Augmented Intelligence System for Personalized Patient Lifestyle Improvement based on Wearable Data

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1 AI FOR WEARABLE ANALYTICS

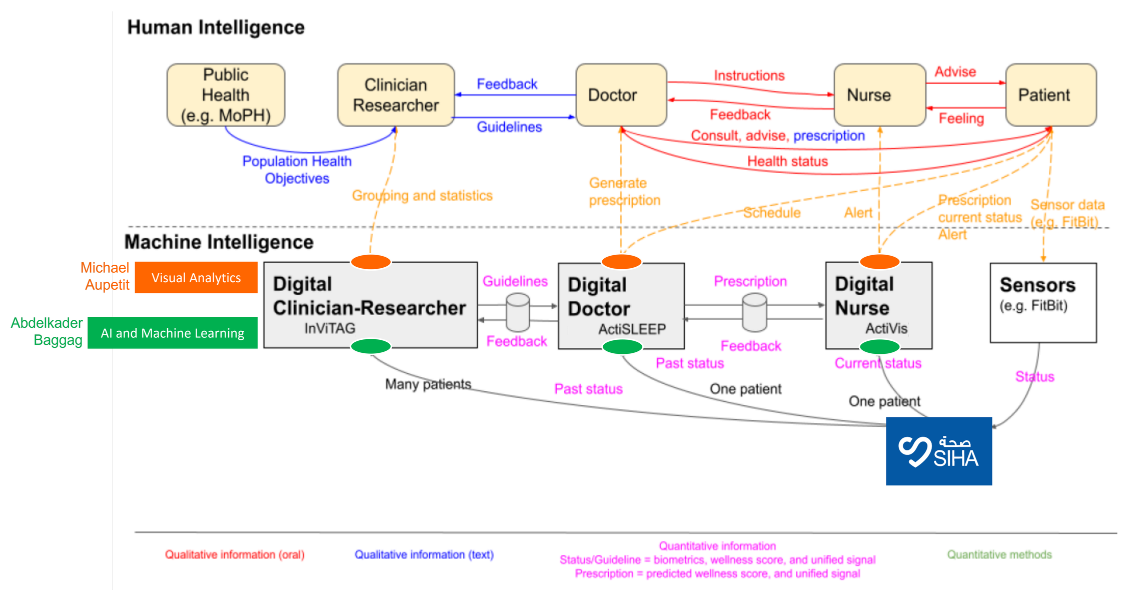


Figure 1: The augmented intelligence system is made of interactive visualizations and machine learning processes, to support health care professionals to help patient get better lifestyle. Wearable data flow through three interconnected components: the **Digital-Clinician-Researcher**, the **Digital-Doctor** and the **Digital-Nurse**.

- **Health is one of the pillars of Qatar National Vision 2030** with the objective of "individualized healthcare and disease prevention driven by emerging research, clinical approach, environment, and lifestyle".
- **Diabetes and obesity** are significant health problems globally and are particularly prevalent in Qatar.
- These serious conditions are driven by lifestyle factors that require a **coordinated effort from clinicians and new technologies**.
- Health care professionals need **smart solutions to help the patients**.

We propose an **augmented intelligence integrated system** (Figure 1)[IP2] designed to support *clinician-researchers, doctors, and nurses to help patients with diabetes or obesity* get a more healthy lifestyle.

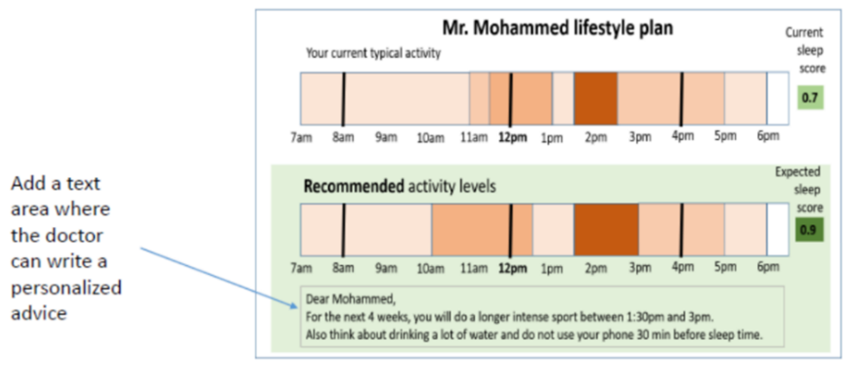
This system supports analysis of clinical data from cohort of patients (InViTAG) and builds on them to recommend physical activities (ActiSLEEP) that may lead to better sleep quality, in order to reduce weight and manage type-2 diabetes. It uses data-driven artificial intelligence models, user-centered designed interactive interfaces, and wearable devices and works as follows:

