

Research on Internet of Health Things: From Theory to Practice

Presenter: Rossana de Castro Andrade

Computer Networks, Software Engineering, and Systems Group (GREat)
Department of Computing (DC)
Federal University of Ceará (UFC) - Fortaleza - CE - Brazil



Short Bio

Rossana Maria de Castro Andrade

- PhD in Computer Science from the University of Ottawa in 2001)
- Master's degree in Computer Science from the Federal University of Paraíba in 1992
- Degree in Computer Science from the State University of Ceará in 1989
- Professor at the Federal University of Ceará (UFC), in the Department of Computing, since 1994, and is currently Full Professor
- Productivity Scholarship Technological Development and Innovative Extension from CNPq - Level 1D
- Co-founder of the GoTest startup
- Coordinator of CENAPAD at UFC since 2003
- Researcher at GREat (Computer Networks, Software Engineering and Systems Group), a group she founded in 2002
- Chief Scientist of Fortaleza City Hall since 2022
- Software Engineering and Computer Networks
 - research focused on the Internet of Things, a natural evolution of its research themes of mobile computing, ubiquitous computing and wireless sensor networks
 - software reuse with software product lines, software standards, frameworks and middleware
 - software testing and software quality
 - security and formal specification of protocols.



UFC
DC and MDCC
GREat

Federal University of Ceará (UFC)

Created on December 16th, 1954, and officially founded on June 25, 1955. Actually, UFC is composed of 8 *campi* (3 in Fortaleza and 5 in the countryside)

- Courses
 - 123+ Undergraduate courses
 - 153+ Graduate courses
- According to the AD Scientific Index (2024), UFC holds the 1st place in Brazil North, Northeast, and Central-West regions, the 10th in Brazil, and 13th in Latin America
- 5,300+ Employees
- 577,000+ Students
- Agreement with more than 300 institutions in more than 30 countries



Department of Computing (DC)

Created on 08/10/1990, DC is part of the Science Center at UFC and has 30 PhD professors

- Undergraduate Courses
 - Computer Science (DC)
 - Computer Engineering (DETI partnership)
 - Data Science (DEMA partnership)
- Graduate Courses (Lato Sensu)
 - Cyber Security (Lenovo partnership)
 - Information Security (Samsung partnership)



Master and Doctorate Program in Computer Science (MDCC)

- Graduate Courses (Stricto Sensu)
 - PhD in Computer Science (CAPES 5)
 - MSc in Computer Science (CAPES 5)

Research Groups

ARiDa - Advanced Research in Database
CRAb - Computer Graphics, Virtual Reality and Animations

GREAT - Group of Computer Networks, Software Engineering and Systems

Logla - Logic and Artificial Intelligence

ParGo - Parallelism, Graphs and Optimization



Contextualization

Our world is aging!



2015



According to WHO,
the number of older
persons is projected to
1.5 billion (15%) in 2050¹

¹ Revision of World Population Prospects: <https://population.un.org/wpp>



Healthcare systems need to be **adapted** to reduce costs, provide better living conditions

Image source: <https://www.raconteur.net/healthcare/ageing-population-healthier/>

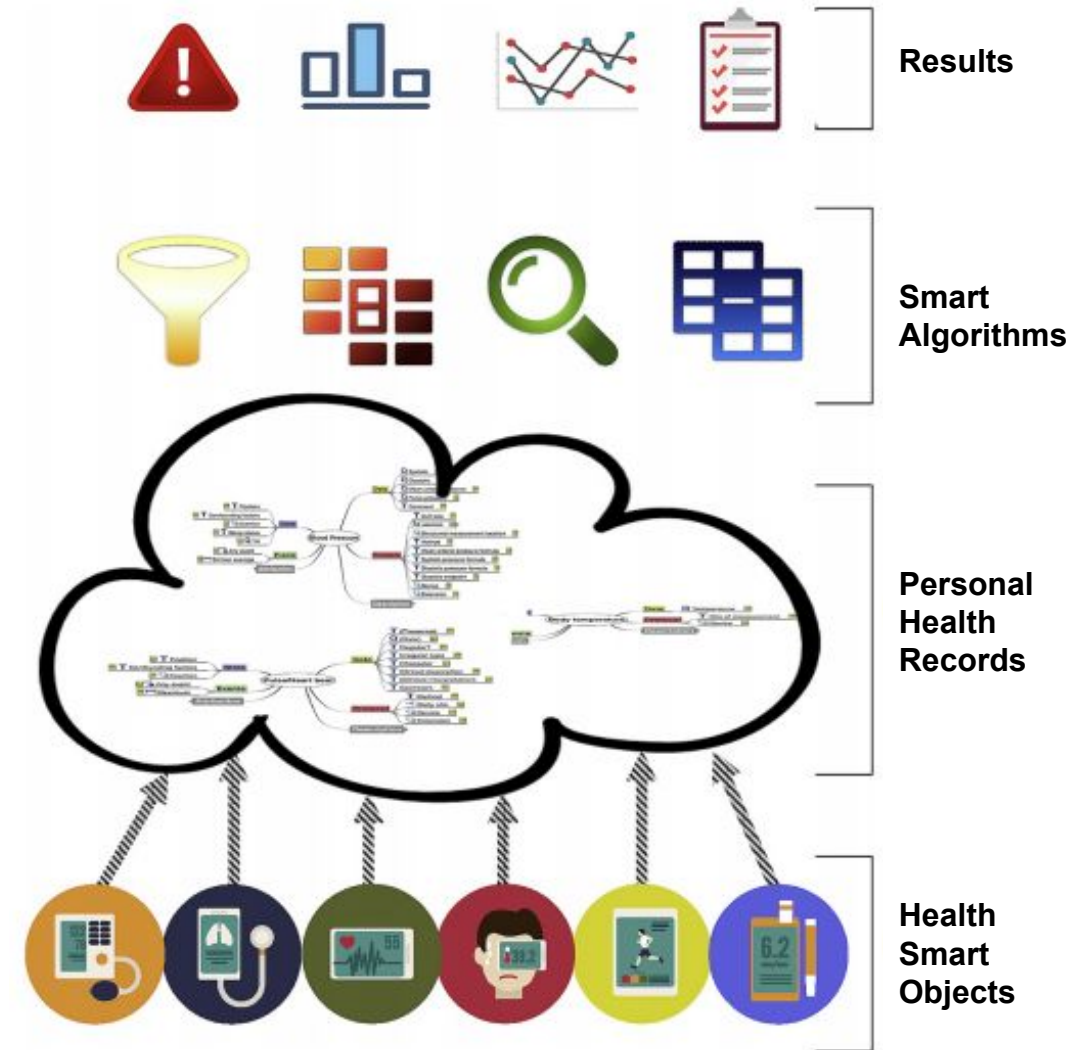
How can we optimize our healthcare system?



Source: <https://pittsburghuppercervical.com/sick-care-vs-health-care>

Internet of Health Things

- The Internet of Health Things (IoHT) encompasses the entire set of solutions based on the Internet of Things aimed at healthcare
- Four-layer view³
 - Acquisition
 - Storage
 - Processing
 - Presentation
- Sensors
 - Smartphones and Wearables
 - AAL
 - Smart Room

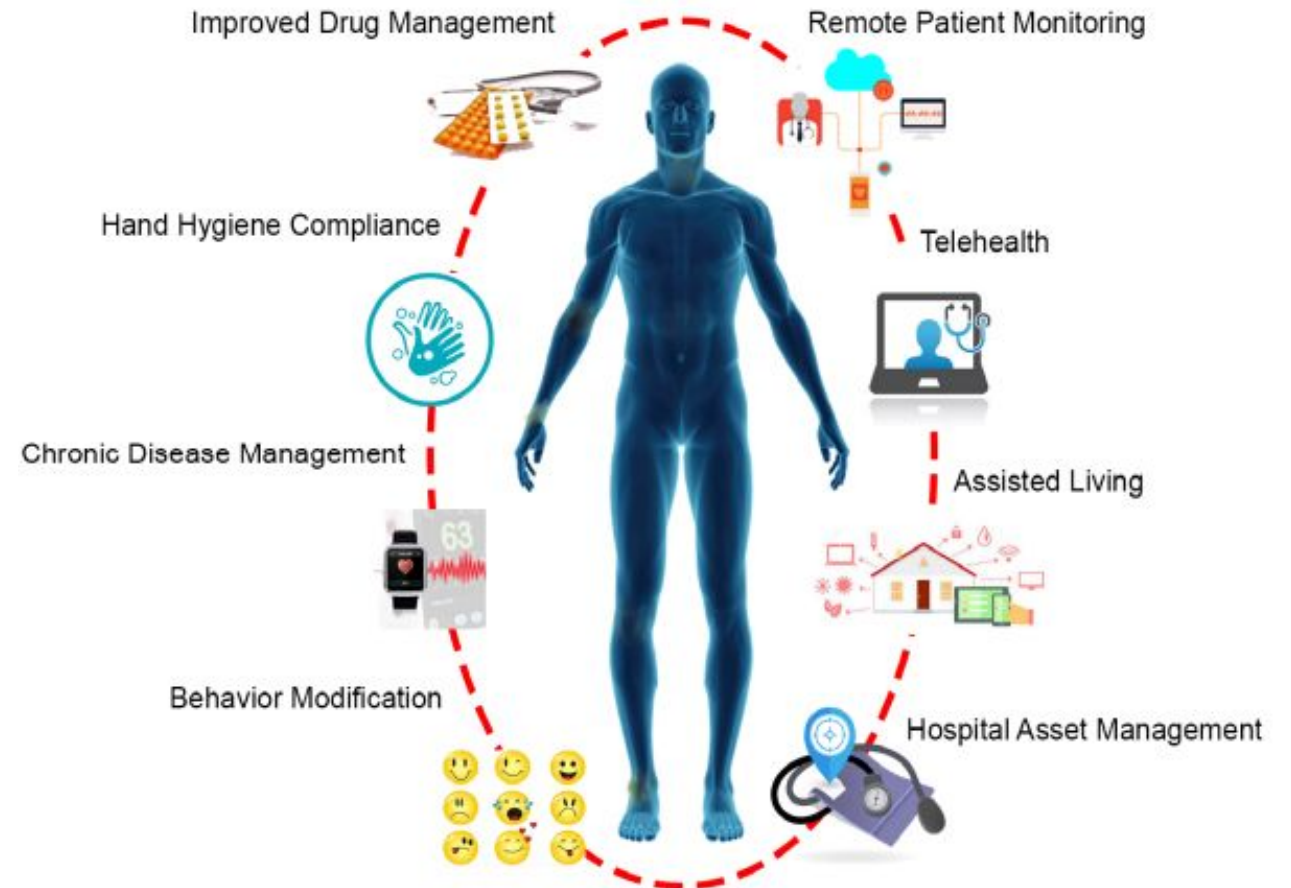


Source: Adapted from (COSTA et al., 2018)

