Development of a novel sensor-based framework for the assessment of movement quality and control in clinical, sport, and ergonomic settings

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INTRODUCTION

- The use of wearable systems is becoming more common in health care, sport, and ergonomic settings [1-2].
- In general, a wearable system for data collection consists of three main components [1]:
  1. The sensing and data collection hardware.
  2. The communication hardware and software.
  3. The data analysis and display.
- While there has been great interest in wearable sensors for in-home monitoring, few researchers have applied such technology to musculoskeletal disorder prevention/rehabilitation [e.g. 3-5].

OBJECTIVE

- To develop a novel sensor-based framework for the assessment of movement quality in clinical, sport, and ergonomic settings that is:

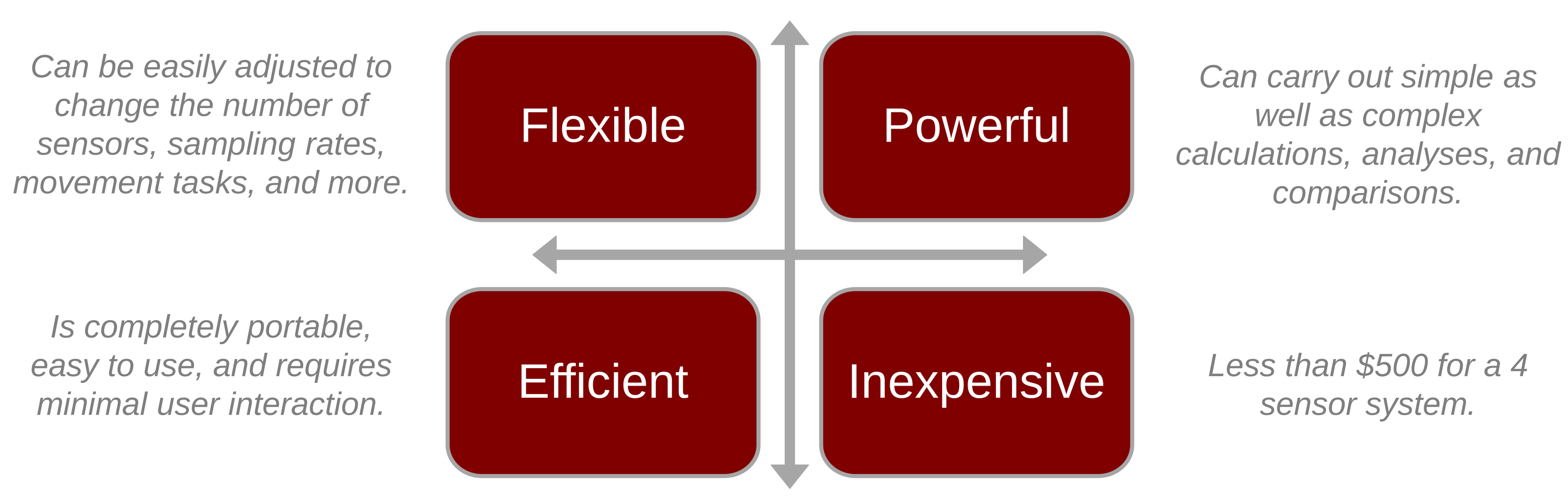

Figure 1. Design criteria for our sensor-based framework for assessing movement quality and control during a variety of movement tasks.

METHODS

- The proposed framework involves six main parts, which are shown in Figure 2. The entire system is run through a custom mobile application. Briefly, when finalized, the system and application will function as follows:

1. Upon opening the application, the user logs in and is then asked to assess a new participant or to reassess an existing participant. The next step involves entering participant demographics as well as having them fill out various questionnaires that the assessor selects. These data are stored to the database as described below.
2. The user selects which assessment task(s) they would like the participant to complete, and the application automatically moves through data collection procedures (e.g., sensor placement details and videos of what the participant will need to complete).
3. The system connects to wireless inertial measurement units (IMU) (MBientLab MetaMotion R, San Francisco, USA) via Bluetooth® and collects data for the length of time based on procedures in part 2. The application provides required feedback such as metronome tones and can also take synchronized videos.
4. On-board calculations can first assess data quality, then movement control and quality variables of interest.
5. Processed data are sent to, stored, and organized in an encrypted cloud database. Data can continuously grow and are tagged to be accessed in a certain fashion (e.g., location where they were collected, user, participant, date, injury, age, etc.). These data can then be used in secondary pattern recognition and machine learning analyses to differentiate motor sub-groups [6].
6. Feedback is provided to the user regarding how the participant compares to themselves at other visits, as well as other people. Specific feedback is being refined, but we can provide z-scores for certain variables, as well as custom scores via machine learning [6].