1) The *Public-Health Authority* (e.g. MoPH) sets up general health objectives for the population (e.g. reduce diabetes or obesity).
2) Each *Patient* generates health status data (biometric data and unified signals from wearable sensors) that the *Clinician-Researcher*, supported by the **Digital-Clinician-Researcher** (InViTAG)[1][2][IP1][IP3], aggregates, summarizes and groups in relation to the optimization of a wellness score (e.g. sleep quality) derived as a proxy from the health objectives.
3) The optimal status for a group of patients generated by the **Digital-Clinician-Researcher** (also known as guidelines), is shared with Doctors through the **Digital-Doctor** interface.
4) The *Doctor*, supported by the **Digital-Doctor** (ActiSLEEP)[IP4], uses that group-optimum status and the *Patient*'s status, to provide a prescription (unified signal and predicted wellness score) taking into account their constraints (e.g. time schedule, health status, maximum level of physical activity) in order to optimize the personalized wellness score of the *Patient*.
5) The *Nurse*, supported by the **Digital-Nurse** (ActiVis)[3], helps the Patient to follow the prescription and advises or alerts the Patient.

2 ML MODELS FOR WEARABLES

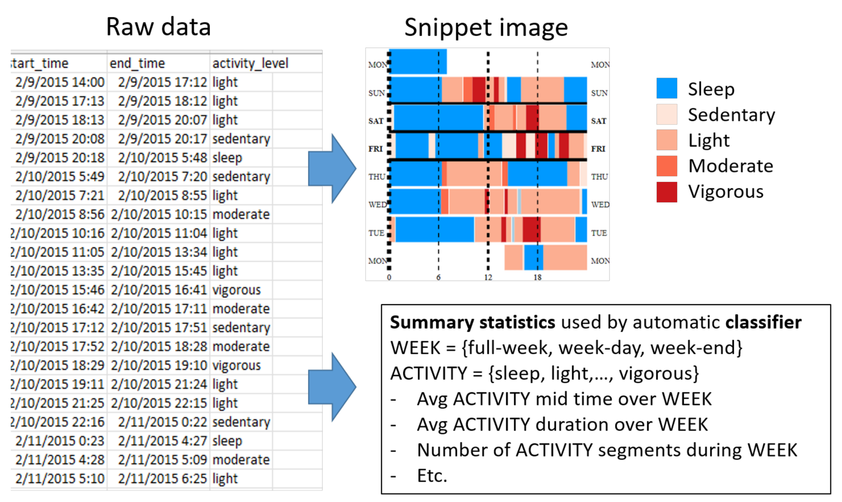
An essential characteristic of the system is that input and output signals across all the components of the system are all of the same type (sequence of states) hence unified. And an essential characteristic of the signal is it is always interpretable and actionable by any of the human agents interacting with these components of the system.

ActiSLEEP is the interface to support the *Doctor* in scheduling physical activities and sleep to improve the wellness score of the patient. It has a recommendation functionality to recommend change of activity for the patient to improve her sleep quality.



Challenge 1: Data representation – The data is not easy to encode as feature vectors input for machine learning models.

- Data from wearable sensors + other physio + demographics + food pictures: QUEST project (2016-2017), two schools in Qatar, 243 children, 1-week measurements.
- **Solution:** Histogram-based descriptors via Optimal Transport (Wasserstein, Sliced Wasserstein).



Challenge 2: Development of a prototypical behavior of each patient to support analysis by clinicians.

- **Solution:** Barycenter with Wasserstein metric.

Challenge 3: Generate activity recommendation that improves wellness while being compatible with patient's life, health and biometrics.

- **Solution:** a recommendation system based on these data and a health-based reward signal could recommend a certain sequence of states (i.e., physical activities) to improve health; starting with a barycenter or sequence of best wellness score.

  A classifier could predict the quality of sleep given such a sequence of states and provide explanatory factors.

Challenge 4: Explanatory factors to support Doctor-Patient discussion and Patient engagement during consultation depends on information granularity (from minute-level activity details to coarse "30 minutes per day" World Health Organization guideline).