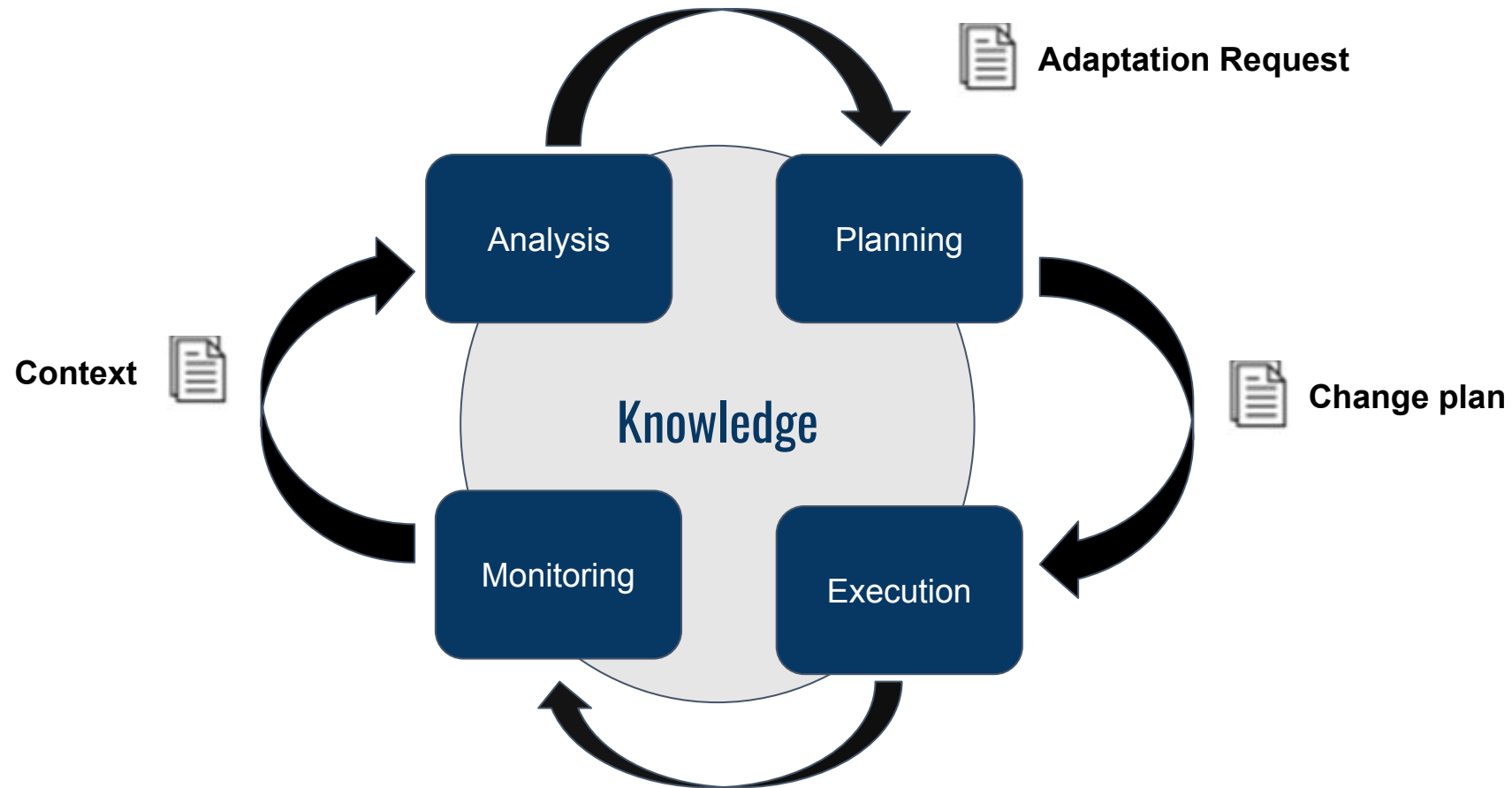
³ COSTA, C. A. da; PASLUOSTA, C. F.; ESKOFIER, B.; SILVA, D. B. da; RIGHI, R. da R. Internet of health things: Toward intelligent vital signs monitoring in hospital wards. Artificial intelligence in medicine, Elsevier, v. 89, p. 61–69, 2018.

IoHT Challenges

- Device interoperability
- Data Collection and Formatting
- Security and Privacy
 - Data anonymization
- Resource management
 - Battery
 - Network level
- Constant changes in the context of IoHT applications



Self-Adaptive Systems



Source: adapted from (JUNIOR et al., 2018)⁴

⁴ JUNIOR, B. R.; ANDRADE, R. M.; MAIA, M. E.; NOGUEIRA, T. P. Succeed: Support mechanism for creating and executing workflows for decoupled sas in iot. In: IEEE. 2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC). [S. l.], 2018.v. 2, p. 738–743

AI applied to the Internet of Health (Medical) Things

- AI algorithms for movement pattern recognition
 - Fall Detection and Prevention
 - Physical Activity Monitoring
 - Identification of Bone Fragilities and Degenerative Diseases
- Monitoring and inference of quality of life level
- IoHT Database Construction
- Machine Learning applied to IoHT



Source: <https://thejournalofmhealth.com/artificial-intelligence-and-the-internet-of-things-in-healthcare/>

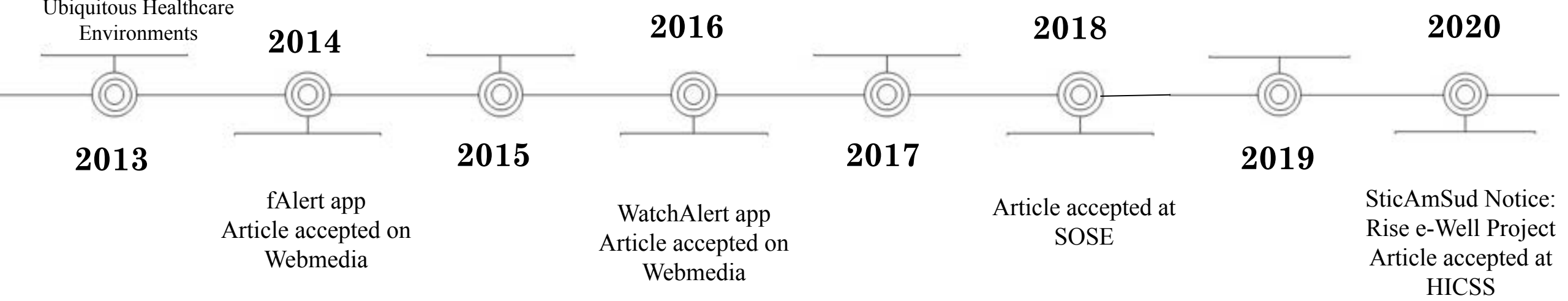
Our Research on Digital Health

Project Contextual
Information Quality
Assessment and Control in
Ubiquitous Healthcare
Environments

Postdoc and students
researching older adult falls

e-Monitor Project

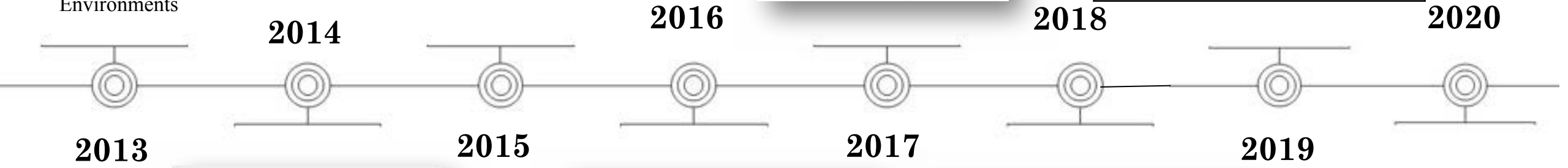
Elderly Digital Health
Project with FioCruz



Project Contextual Information Quality Assessment and Control in Ubiquitous Healthcare Environments

Postdoc and students researching older adult falls

PROJETO
Inteligência de Governança para Tomada de Decisão na Gestão de Sistemas de Saúde com Enfoque na Atenção Integral à Saúde do Idoso.



fAlert : Um sistema android para monitoramento de quedas em pessoas com cuidados especiais

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WatchAlert: Uma evolução do aplicativo fAlert para detecção de quedas em smartwatches

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An Algorithm for Fall Detection using Data from SmartWatch

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Proceedings of the 13th Hawaii International Conference on System Sciences (HICSS)

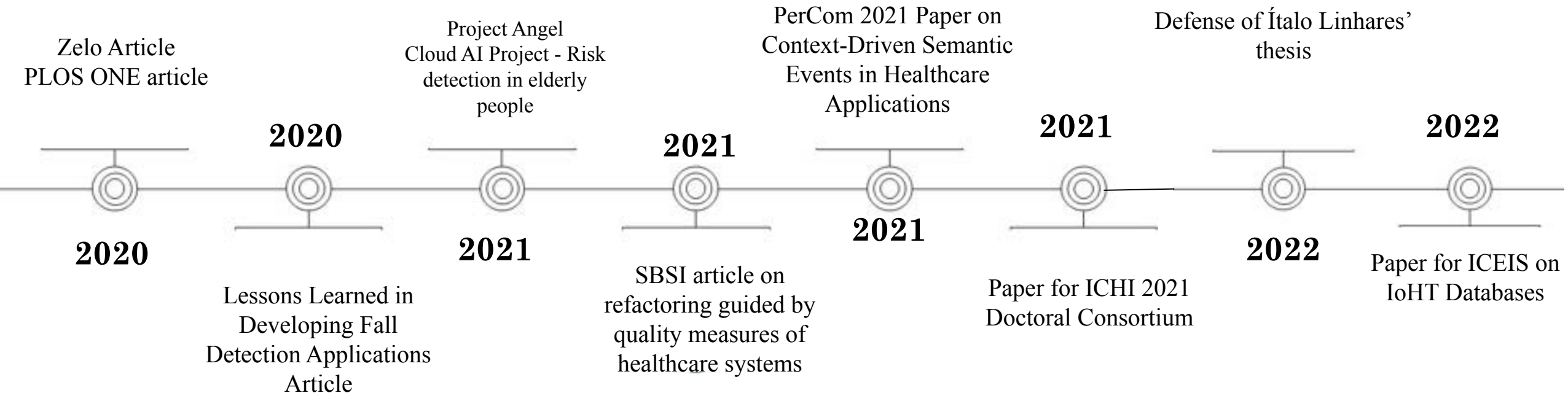
Towards a Taxonomy for the Development of Older Adults Healthcare Applications