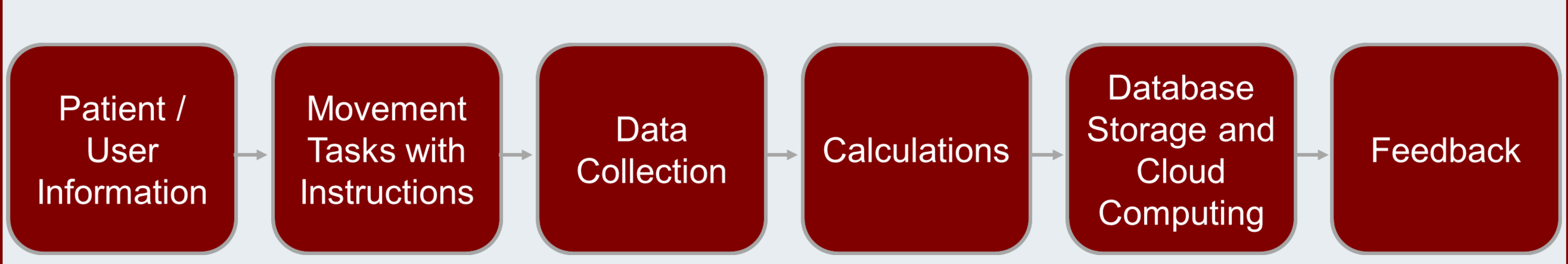

Figure 2. Flow diagram outlining the six stages of our sensor-based framework, which is run through a custom application.

PRELIMINARY RESULTS: SIMPLE APP

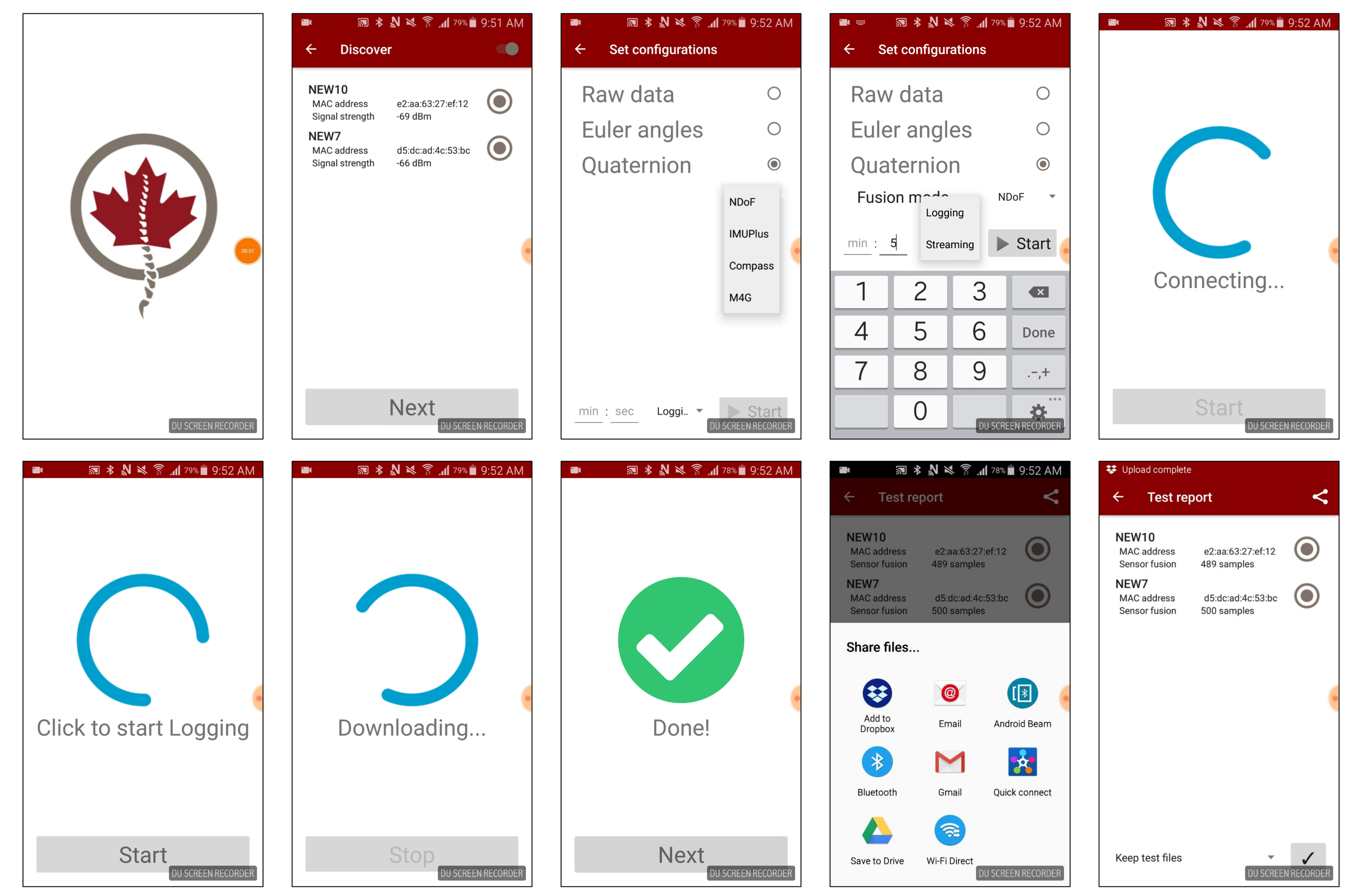

Figure 3. Screenshots displaying the workflow of a simple working version of the application that collects IMU data and shares it via a number of options. The full functionality of the proposed framework is currently being programmed and finalized.

