

Home Assessment of Physical and Physiological Parameters: Collaborative Research on Aging Using Technology

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Abstract – Thanks to advances in technology, home sensors are increasingly being used in the healthcare field, particularly for health assessment of the elderly. CART France is a research and development project that aims to improve the quality of life of the elderly. To do so, it aims at coupling digital biomarker information with biological and clinical biomarkers. Digital biomarkers mainly concern meal intake and mobility data. This paper presents the analysis of the first data obtained from the deployment of ambient sensors in a house. The combination of two types of sensors placed in the kitchen allows us to identify a correlation between mobility and personalized nutritional information.

Keywords: Sensors, Aging, CART, Physical Activity, Biomarkers

I. INTRODUCTION

With the evolution of technology, the use of home sensors is advancing in healthcare, particularly for health assessment of the elderly. Technologies related to health and wellness monitoring have advanced significantly with the availability of computer-based techniques, wearable, wireless and mobile technologies, and high-dimensional data analysis [1]. High-frequency assessment using digital technologies has been shown to provide earlier and more sensitive detection of changes in health, cognition, and function, which can lead to improved diagnosis, prevention, and treatment specific to the individual's situation that health professionals are able to implement. Our work focuses on the use of digital biomarkers and how they can be implemented in the care pathway [2]. Overall, adults aged 65 and older living alone represent a significant proportion of the population in the United States (13%) and France (19.6%) [3]. However, the adoption of these digital approaches in clinical research [4] and their use in e-health [5] has been relatively limited. The reasons have already been identified [6]: sample size, duration of the study, absence of real data, limited scalability of home sensor platforms.

In the United States, Oregon Health & Science University has created an innovative research center called ORCATECH. In order to find solutions to problems associated with home assessment research; CART (Collaborative Aging Research using Technology) initiative was developed [7]. In this study, we examine the benefits of home monitoring methods for the assessment of older adults, the current state of home monitoring technologies for cognitive health, and how they are used. The paper presents the French CART home technology platform and show some preliminary results from data collected to identify habits through room mobility [8] and kitchen use. We hypothesize that the use of digital biomarkers not only allows us to identify the physical and physiological state of the person, but also to follow in real time their habits and to detect any changes in order to predict any early danger. The French CART project aims to provide a general follow-up of the activities of elderly people at home and outside. We focused our study on the nutritional status of individuals.

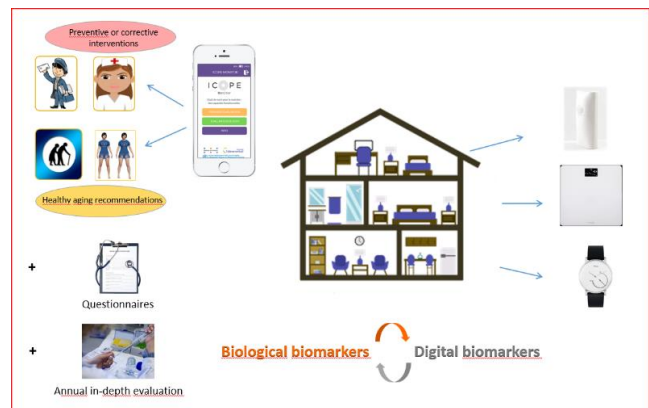


Figure 1. Architecture of the tools in both approaches

As shown in Figure 1, the digital analysis will be completed with the clinical analysis. The clinical analysis consists of a

self-evaluative examination to determine biological biomarkers and correlation of biological and digital biomarkers by a clinical expert (e.g., in the past week, did you spend one or more nights away from home? In the past week, have you had any visitors stay with you? In the past week, have you changed treatment OR started a new treatment?). The combination of these approaches is intended to develop a model that allows correctly diagnose health status and provide a primary analysis to clinicians.

II. RELATED WORKS

In-home sensor platforms offer possible advantages for collecting information related to cognition and physical and physiological measurements over conventional assessment methods [9].

Gambi et al. [10] propose an application to monitor individual's food intake actions during a meal. The eating actions are estimated from deep image analysis. In order to optimize and increase the performance of algorithms, the author's idea is to automate the process, which allows to identify the different food acts.

Hilde Lohne-Seiler et al. [11] propose the ActiGraph GT1M accelerometer to measure Physical Activity (PA) for seven consecutive days. A questionnaire was used to record self-reported health status.