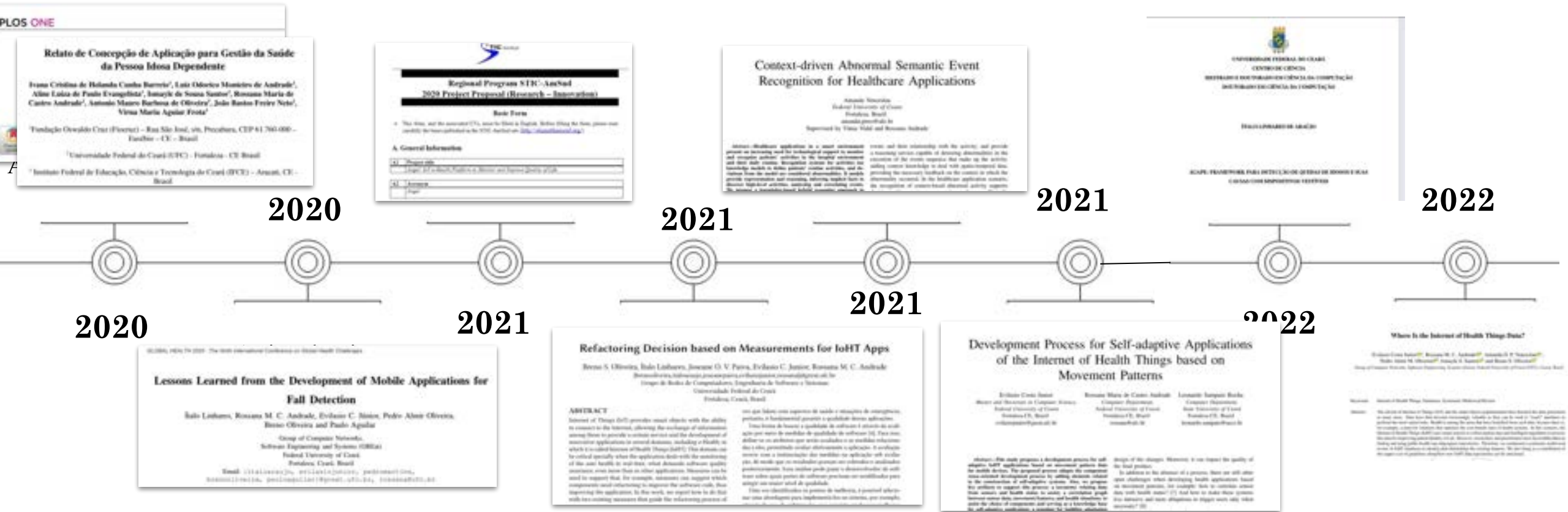
Ítalo Lins de Araujo, Evandro Costa, Ismael Paulo Duarte, Ismael de Sousa Santos, Paulo César Martins Oliveira, Cláudio Henrique Oliveira Mendes, and Rosana Maria de Castro Andrade
Federal University of Goiás - Brazil
{italoaraujo, lucasdourado, leticiagfernandes, pauloaguiar, rosana}@ufg.br

Track Chairmen: Evandro Costa, Ismael Paulo Duarte, Ismael de Sousa Santos, Paulo César Martins Oliveira
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Abstract

The world population is aging and this increases the development of ageing-related diseases. In the domain of healthcare, there is a need for a taxonomy of the information used in these systems. In order to address this gap, we present a taxonomy of information used in these systems. This work has as goal to identify through dialogue with health experts or using instruments for the collection of elderly health data already mentioned by these professionals. Hence, this work has as goal





Papers about Quality of Life for HICSS

Article GRAFIT

Defenses of Amanda Pires, Evilasio Costa Junior and Pedro Almir Martins Thesis

FRIEND Project in partnership with GoTest and Funcap

2023

2023

2023

2024

2023

2023

2023

2024

Paper Lessons Learned in Developing mHealth Applications

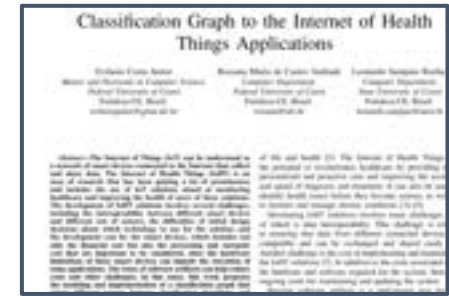
Article KREATION

Submission Paper about Insights on Developing IoHT Applications

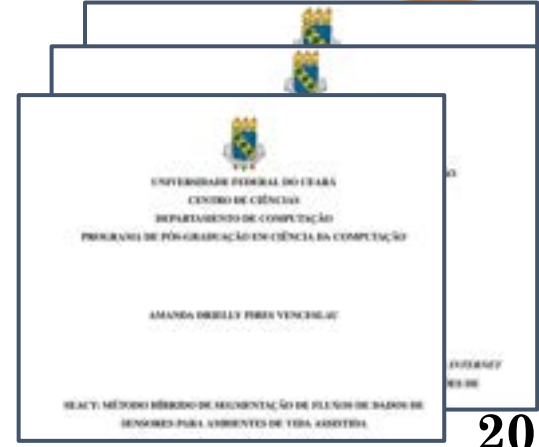
Project QoL-Monitor (Entrepreneurial Researcher Funcap)



2023



2023



2023

FRIEND Project in partnership with GoTest and Funcap

2024

2022



2023



2023

Submission Paper about Insights on Developing IoHT Applications

2024

Project QoL-Monitor (Entrepreneurial Researcher Funcap)

IoHT Research PhD Results

Short Bio

Ítalo Linhares de Araújo

- Degree in Computer Science from Federal University of Piauí (2011)
- Master's Degree in Academic Master's Degree in Computer Science from Federal University of Ceará (2014)
- PhD in Computer Science from the Federal University of Ceará (2022)
- Assistant Professor at the Federal University of Ceará (UFC), Itapajé Campus
- More than 10 years of experience with software development and research in the area of Computer Science and Software Engineering, working mainly on the following topics:
 - Software Engineering
 - Digital Health;
 - Internet of Things;
 - Internet of Health Things.



Agape Framework

- Agape is a framework that helps the implementation of applications for automatic detection of falls and their possible causes



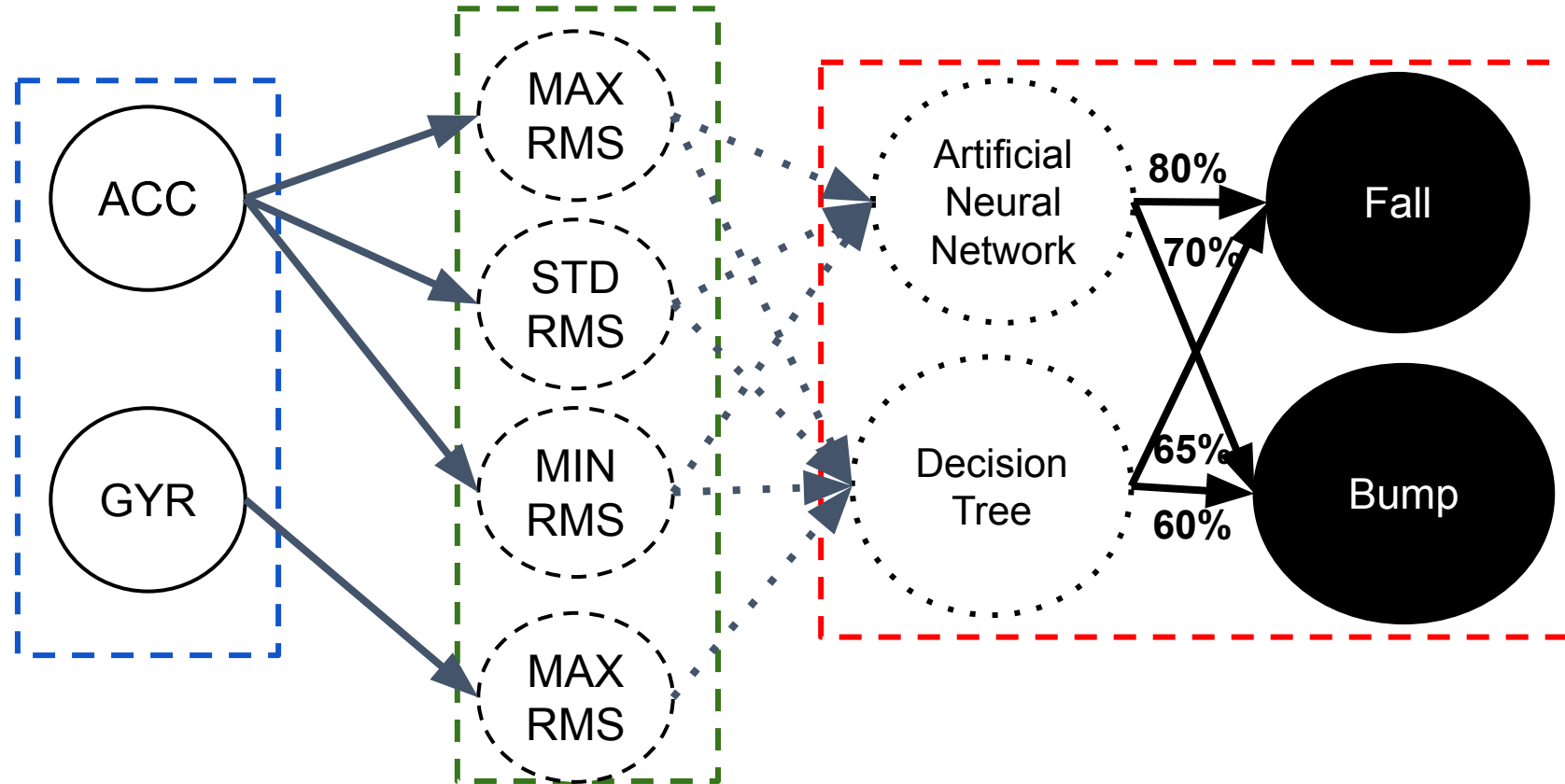
Short Bio

Evilasio Costa Junior

- Degree in Computer Science from the State University of Ceará (2010)
- Master's Degree in Academic Master's Degree in Computer Science from the State University of Ceará (2015)
- PhD in Computer Science from the Federal University of Ceará (2023)
- Assistant Professor at the Federal University of Ceará (UFC), Sobral Campus
- Substitute professor in the undergraduate course in Computer Science at the State University of Ceará between 2015 and 2017 and at the Federal University of Ceará in 2022
- More than 10 years of experience with software development and research in the area of Computer Science and Software Engineering, working mainly on the following topics:
 - Digital Health;
 - Internet of Things;
 - Internet of Medical Things;
 - Software Modeling,
 - Self-Adaptive Systems;
 - and Service-Based Self-Adaptive Systems



GRAFIT: *Classification Graph for IoHT Applications*



Labels

ACC = Acelerometer GYR = Gyroscope MAX= Maximum Value RMS = *Root Mean Square* STD = Standard Deviation MIN = Minimum Value

