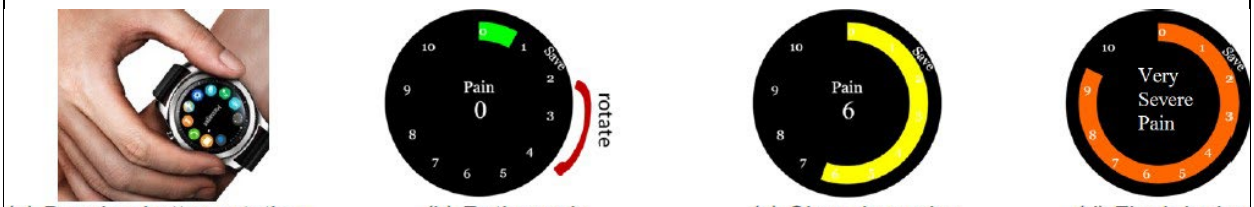
Real-time Online Assessment and Mobility Monitor (ROAMM) app

ROAMM (Real-time Online Assessment and Mobility Monitor) is a customizable platform, developed at the University of Florida, designed specifically for smartwatches. It offers long-term and continuous connectivity, bidirectional interactivity, and remote programmability through a smartwatch. The goal of this platform is to allow for remote monitoring of patients using smartwatches. This approach reduces and potentially removes in-person repeated follow-up visits while also providing detailed objective information surrounding the onset and recovery from a fall or other episodic health events (e.g. hospitalizations). Moreover, because of their immense popularity, mobile devices overcome racial, geographic and educational divides and has potential of digitally engaging and retaining diverse populations in healthcare research.

ROAMM spans four main categories of measurement: i) mobility, ii) ecological momentary assessment/patient reported outcomes; iii) cognition; and iv) intervening health events monitoring using a smart watch platform. The components include: 1) a secure smart watch application (app), which collects and summarizes sensor monitored data (e.g. tri-axial accelerometer, GPS location); 2) a graphical interface allowing ecological momentary assessments; 3) interface and/or voice recording for cognitive assessment; and 4) secure servers for configuring the application parameters, data storage, advanced analytics, web-based data visualization and remote management of sensors.

ROAMM watch app. The watch application is built on the Samsung Galaxy and Apple watch. The application collects self-reported as well as sensor- monitored data and processes them into informative features. The mobile application has the following unique features and advantages:

1. Data is transferred using 4G and LTE GSM allowing for automatic real-time data uploads in a minimally obtrusive manner
2. It is flexible enough to accommodate different types of studies with different targets and outcomes while allowing for constructions of variables instantly from the raw data on the device.
3. It supports interactive interfaces (e.g., prompting for reporting symptoms or asking to recharge), as seen in Figure 2.
4. Configuration can occur remotely (e.g. stopping GPS to save battery life).



(a) Bezel or button rotation (b) Rating pain (c) Changing color (d) Final design

Figure. ROAMM app interface showing rating of a patient reported outcome (e.g., pain)

ROAMM server. The server configures the application parameters for data collection and provides a means for data storage, analysis, and visualization services to the researcher/administrator. The server software consists of the following features and advantages:

1. It provides a user-friendly platform to configure and review data from the watches' applications remotely. Such configuration includes identifying the sensors to use, their sampling rate, and setting the parameters necessary for aggregating the collected raw data. It provides a user interface that summarizes statistics about the status of the watches and the underlying data.
2. For better control, user management and security modules are housed on the server. New roles (e.g., researcher and administrator) with the desired access and privileges are defined and assigned.

The server can receive data from hundreds of smart watches operating simultaneously in the field and store the data in a high-performance and fault-tolerant database. Data security is maintained by granting the access to the database only through the web interface, which itself retrieves data via a database view with least privileges. The server is founded on Amazon Web Services (AWS) which allows flexible options for ROAMM to grow. AWS give us the tools to provide a user-friendly platform interface for visualization, campaign management (activating the watches, participant management, creating new campaigns, downloading the data) and to modify configurations remotely. Configuration includes identifying the sensors to use, constructing questions, timing, sampling rate, and aggregating raw data. AWS is used to develop highly scalable, secure serverless architecture to enable remote data collection and real time transmission. For security, including Identity and Access Management, only admins are permitted to manage user access to different resources (software-and hardware-based encryption) that protects against distributed denial-of-service attacks (DDoS attacks). We currently use the following services to enable the ROAMM platform:

Elastic Computer Cloud (EC2), Lambda, API Gateway, Dynamo Database, Simple Storage Service (S3), Transcribe, relational database services (RDS).

a. Lambda is used to define micro services that support real time campaign management, data collection, transmission, and user management.
b. API gateway is used as a management tool that sits between the watches and Lambda.
c. RDS, S3 buckets are used to store the data collected and support the visualization dashboards hosted on an EC2 instance.

ROAMM campaigns. Study "campaigns" allow investigators to customize their watch graphical interface while also adjusting sensor settings. Campaigns are built through a tabbed workflow via a user-friendly web-portal. The portal also serves as a hub for initializing smartwatches and aggregating information from sensors and EMA in a uniform way that can be visualized in real-time. First, users are able to control how the sensors operate on the smartwatch (sampling rate, activation status) and what aggregate features to compute and store in the database (total activity, raw accelerometer). Second, users are able to select and control ecological assessments and patient reported outcome prompts via the graphical interface - when they are delivered, what questions to ask, scaling choices (e.g. 0-10, 1-5), frequency and color scheme. During this customization, certain limits are placed on users— e.g. amount of text and scaling placed on the screen. Importantly, software developers or computer programing expertise is NOT required to customize these elements— modifiable elements are presented in a simple "user friendly" interface and work flows through the ROAMM web portal.

The *ROAMM web portal* section provides details about the components of this customizable portal. Following is a summary of the flexible features ROAMM campaigns provide:

- Allows a researcher to execute a study that is customized to their needs.
- Allows to configure both user-reported out comes and sensor-based data
- Supports the collection and analysis of this data in a robust and scalable fashion, we developed an event driven, serverless computing platform using AWS cloud services
- Allows multiple campaigns to run concurrently each under the auspices of a different researcher

ROAMM data security. Data security during transmission and storage are of utmost importance for our future goals. We have cleared our existing approaches through the UF security protocols. Data are transmitted to a cloud-based storage and database management environment on Amazon Web Services (AWS). AWS security standards for data storage and HIPAA risk management program aligns with FedRAMP and NIST 800-53, which are higher standards than the HIPAA Security Rule. Following are the AWS security features provided by the ROAMM platform.

- **HIPPA compliant**: AWS enables covered entities and their business associates subject to HIPAA to securely process, store, and transmit PHI
- **Identify & access management**: securely manage identities, resources, and permissions among team members and customers.
- **Data protection**: AWS provides services that help you protect your data, accounts, and workloads from unauthorized access. AWS data protection services provide encryption and key management and threat detection that continuously monitors and protects your accounts and workloads.
- **Infrastructure protection**: AWS protects web applications by filtering traffic based on rules that you create. For example, you can filter web requests based on IP addresses, HTTP headers, HTTP body, or URI strings, which allows you to block common attack patterns, such as SQL injection or cross-site scripting.

Facilities, resources and equipment

DIAL-AI space. The core has 800 sq. ft. of dedicated space to conduct research. This space is outfitted with 8 workstations with large monitors (>20 inches). It also has an 8X4 ft. conference

table that serves as collaboration space. The space is designed for programmers and trainees to analyze data and is situated immediately to office/work areas of clinic research staff that include study coordinators, student assistants, and collaborating investigators.

DIAL-AI Computing and software. Computers have software critical for inter-investigator communication and writing collaborations that include programs Microsoft Office, WinEdt for LaTeX editing, Adobe Acrobat Professional, Adobe Creatively and Design suite (e.g. photoshop), Skype, and FaceTime (iPad). It also has a large suite of software to conduct a variety of analyses and visualization. These include STATA, SAS, SPSS, StatTransfer, MatLAB, Labview 16.0, R v3.4, JAVA and Enthought Canopy (Python). Data are Visualized using GraphPad Prism 5.0, Tableau, Visual Studio, Adobe Photoshop, Adobe Illustrator and custom visualization packages in R.