S. Coradesch et al. [12] propose the Giraff telepresence robot which uses a Skype-like interface to allow caregivers to virtually visit an elderly person at home. The system monitors daily activities and physiological parameters and can provide a more reliable view of the person's health status, both for the person themselves and for the caregivers and family. The system can also trigger alarms and present long-term data that may indicate health deterioration.

As mentioned previously, the main problem with this technology is the limited number of participants and the lack of study duration. The use of digital biomarkers in the care pathway requires relevant real-life data in order to integrate them into the patient health care pathway record.

The CART study aims to provide a solution to this limitation by using a set of sensors in a real environment and for a long monitoring period. In the next section, the CART experimentation is presented.

III. PLATFORM FOR A REAL-LIFE HOME MONITORING

The CART initiative has developed an administrative and operational infrastructure for a scalable technology platform to support research on aging in place [13].

The platform includes a computer hub (Raspberry Pi) that is connected to the participant's internet service. It communicates

with the sensors using wireless protocols (Zigbee, Wi-Fi, Bluetooth) for data collection.

As described in [14-15], monitoring of participants' activity in the home is performed using PIR sensors (NYCE) mounted on the wall of each room at shoulder height. To measure walking speed, four narrow-field PIR sensors are placed on the ceiling (at intervals of approximately 61 cm) in an area regularly traversed by participants in the home, such as a hallway. Contact sensors (NYCE) are also placed on all exit doors in the home. Step counts, activity levels, and sleep measurements are collected using an activity tracking bracelet that participants asked to wear. Other actigraphs and wearable devices may also be used. Participants' activity is monitored at home using a wireless sleep measurement device, placed under the mattress and operating on the principle of cardiography, which provides information on sleep periods and records heart rate, breathing rate and movements during the night.

Medication monitoring is recorded with an electronic pillbox. This allows the physician to determine when to open and close each of the daily compartments. An electronic scale collects physiological measurements (weight, body mass index, reference weight, etc.).

A computer application collects computer usage data for people using a Windows operating system on a desktop or laptop computer, including the number and duration of computer activities.

A sensor connected to participants' car port provides information on driving behavior, including number and time of trips, time spent on the highway and hard acceleration and braking.

The CART initiative platform is illustrated in Figure 2.

Data is sent securely from the hub (Raspberry-pi) to a central database via a virtual private network (VPN).

Collaboration between ORCATECH and CHU-Toulouse allows the same CART US platform to be used in the CART France project. CART France is a living lab project based on 100 connected homes. The differences between the French CART project and the U.S. CART project are the number of sensors used in both projects, as CART France selected the types of sensors that enable us to monitor behaviors associated with nutrition. Another difference is the study environment in terms of home infrastructure and the difference in culture (habits) between the two populations.

As shown in Figure 3, the sensors used in CART France are physical and physiological sensors. i.e., PIR and contact sensors to identify physical activities inside and outside the house using a smart watch. Physiological parameters [16], such as nutrition, require weight monitoring, which explains the use of a scale in this case.



Figure 2 The CART initiative platform hub computer and sensors [10]

III. SYSTEM OVERVIEW

A. SYSTEM ARCHITECTURE

Based on the similar concept of CART US, as shown in Figure 4, each house is equipped with a Raspberry-pi hub, a ZigBee dongle, 4 Nyce line sensors, 1 or 2 contact sensors, each one for the front door and, in each room, a PIR Nyce wall sensor. The sensors are all interoperable because they all use the same Zigbee protocol. To improve the nutrition database, our research team chose to use contact sensors in the kitchen, in the refrigerator and cupboard doors, and in the microwave. The total number of sensors for measured physical activity averaged 13-16 sensors per home.

B. DATA COLLECTION

The deployment of the CART FRANCE project was launched in July 2022 after obtaining all the necessary authorizations from the Committee for the Protection of Individuals and the National Commission for Information Technology and Liberties.

At the moment, we have already equipped 10 houses in the Occitanie region. Data and recordings are sent on a regular basis. Some criteria have been defined before each installation as: The commitment of the person for the duration of the study which is on average 5 to 10 years, the participant must be already included in a more global project, Inspire national Project [17], the participant must be 75 years old and more, and live alone in the house without having an assistant, robust and have an internet connection.