KREATION: Kotlin Framework for Self-adaptive IoHT Applications

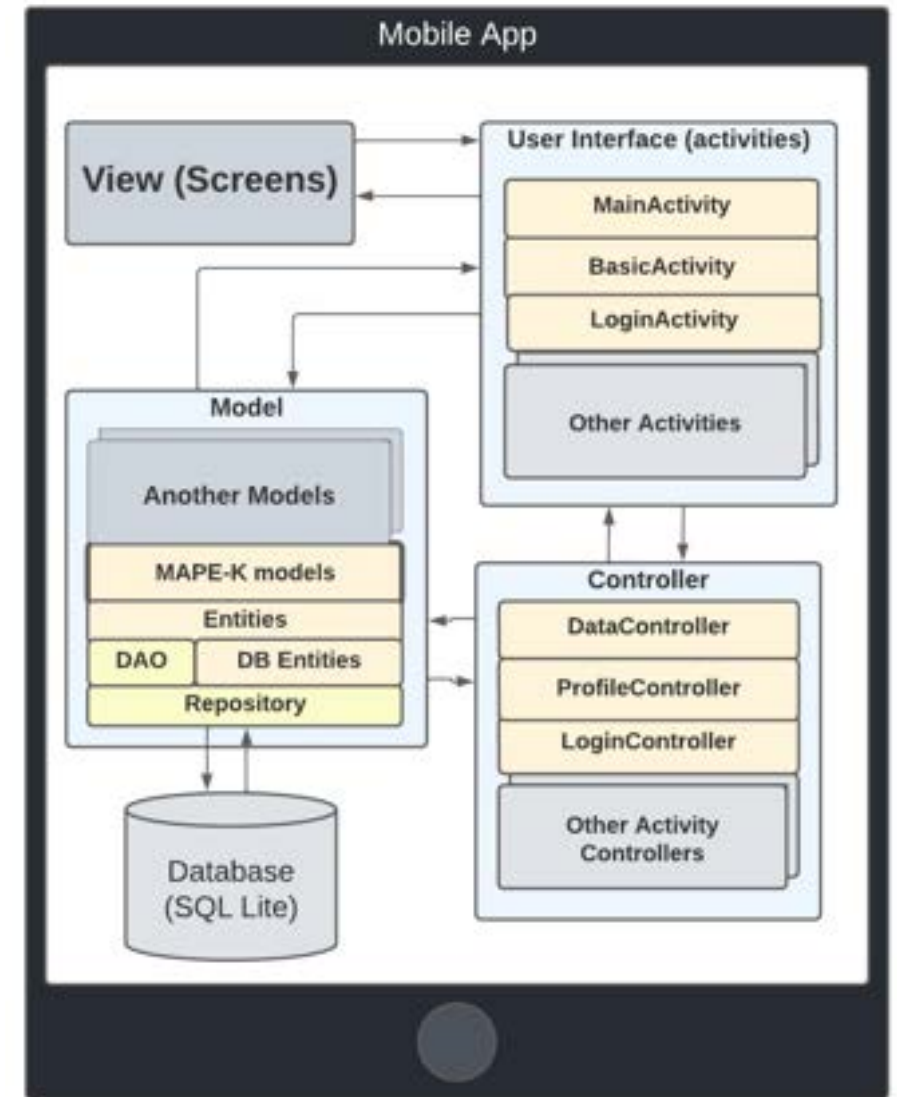
- Kotlin language
- Android Components
- MVC architecture
- Reuse Artifacts
 - Observer, DAO, Repository Patterns
 - Google API login
 - Google Fit API
 - GRAFIT, ARTe, framework SUCCEED

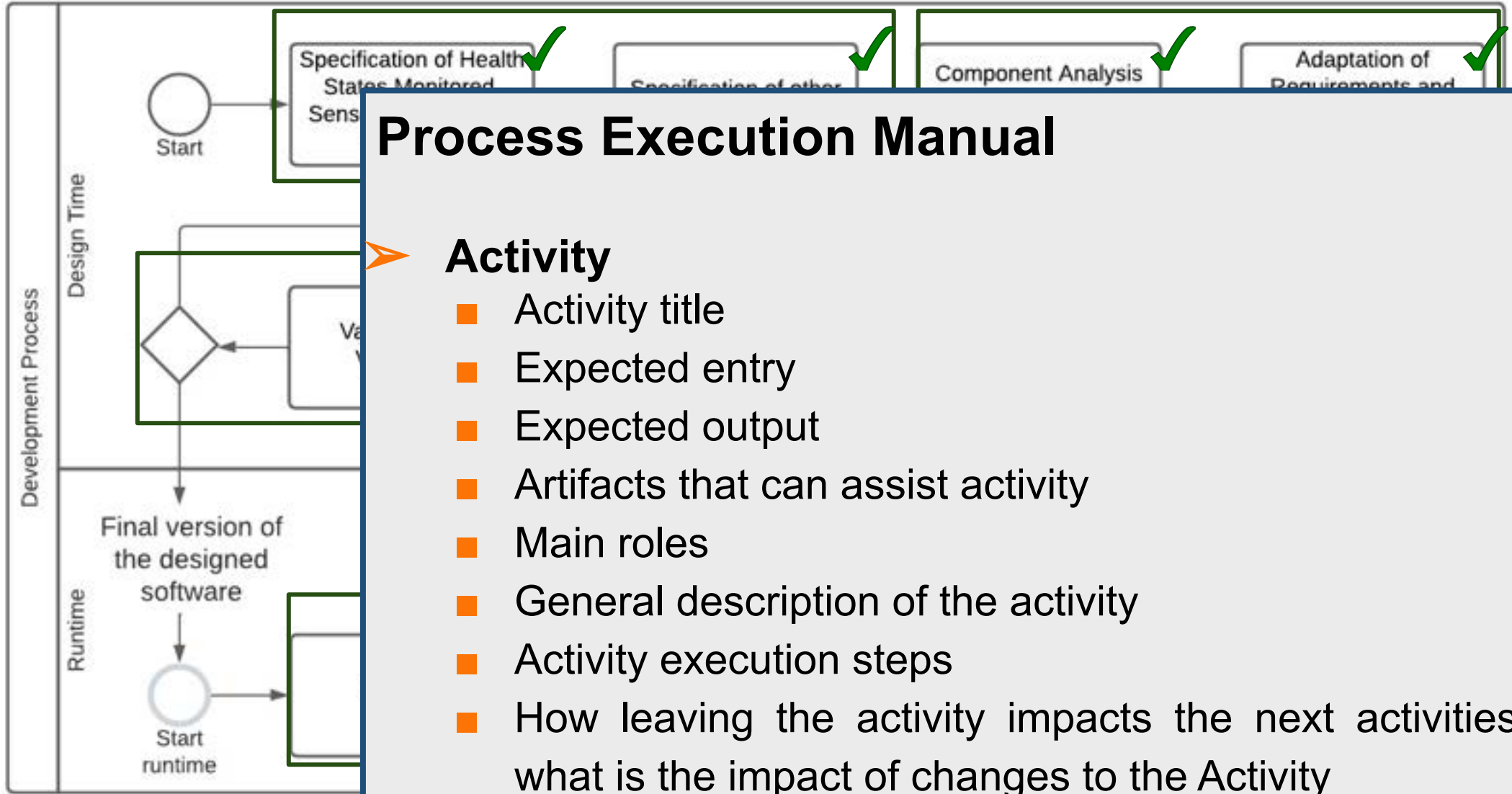


Download of *framework* KREATION

KREATION - MVC Components

- View: Screens and Activities
- Controller
- Model
 - Entities
 - Util
 - Database
 - Server Access
 - MAPE-K Loop





Process Execution Manual

Activity

- Activity title
- Expected entry
- Expected output
- Artifacts that can assist activity
- Main roles
- General description of the activity
- Activity execution steps
- How leaving the activity impacts the next activities and what is the impact of changes to the Activity

Short Bio

Pedro Almir

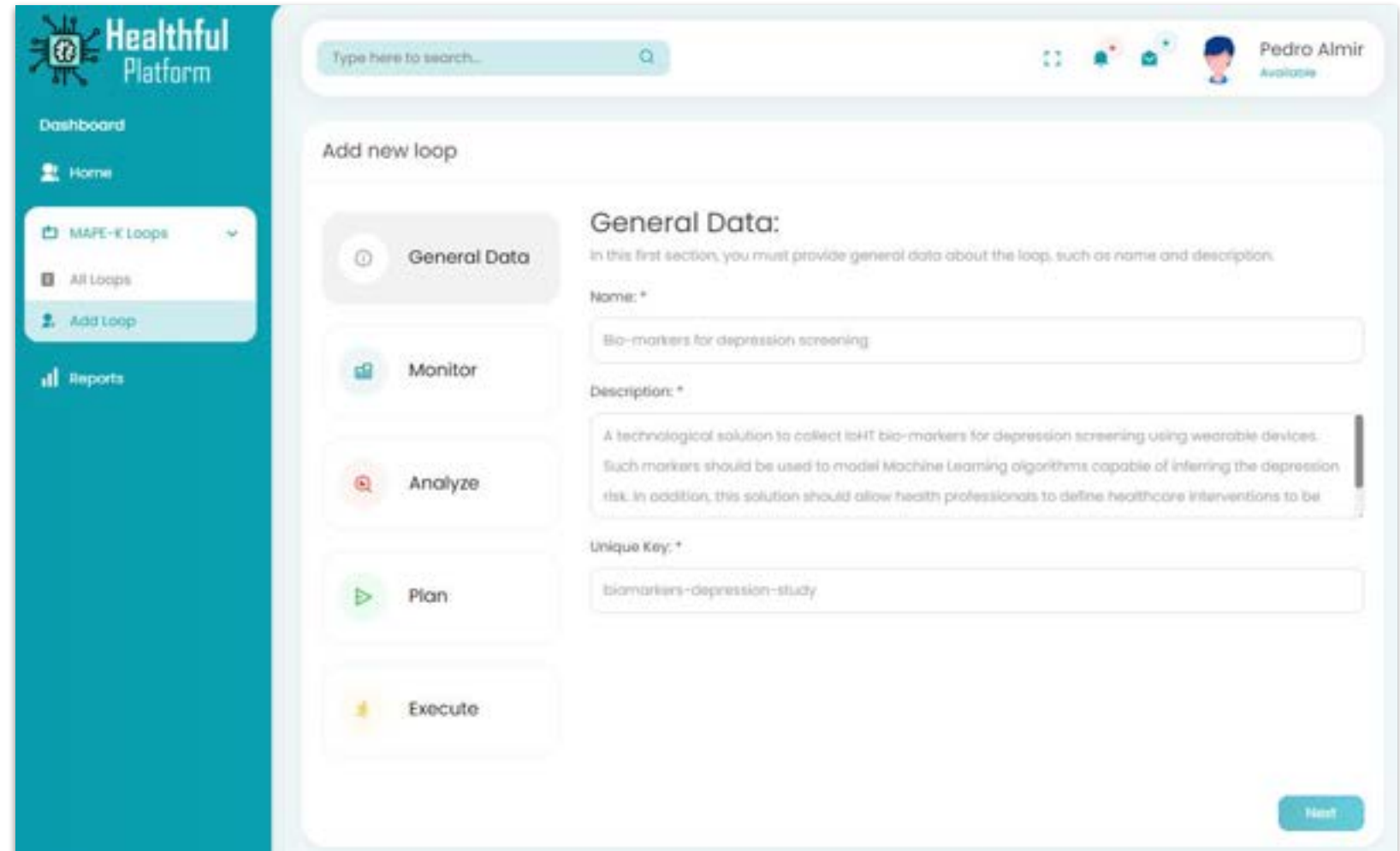
- Degree in Computer Science from Federal University of Piauí (2013)
- Master's Degree in in Computer Science from Federal University of Piauí (2016)
- PhD in Computer Science from the Federal University of Ceará (2023)
- Assistant Professor at the Federal Institute of Maranhão (IFMA)
- More than 10 years of experience with software development and research in the area of Computer Science and Software Engineering, working mainly on the following topics:
 - Software Engineering
 - Digital Health;
 - Internet of Things;
 - Internet of Health Things
- In 2024, received **Artur Ziviani award** for the best thesis of Computer Science Applied in Health



