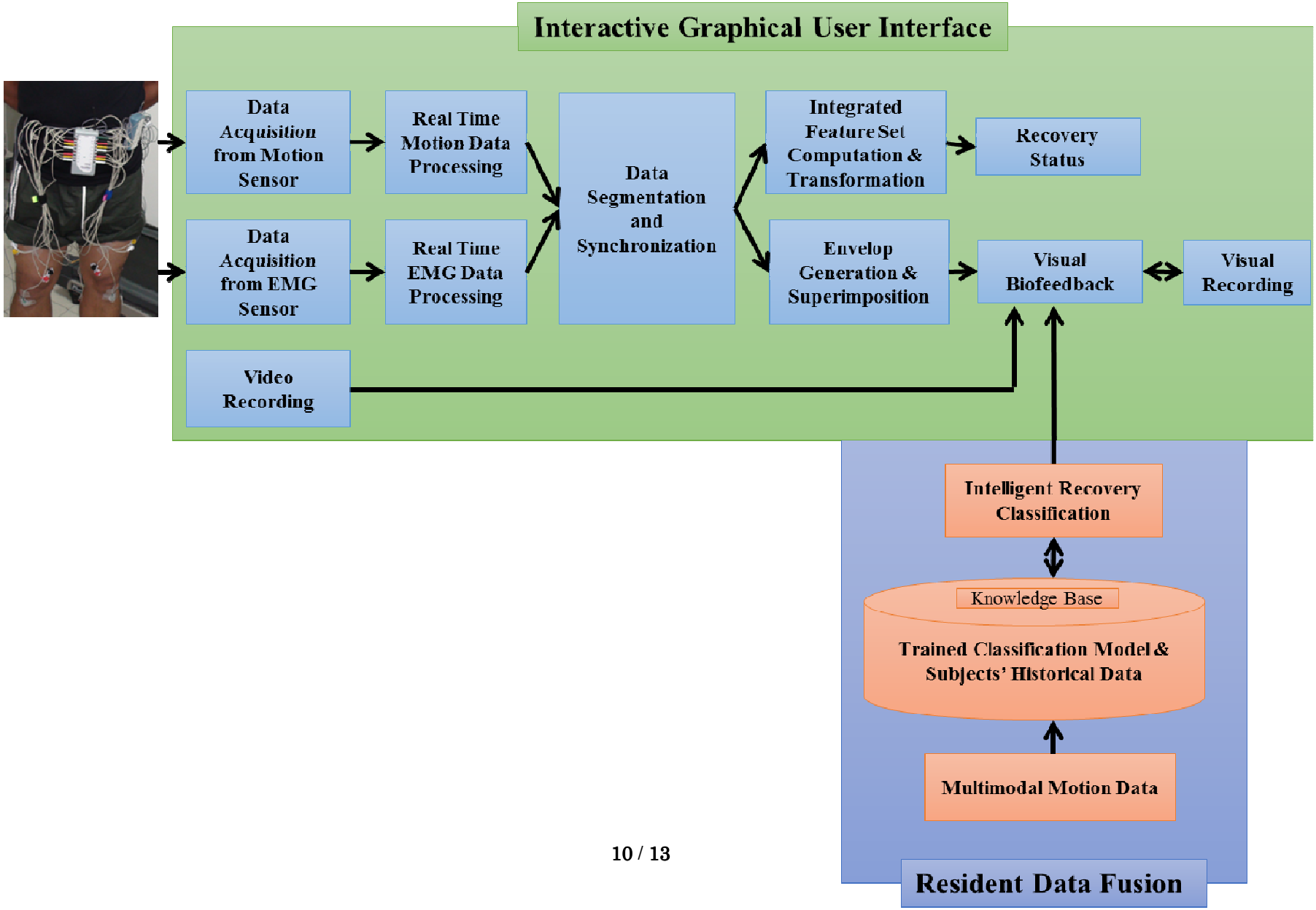


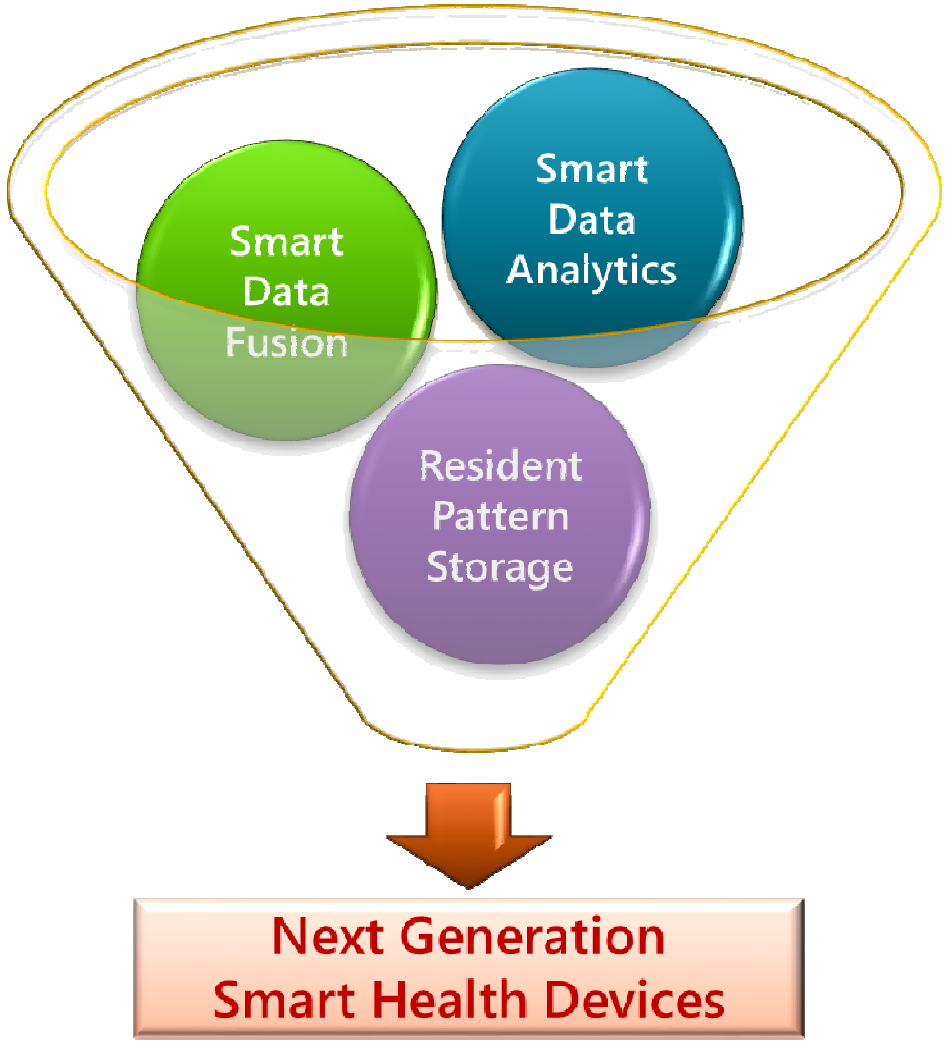
Layer 1

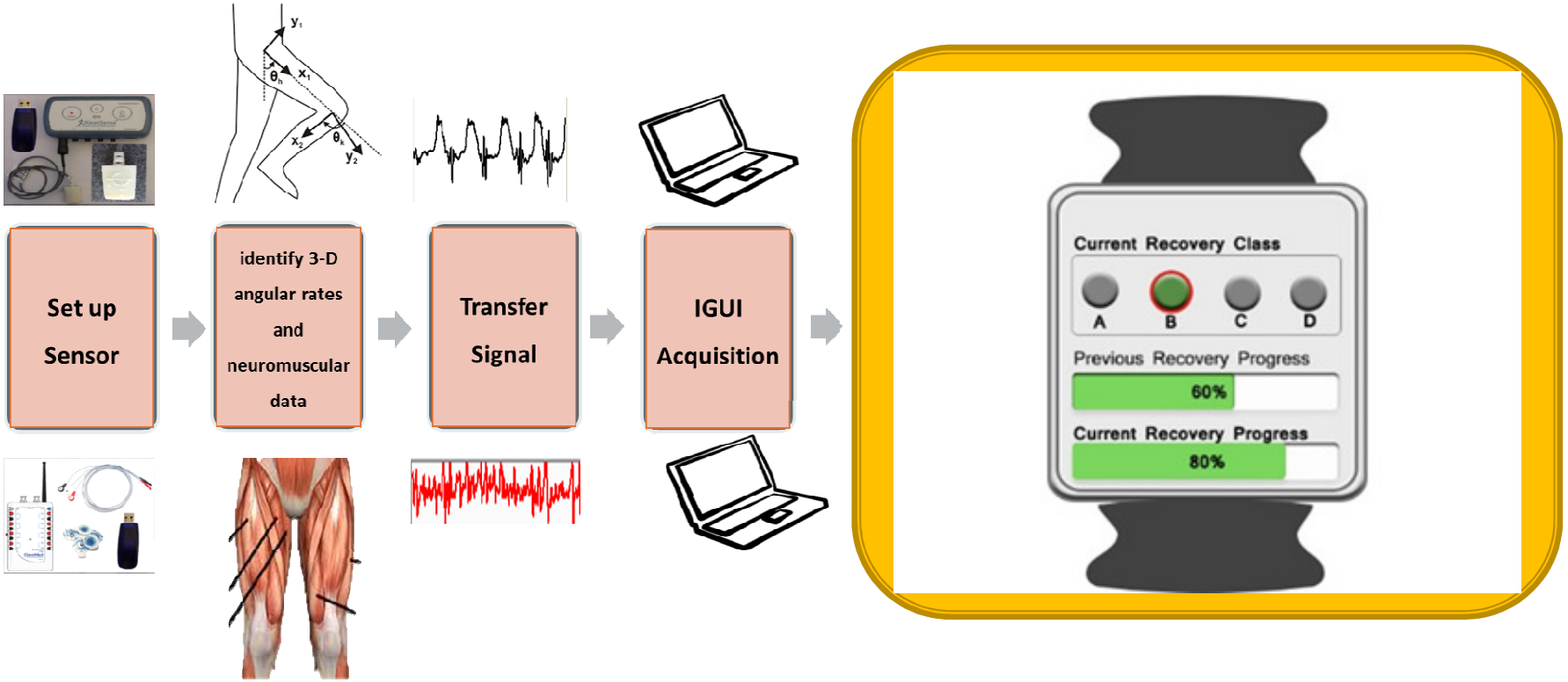


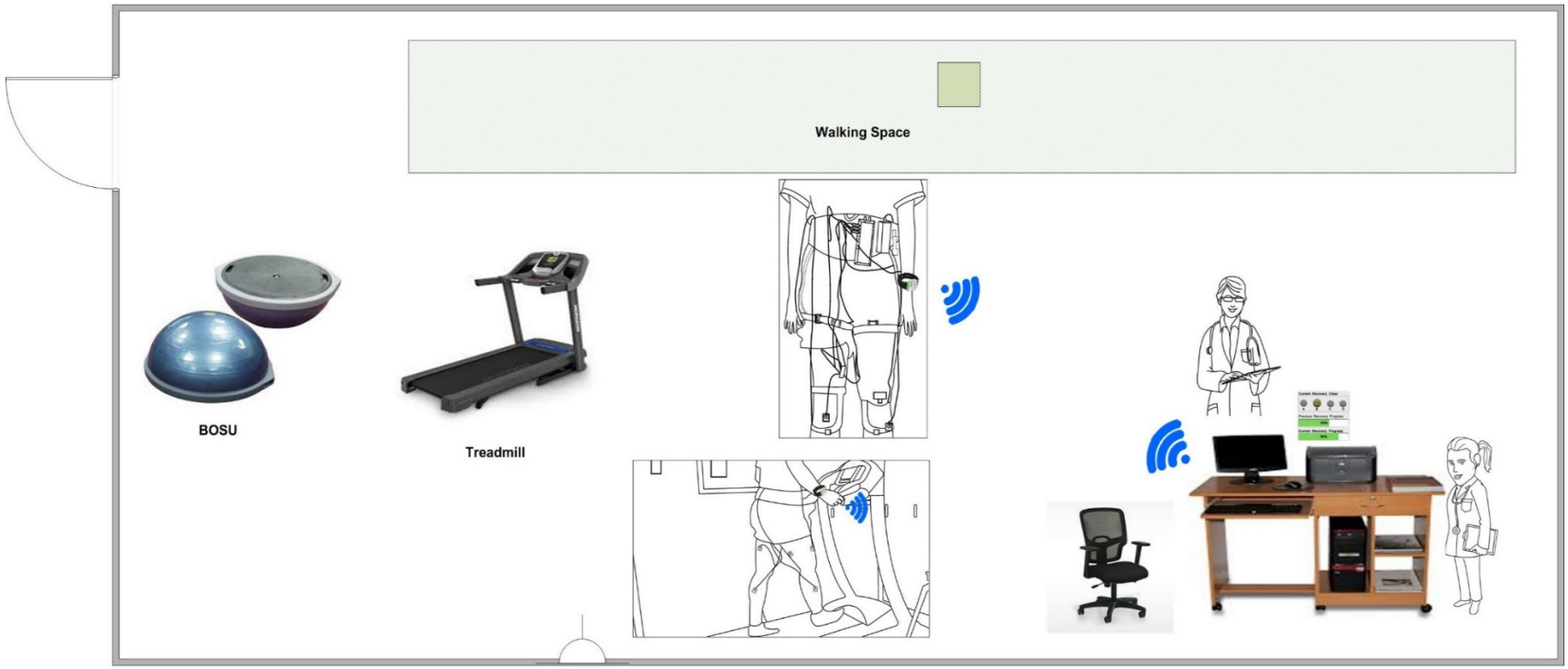





Interactive Graphical User Interface
Data Acquisition from Motion Sensor
Real Time Motion Data Processing
Data Acquisition from EMG Sensor
Real Time EMG Data Processing
Data Segmentation and Synchronization
Integrated Feature Set Computation & Transformation
Recovery Status
Envelop Generation & Superimposition
Visual Biofeedback
Visual Recording
Video Recording
Intelligent Recovery Classification
Knowledge Base
Trained Classification Model & Subjects' Historical Data
Multimodal Motion Data
Resident Data Fusion


Smart
Data
Fusion
Smart
Data
Analytics
Resident
Pattern
Storage
Next Generation
Smart Health Devices


Set up Sensor
identify 3-D angular rates and neuromuscular data
Transfer Signal
IGUI Acquisition
Current Recovery Class
A
B
C
D
Previous Recovery Progress
60%
Current Recovery Progress
80%


Walking Space
BOSU
Treadmill