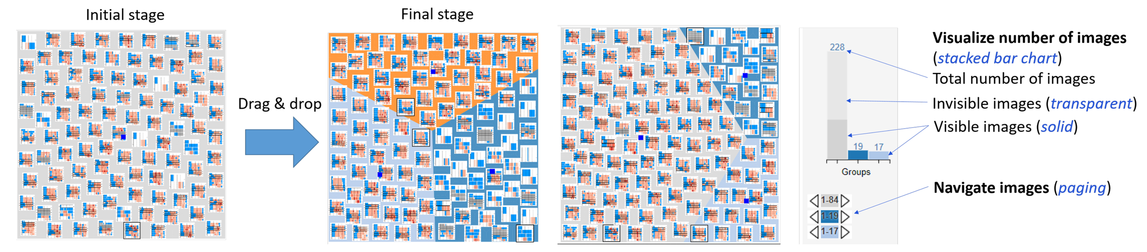
- **Solution:** Prototypical sequence of states based on Wasserstein metric and predicted wellness score extracted from large datasets could provide the right scale to give explanatory summaries of behavioral data.

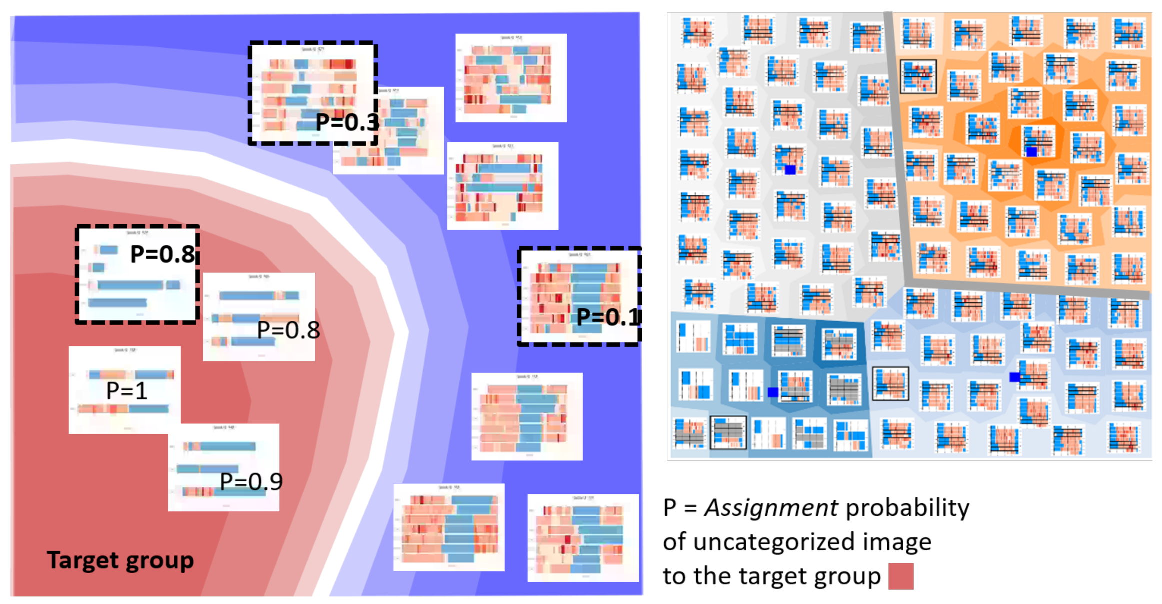
3 INTERACTIVE VISUALIZATION

Integrating interactive visualization with machine learning techniques seamlessly is the main user experience challenge. All visual interfaces are unique to their user's needs:

- the *Clinician-Researcher* explores clinical data from cohorts of hundreds of patients. There are challenges in terms of interactively grouping many patient data based on patterns of activity. Specific visual encoding are required to seamlessly manipulate that number of data assisted with machine learning techniques (InViTAG)[1][2][IP1][IP3].
- the *Doctor* prepares a physical activity plan for the *Patient*. The interactive visualization must let them co-design the plan based on patient capacity, time schedule and other constraints, while giving guidance to select the best activity option [IP4].
- the *Nurse* checks that the *Patient* is following the prescription. The interface indicates out of range indicators, and helps the patient follows of the target plan [3].