Healful Platform

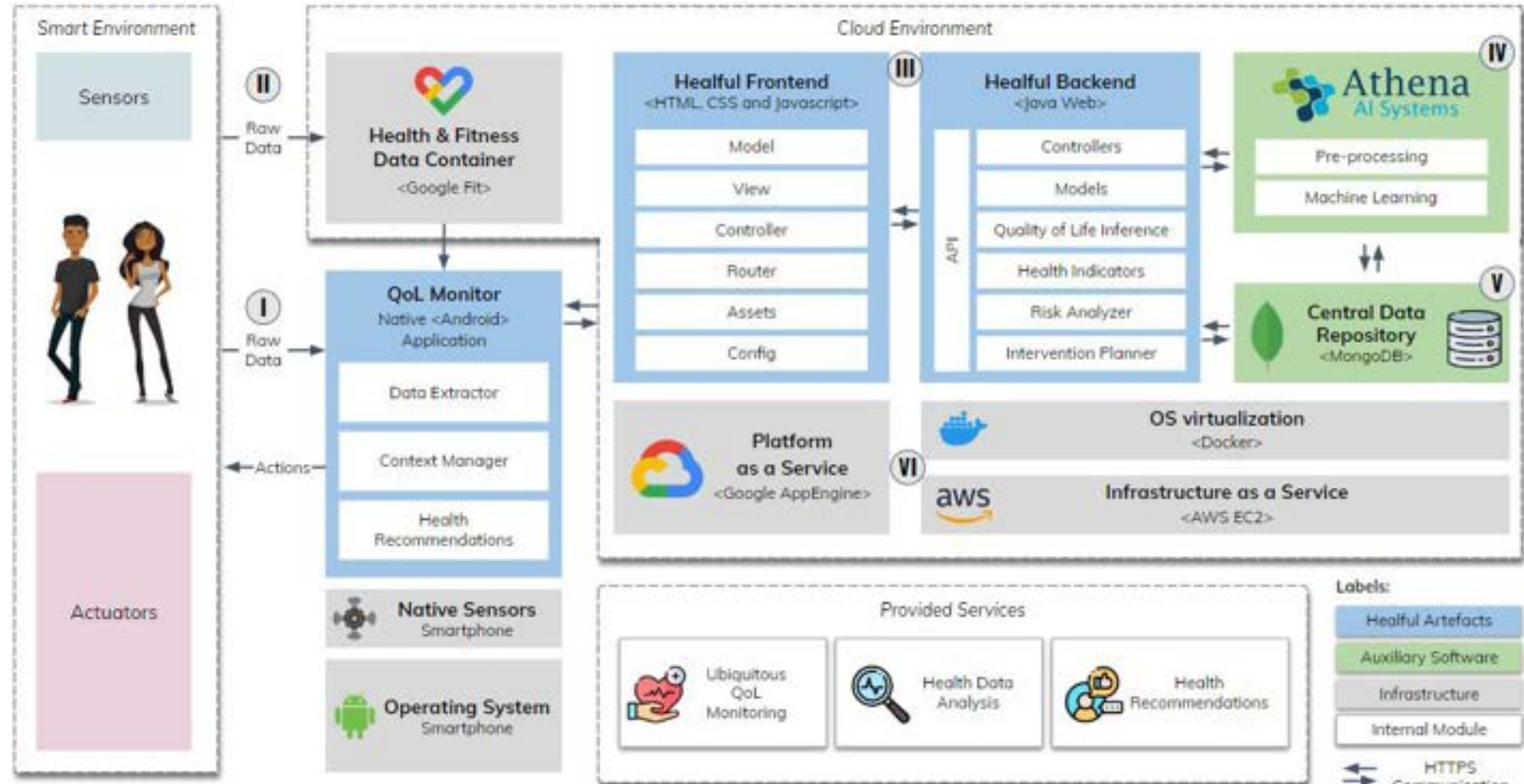
Web System

- **Healful** was designed to help build IoHT systems with a focus on Quality of Life monitoring
- However, given its ability to configure sensing and data analysis, it can be used in several other health monitoring scenarios.



Healful Platform


- In this architectural view, it is possible to observe
 - (I) the monitoring app, called QoL Monitor
 - (II) the middleware (Google Fit) used to extract data from wearables
- Furthermore, the platform is provisioned in a cloud environment



Icons created by srip - Flaticon (<https://www.flaticon.com/free-icons>)

Data collection workflow

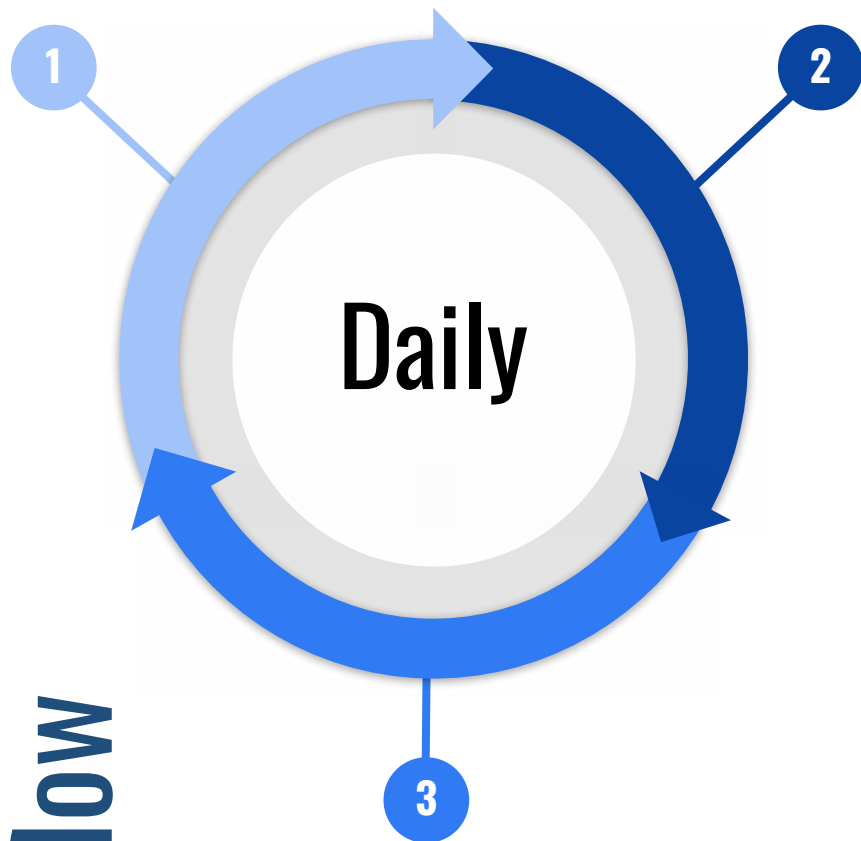
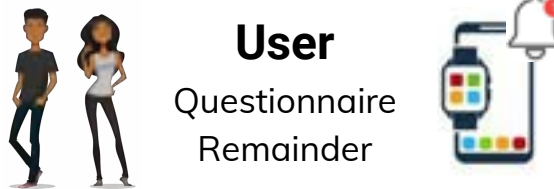
User
Daily Activities
Ubiquitous Monitoring



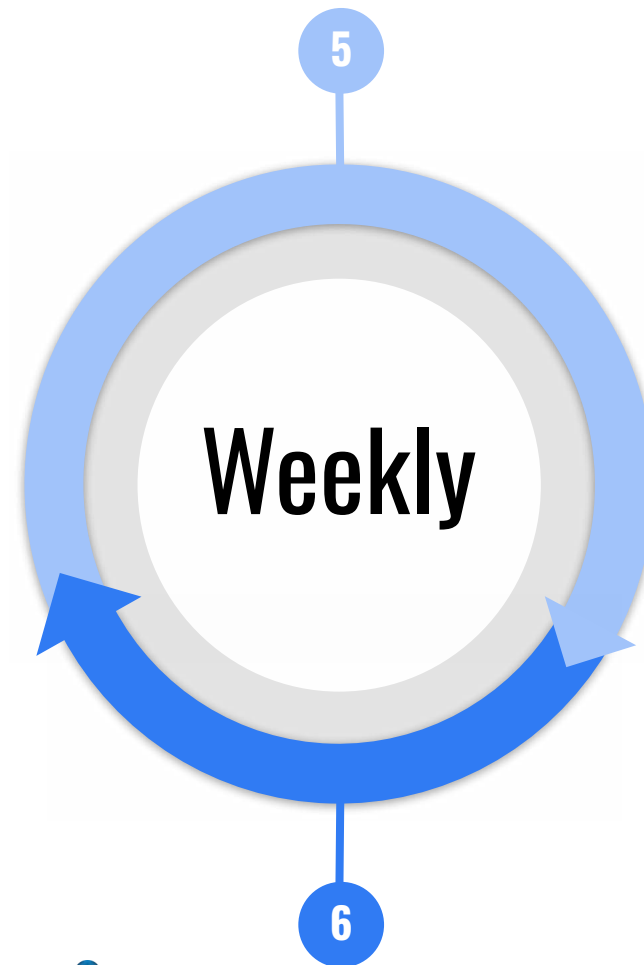
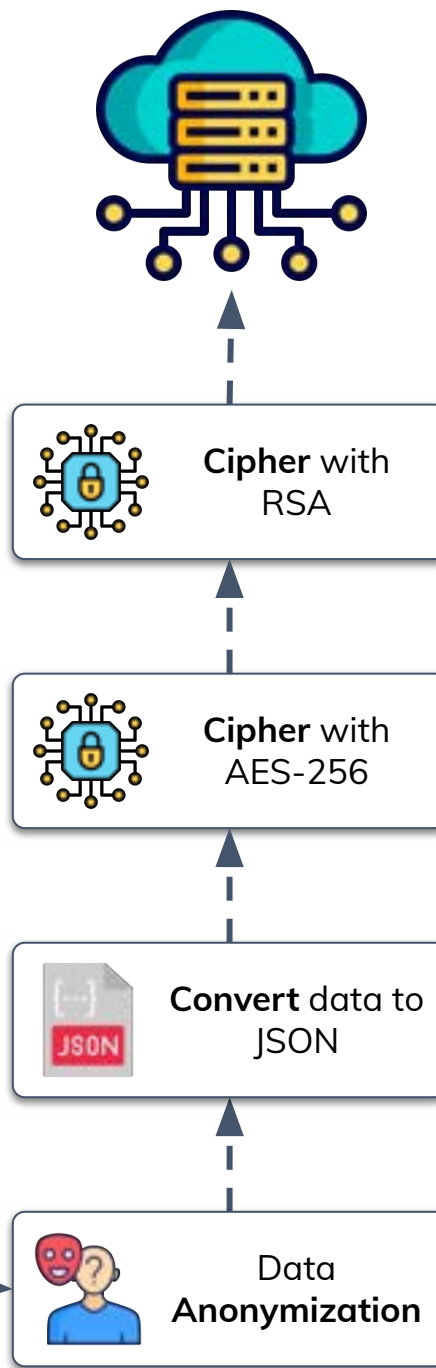
Google Fit
Data Sync