PRELIMINARY RESULTS: SENSORS

- During validation work on 10 participants carrying out repetitive spine flexion extension we have shown promising initial results for our chosen IMU sensors when compared to optical motion capture [7].
  - RMSE < 2.46° for all axes. $ICC_{2,1}$ > 0.829 for local dynamic stability.
  - Currently optimizing placement and analysis procedures to further improve results.

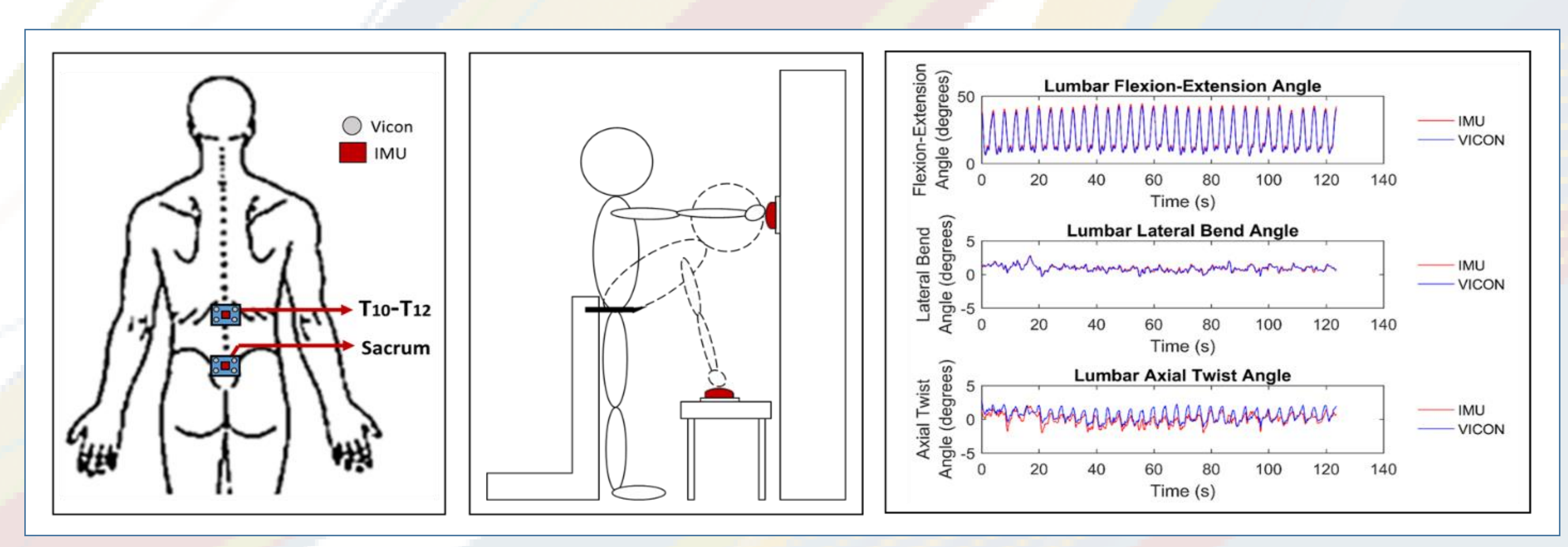

Figure 4. Experimental setup and sample lumbar spine results for one participant.

DISCUSSION / CONCLUSION

- We have developed a novel sensor-based framework for the assessment of movement quality and control that meets each of our original criteria, and are in the process of implementation and validation.
- The system is:
  1. *Flexible* → number of sensors and sample rate can be adjusted, and additional movement tasks and analyses can be added at any time.
  2. *Powerful* → can program any type of analysis directly into the application and can also harness cloud-computing and machine learning algorithms to differentiate groups (e.g., healthy vs. injured) [6].
  3. *Efficient* → will walk the user and participant through the required steps and automatically store data to the database with minimal user interaction.
  4. *Inexpensive* → off-the-shelf IMU sensors (Meta Motion R, MbientLab Inc., CA, USA), retailing for ~$78 USD/unit and are much less expensive in bulk.
- These characteristics make this framework ideal for use in numerous settings.

REFERENCES & ACKNOWLEDGEMENTS

1. Patel S, et al. *J Neuroeng Rehabil.* **9**:21, 2012. 2. Hadjidj A, et al. *J Netw Comput Appl.* **36**:1–15, 2013. 3. Chhikara A, et al. 30th Ann. Int. Conf. of the IEEE EMBS, Vancouver, Canada, Proceeding, 2008. 4. Charry E, et al. 7th Int. Conf. Intell. Sensors, Sens. Networks Inf. Adelaide, Australia, Proceeding, 2011. 5. Kent P, et al. *BMC Musculoskelet Disord*. **16**:131, 2015. 6. Ross G, et al. *Med Sci Sports Exerc.* **50**:7, 2018. 7. Graham R, et al. *J Biomech*. **47**, 2014. 7. Beange, K. et al. 8th WCB, Dublin, Ireland, Proceeding, 2018.

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