InViTAG is the interface for the *Clinician-Researcher*:

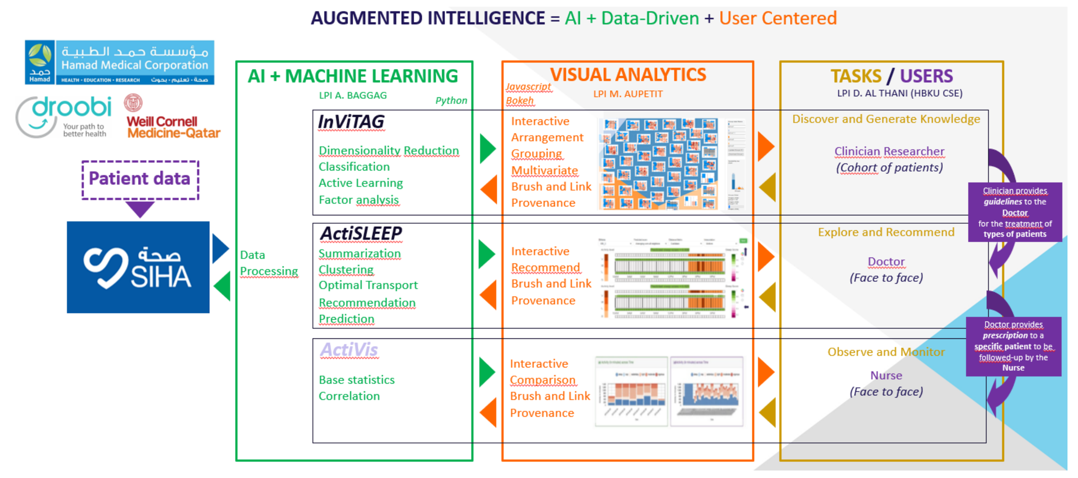




4 IMPACT AND COMMERCIALIZATION

- Raising awareness of wearable technology potential through multiple formative evaluations and collaborative design workshops with health care professionals.
- Develop a portfolio of application use cases to attract investors.
  - The InViTAG system final (summative) evaluation with HMC and Weill Cornell Medicine Qatar clinicians is planned for 2023 T2.
  - The ActiSLEEP system is designed in collaboration with doctors and educators in the HMC diabetes clinic.
- Commercialization objective. One step towards commercialization is to have patents.
  - A complete portfolio of 4 Invention Disclosures and 1 US Patent are with the Office of Industry Development and Knowledge Transfer (IDKT) of Qatar Foundation.

5 CLUSTER QNRF GRANT



NPRP11C-0115-180010 Qatar Diabetes Prevention Program.

[LPI1] A. Baggag, Lead PI of Work Package 7.4 "Data-Driven Models for Health and Lifestyle Analytics"

[LPI2] M. Aupetit, Lead PI of Work Package 7.3 "Visual Analytics"

6 PATENT, INVENTION DISCLOSURES

[IP1] Ala Abuthawabeh, Michael Aupetit. "Interactive visual data categorization systems and methods" US Patent 11/01/2022 US11222453

[IP2] Abdelkader Baggag, Michael Aupetit. "Augmented Intelligence System for Patient Health Improvement based on Wearable Data" # D2022-0072

[IP3] Abdelkader Baggag, Ala Abuthawabeh, Michael Aupetit. "Zamanya-InViTAG for active learning for scalable arrangement and grouping of wearable data" # D2022-0035-01

[IP4] Abdelkader Baggag, Michael Aupetit. "ActiWish" # D2020-118

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[1] Ala Abuthawabeh, Abdelkader Baggag, and Michael Aupetit. Augmented Intelligence with Interactive Voronoi Treemap for Scalable Grouping: a Usage Scenario with Wearable Data. In Marco Agus, Wolfgang Aigner, and Thomas Hoellt, editors, *EuroVis 2022*. The Eurographics Association, 2022.

[2] Michael Aupetit, Ahmed Ali, Abdelkader Baggag, and Halima Bensmail. Classmat: a matrix of small multiples to analyze the topology of multiclass multidimensional data. In *2022 Topological Data Analysis and Visualization (TopoInVis) @ IEEE VIS*, pages 70–80, 2022.

[3] Kamran Khowaja, Wafa Waheeda Syed, Meghna Singh, Shahrad Taheri, Odette Chagoury, Dena Al-Thani, and Michaël Aupetit. A participatory design approach to develop visualization of wearable actigraphy data for health care professionals: Case study in qatar. *JMIR Hum Factors*, 9(2):e25880, Apr 2022.

Acknowledgements

We plan to run a quantitative user study as part of the QNRF Qatar Diabetes Prevention Program NPRP11C-0115-180010, to evaluate thoroughly the usefulness and usability of this Augmented Intelligence System, and its benefits in terms of time, effort, and trustworthiness. The statements made herein are solely the responsibility of the authors.