User
Questionnaire
Reminder



QoL Monitor
Data Extraction

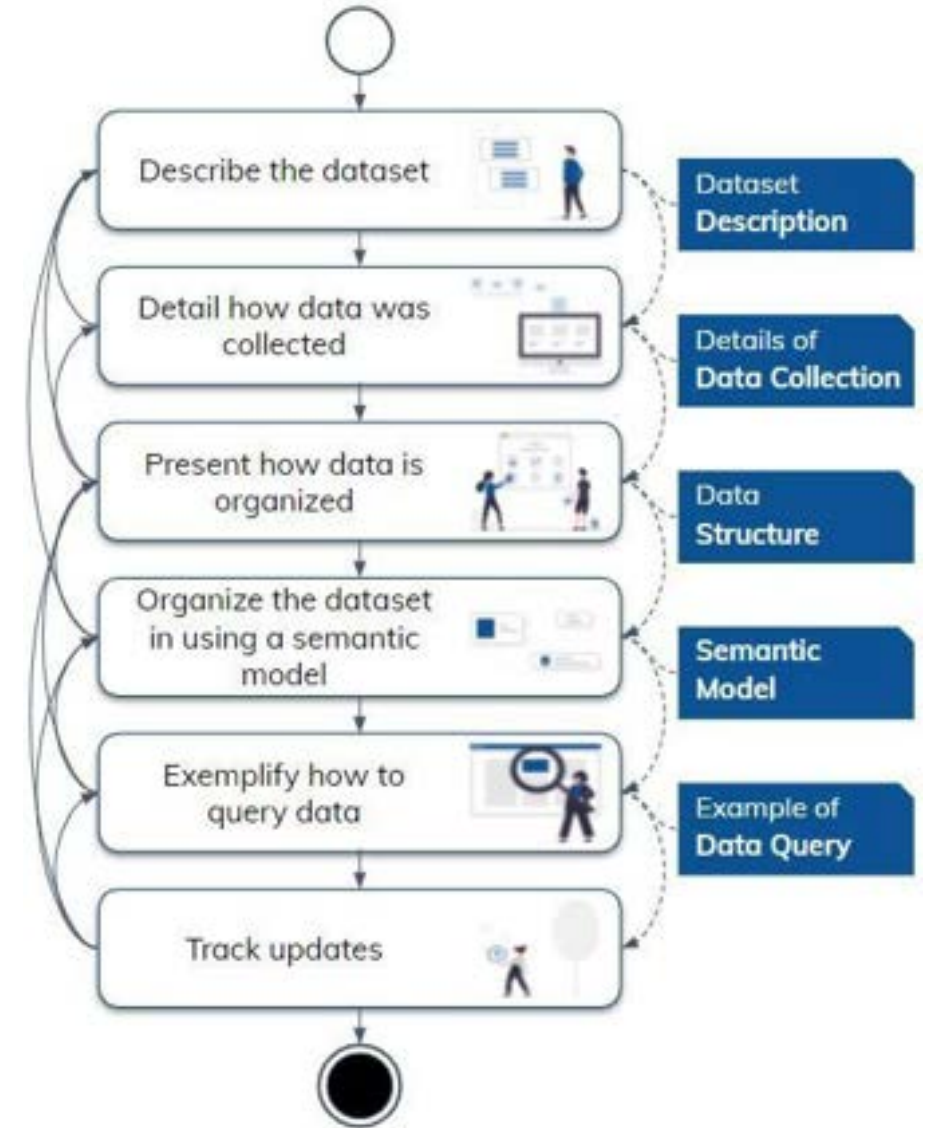


QoL Monitor
Collect User's Answers



Guidelines for IOHT databases

These **guidelines for building sensor databases for use in Internet of Medical Things** applications were constructed based on extensive research into public IOHT databases and our expertise with developing IOHT systems.



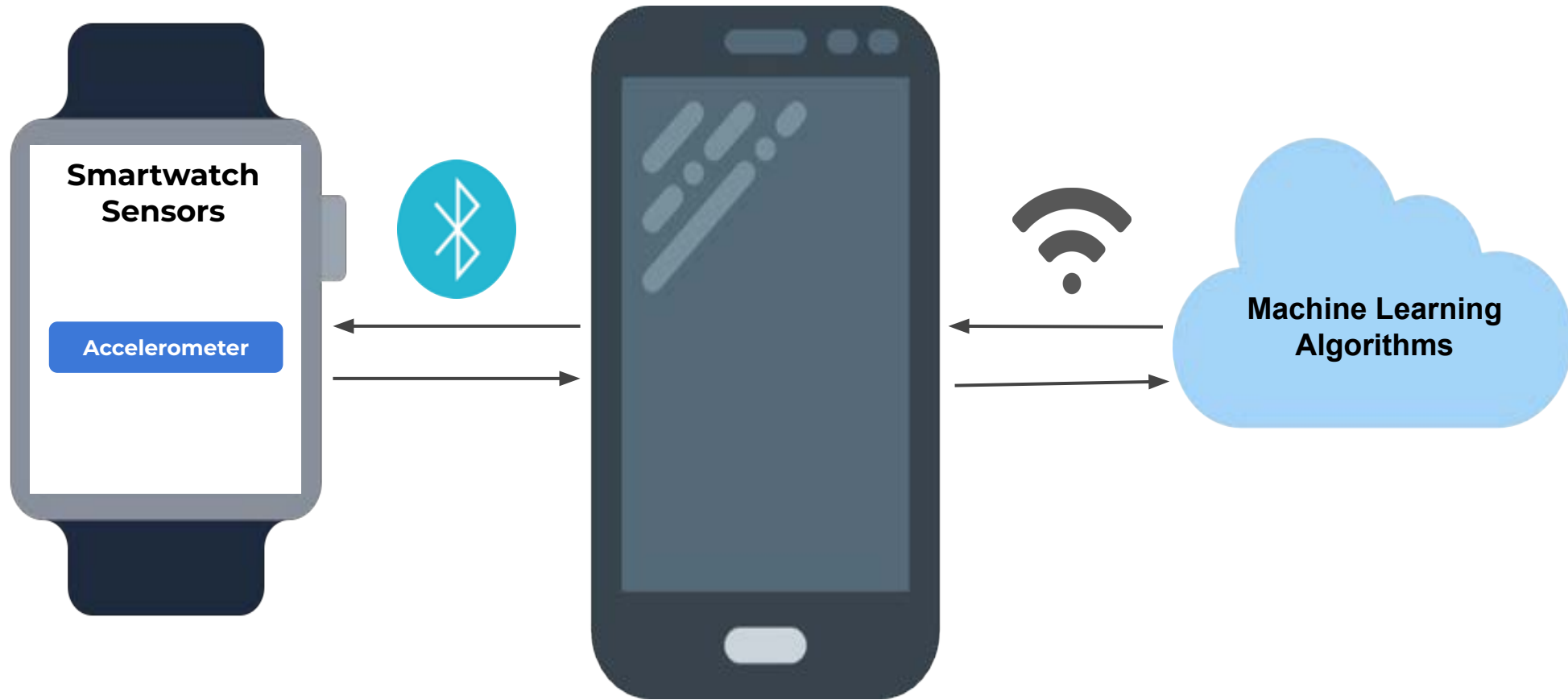
Taxonomy for the Development of Older Adults Healthcare Apps

- Based on the **Brazilian Health Handbook for the Elderly**
- **7 types of Applications**
- **87 characteristics** in **21 categories**
- For each application, the taxonomy defines which characteristics are **Essential**, **Optional** or **No related** to the type of application

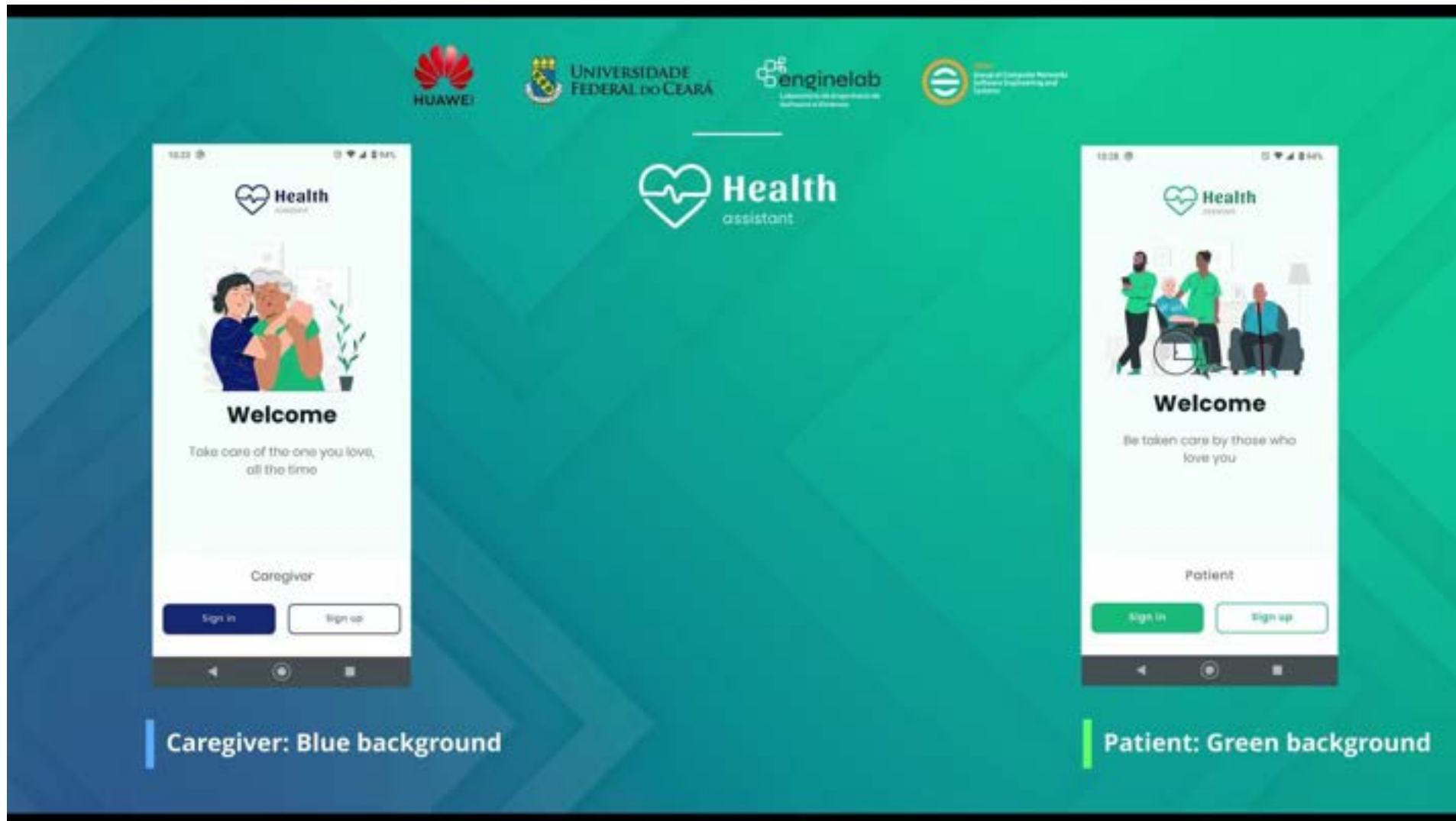
	Classification of the older adults regarding dependence		Relation with the reference person		
	Independent	Dependent	Family person	Professional caregiver	Doctor
Application to assist older adult care	E		E	E	E
Applications of medical treatment and follow-up	E		E	E	E
Home monitoring healthcare systems	E		E	O	E
Selfcare application	E		N	E	E
Epidemiological clinic systems	E		E	O	E
Medical normative systems	E		O	E	E
Medical governance applications	E		E	N	E