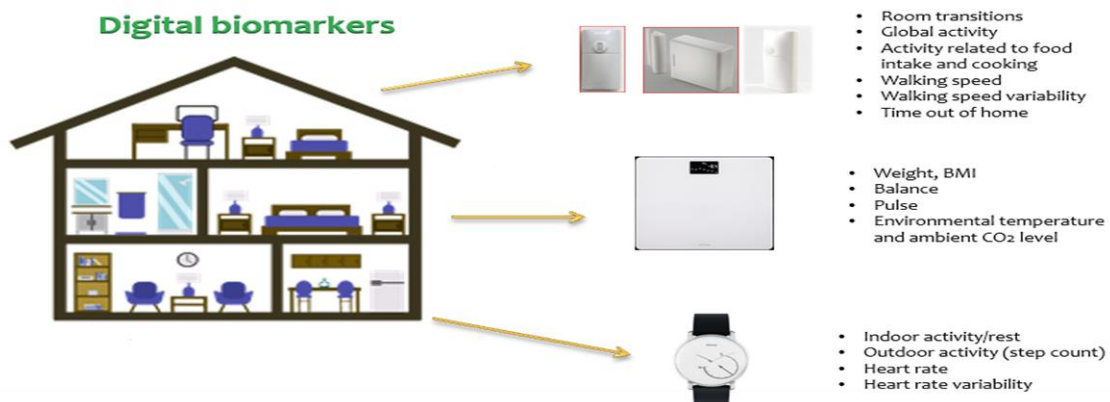


Figure 3. Overview of devices in the CART France project devices

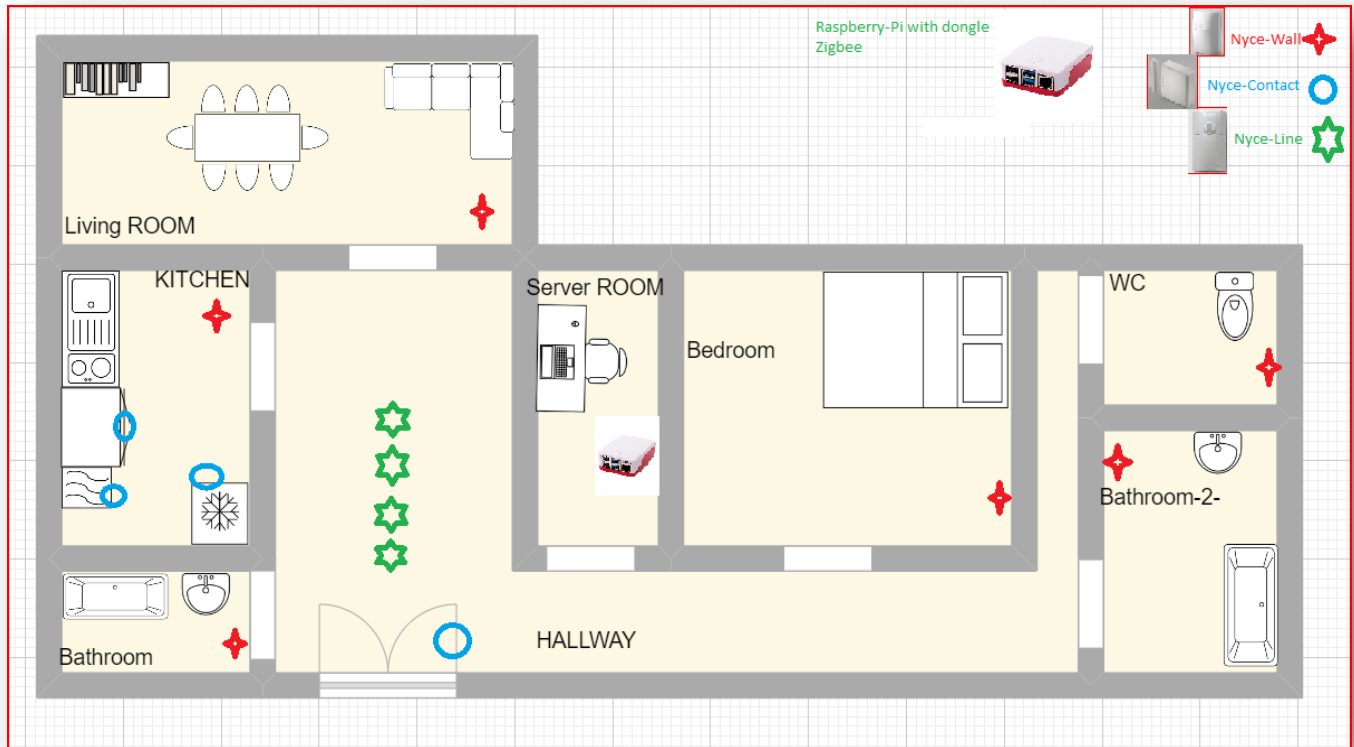


Figure 4. Distribution of sensors at home

stamp	areaid	event	month	month_days	weekday
01/11/2022 06:29	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:29	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:30	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:32	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:35	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:43	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:43	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:44	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:45	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:46	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:47	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:47	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:49	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:50	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:54	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:56	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:57	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:57	KITCHEN	1	11	01/11/2022	Tuesday
01/11/2022 06:57	KITCHEN	1	11	01/11/2022	Tuesday