The core has full access to The Department of Computer and Information Sciences and Engineering (CISE) computer cluster space consisting of a head node with dual Opterons, 16GB of memory and 3.5TB of storage with 20 worker nodes with dual Opterons and 32GB of memory running Linux (Ubuntu Server 10.04). These will be used for prototype software development. All graduate students have access to a workstation that can be used to access this cluster. All faculty offices are equipped with a Windows or Linux workstation with standard software installations. Wireless access is available throughout the CSE Building and all of campus.

DIAL-AI Wearable sensors. The Core houses several types of wearable sensors for temporal measurement movement patterns, community mobility via global positioning systems and bio-sensors (e.g. heart rate, galvanic skin response, skin temperature). The Core has 70 Actigraph GT1M, GT3X or LINK accelerometer models (The Actigraph Inc. Pensacola, FL). The monitors are small (3.8 x 3.7 x 1.8 cm), lightweight (27 g) and include a uniaxial and triaxial accelerometers. The accelerometers measure accelerations in the range of 0.05-2 G with a band-limited frequency of 0.25-2.5 Hz. The monitors are initialized and data downloaded with the ActiLife software (Version 3.3.0). The Core also uses multi-sensor technology through a portable armband (HealthWear Bodymedia, Pittsburgh, PA). The Sensewear armband uses a dual-axis accelerometer, a heat flux sensor, a galvanic skin response sensor, a skin temperature sensor, and a near-body ambient temperature sensor to capture data. Data from multi-sensor technologies are comparable to energy expenditure measured with doubly-labeled water. The core possesses 4 Empatica E4 wristband wrist worn wearable multi-sensor. The E4 measures blood volume pulse through a photoplethysmography Sensor - from which heart rate, heart rate variability (HRV), and other cardiovascular features are derived. An electrodermal Activity Sensor measures sympathetic nervous arousal and derives features related to stress, engagement and excitement. It also has a tri-axial accelerometer, event mark button and infrared thermopile for peripheral skin temperature. Lastly, the core owns 15 Samsung Gear S and 15 Apple smartwatches that possess customized software to program “apps”.

RC4 databases available (stored publicly or in a local repository) for secondary data analyses.

Available database for secondary data analyses

Study name	N	Age	Design
ADAPT	316	65+	RCT
ENRGISE	300	70+	RCT
COVID-19 survey*	1392	20+	OLC
GEM	3069	75+	RCT
LEAPS	408	62	RCT
LIFE^	1,635	70-89	RCT
LIFE-Pilot ^	424	70-89	RCT
PEAKS	100	70+	OCS
LOOK-AHEAD	5,145	45-75	RCT
SHEP	4,736	60+	RCT
TRAIN	290	50+	RCT
TTrial	790	65+	RCT
ChoresXL	280	20+	OCS
Baltimore Longitudinal Study of Aging ^	1581	20+	OLC
Sacopenia Definitions and Outcomes Consortium *	18,767	70+	OLC
EPESE ^	14,000	65+	OLC
OneFlorida Data Trust*	15,700,000	20+	OLC/EHR
Health ABC^	3,075	70-80	OLC
InChianti	1,020	65+	OLC
mtDNA genomic sequence*	3,499	70-89	OLC+RCT
NHANES ^	1,286	65+	OCS
UDS-NACC Alzheimer's ^	32,364	50+	OLC
Aging EHR hospital repository*	21,615	65+	OCS/EHR
UK Biobank* ^	502,625	20+	OLC
PECAN - preoperative physical & cognitive impairment	14,000	65+	OLC/EHR
UF OAIC pilot studies[24]	519	60+	RCT, OLC
UF INFORM**	9,000	50+	OLC
WHAS	1,002	65+	OLC
WHI	161,808	50-79	RCT, OLC
WHIMS	4532	50-79	RCT, OLC
Health & Retirement survey	44362	50+	OLC
Coping with COVID	1,168	60-99	OLC
Total	**16,555,108**	**45-99**	

Note: all studies have *=new study; ** Movement disorders database, see letter of Dr. Okun; RCT=Randomized Clinical Trial; OLC= Observational Longitudinal Cohort; OCS= Observational Cross-Sectional; EHR=Electronic Health Records. ^ data used by OAIC and is available for analysis