Applications Developed by our e-Health Team

WatchAlert



Health Assistant (partnership with Huawei)

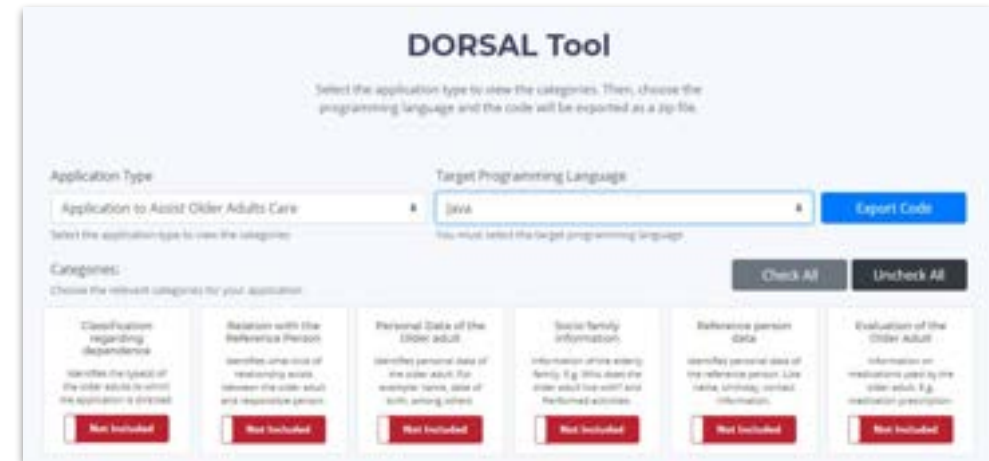
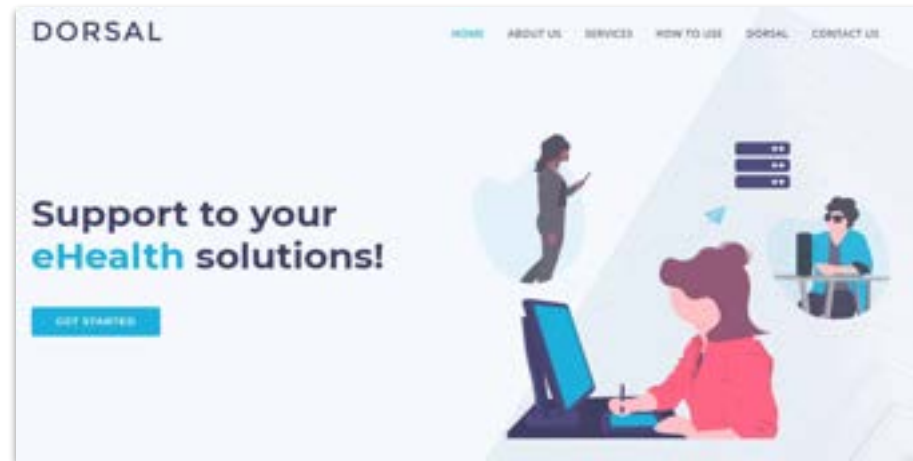


Caregiver: Blue background

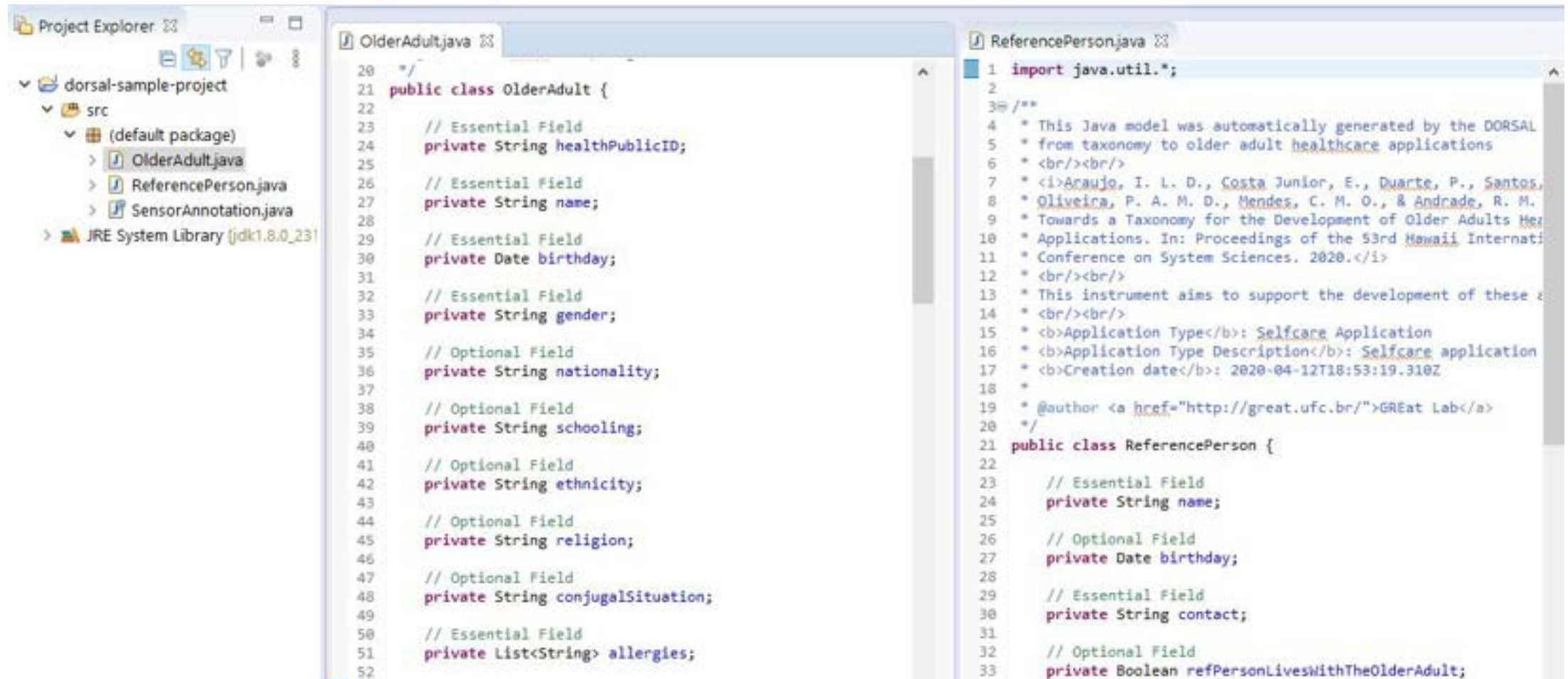
Patient: Green background

Dorsal

- The **Dorsal tool** to support the use of our taxonomy in the automated generation of data models for applications (Web and/or mobile applications) aimed at health and elderly care
- Dorsal was developed in Javascript and is available as a web service at the link: <https://great-ufc.github.io/dorsal>



Example of a Java model generated by the tool

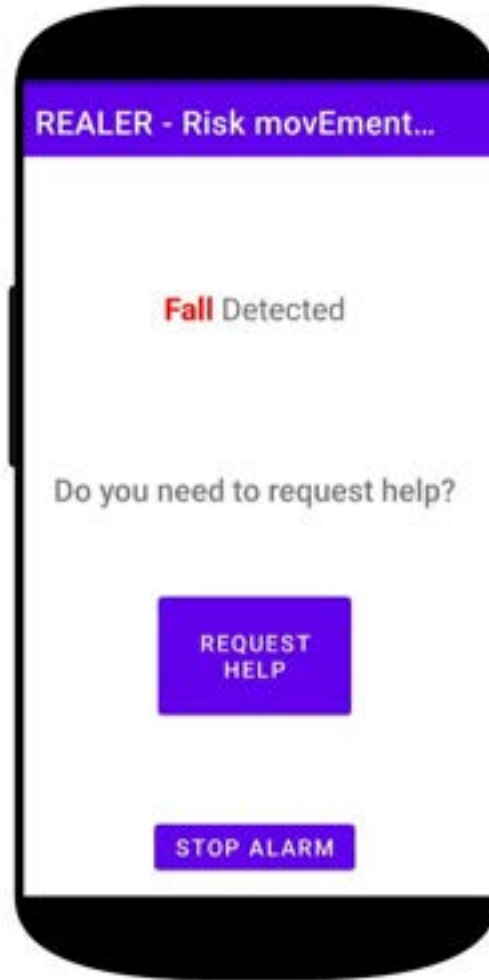
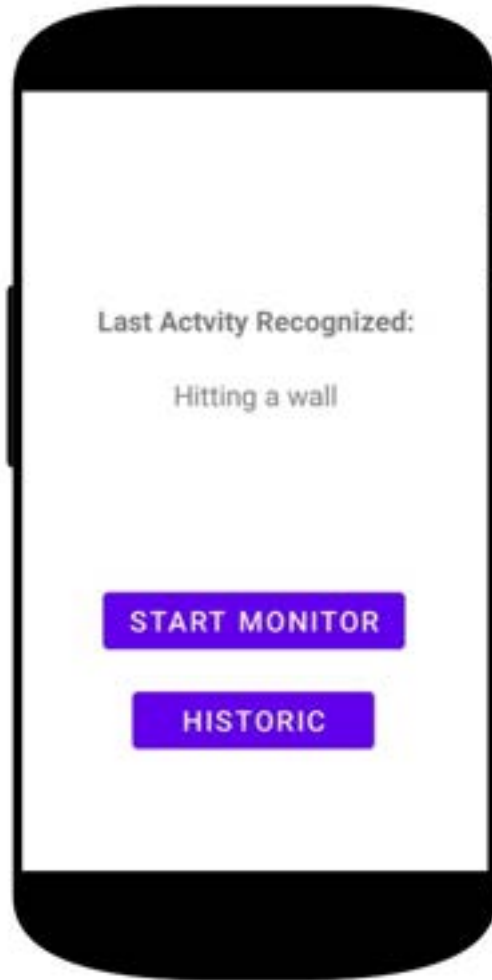


```
Project Explorer:
└─ dorsal-sample-project
   └─ src
      └─ (default package)
         ├── OlderAdult.java
         ├── ReferencePerson.java
         └── SensorAnnotation.java
      └─ JRE System Library [jdk1.8.0_231]

OlderAdult.java
20  /*
21  public class OlderAdult {
22
23      // Essential Field
24      private String healthPublicID;
25
26      // Essential Field
27      private String name;
28
29      // Essential Field
30      private Date birthday;
31
32      // Essential Field
33      private String gender;
34
35      // Optional Field
36      private String nationality;
37
38      // Optional Field
39      private String schooling;
40
41      // Optional Field
42      private String ethnicity;
43
44      // Optional Field
45      private String religion;
46
47      // Optional Field
48      private String conjugalSituation;
49
50      // Essential Field
51      private List<String> allergies;
52

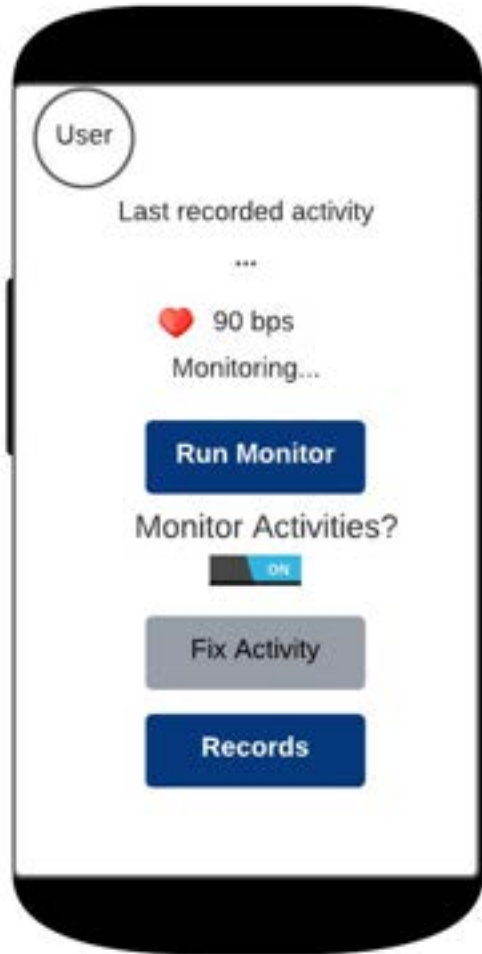
ReferencePerson.java
1  import java.util.*;
2
3  /**
4   * This Java model was automatically generated by the DORSAL
5   * from taxonomy to older adult healthcare applications
6   * <br/><br/>
7   * <i>Araujo, I. L. D., Costa Junior, E., Duarte, P., Santos,
8   * Oliveira, P. A. M. D., Mendes, C. M. O., & Andrade, R. M.
9   * Towards a Taxonomy for the Development of Older Adults Health
10  * Applications. In: Proceedings of the 53rd Hawaii Internati
11  * Conference on System Sciences. 2020.</i>
12  * <br/><br/>
13  * This instrument aims to support the development of these c
14  * <br/><br/>
15  * <b>Application Type</b>: Selfcare Application
16  * <b>Application Type Description</b>: Selfcare application
17  * <b>Creation date</b>: 2020-04-12T18:53:19.310Z
18  *
19  * @author <a href="http://great.ufc.br/">GREat Lab</a>
20  */
21  public class ReferencePerson {
22
23      // Essential Field
24      private String name;
25
26      // Optional Field
27      private Date birthday;
28
29      // Essential Field
30      private String contact;
31
32      // Optional Field
33      private Boolean refPersonLivesWithTheOlderAdult;
```


REALER

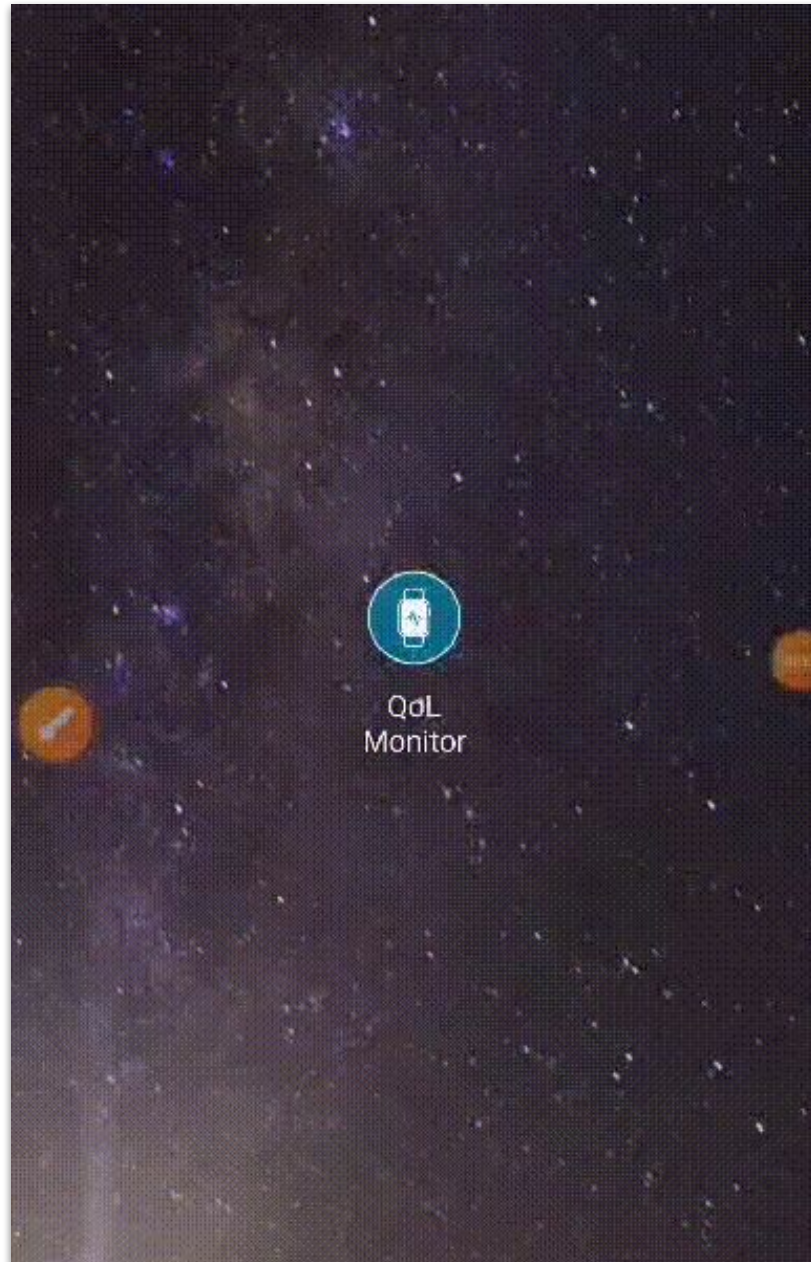


Download the REALER app code

ARCANA



Download the ARCANA app code



- **QoL Monitor** is the app that allows the extraction of fundamental data for monitoring Quality of Life indicators
- Once extracted, the data is anonymized and encrypted before being sent to the cloud. Then, the data is processed and submitted to the intelligent models of the Healful platform
- For the user, the result is ubiquitous monitoring of their Quality of Life in the physical and psychological sphere

 qol-monitor.com

 github.com/great-ufc/QoLMonitor

 play.google.com/store/apps/details?id=br.ufc.great.qolmonitor



Some accesses will be restricted while the tool is not registered on the INPI platform.

BACK
TO
THE FUTURE

New technologies can benefit from the use of AI applied to IoHT

- 5G and 6G networks applied to IoHT
 - Data Collection and Transmission
 - Security
 - Resource consumption
- Ambient Assisted Living
 - Device interoperability
 - Controllers
- Cloud computing applied to IoHT
 - Storage
 - Big Data Processing
 - Machine Learning Services
- Conversational and Generative AI
 - Chatbots
 - Custom care plans for patients

5G



Our Team

Members and Collaborators



Rossana M. C. Andrade



Evilasio Junior



Ítalo Linhares



Ismayle Santos



Pedro Oliveira



Amanda Pires



Lourival



Francisco Victor



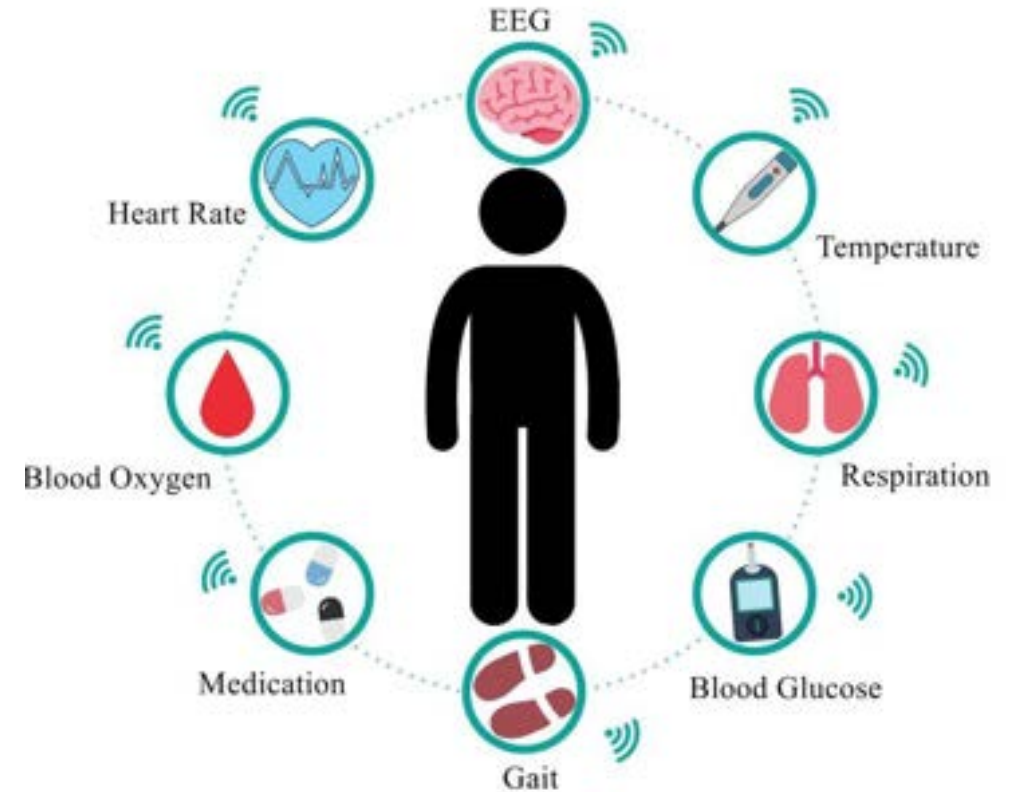
Laurindo



Nadiane



Leonardo Sampaio



Source: https://www.researchgate.net/publication/335277281_Health_Monitoring_in_Smart_Homes_Utilizing_Internet_of_Things.



Thank You!

Rossana Maria de Castro Andrade

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[@rossanamcandrade](https://www.instagram.com/rossanamcandrade)

Questions?