Figure 5. Data collection sample

For PIR sensors, each activity detected by the sensor in the room sends 1, which means the presence of the person in the room, otherwise it sends 0.

As for the contact sensors, the detection of the opening sends 1 and the closing 0.

The use of the watch allows to follow the physical activities outside the house.

The scale must be used regularly to have a real time monitoring of all BMI and weight variations.

As shown in Figure 5, the database collects 3 essential data (areaid which means the name of the room, stamp which means the time and event which means the presence or not in the room).

From this data, we can identify the different types of activity in the house, the time slot of each activity and the presence rate in each room.

To perform a behavioral analysis study, we will use data from one of the houses we have already equipped.

IV. RESULTS AND DISCUSSION

As the objective of the CART France Project is to evaluate the nutritional status of the person, we have chosen to focus on the kitchen room in this study. The data from the PIR sensors attached to the walls will be used to determine the mobility of this person in the room. Thus, using the contact sensor in the refrigerator allows us to associate the mobility part with the meal preparation activity. The first step is to analyze the behavior by calculating the mean before using event classification and standard deviation calculations to detect high risk events.

Figures 6 and 7 show the activity levels in the kitchen over a one-month period. The main analysis that this graph can provide us is the disparity of the data between days, for example, we can observe that this person was present in the kitchen some days more than others.

The sequential analysis of each day (Figures 8 and 9) shows the time slots of the person's activities.

Figure 8 shows the different time slots in the kitchen room for a day. The time periods of 10-12am, 1-2pm, and 7-9pm contain the highest number of events detected by the sensors.

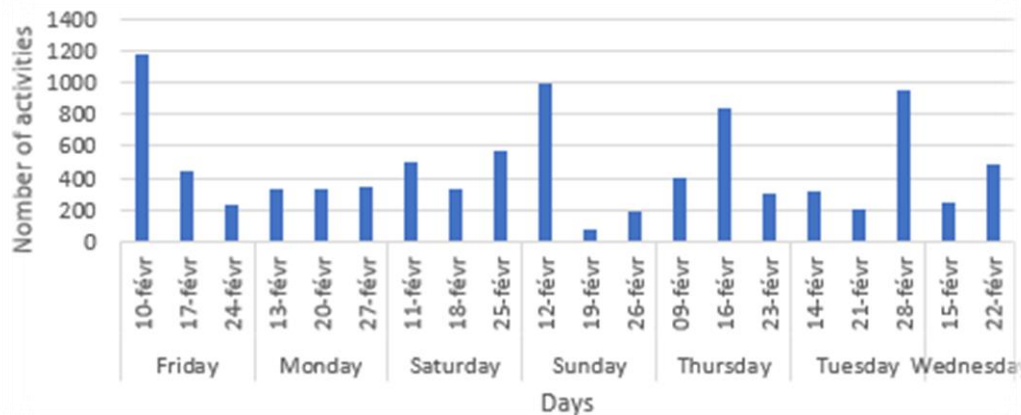


Figure 6. Number of events in the kitchen detected by the sensors in one month for a participant

When the maximum number of activities is detected during the day, we can attribute this mobility to different activities such as the preparation of meals or taking meals. The use of a second type of data such as the opening of refrigerators allows us to position well on what corresponding events (Figure 9). A time analysis between the two graphs in Figures 8 and 9 shows a correlation especially over the period 10-12am for the mobility graph and at 11am for the refrigerator activity graph. This correlation allows us to assume that this period corresponds to the meal preparation events. We hypothesize

that other activities in the kitchen are related to the activation of meal intake.

Identifying the physical activity in the kitchen related to nutrition using its sensors and physiological measurements (weight) allows us to have a digital nutritional study (identify digital biomarkers) on the person monitored. We can also combine data from other sensors to calculate other aspects such as fall detection [18].

In parallel to this analysis, a weekly questionnaire is sent to the participants allows us to better understanding of the results of the numerical biomarkers.

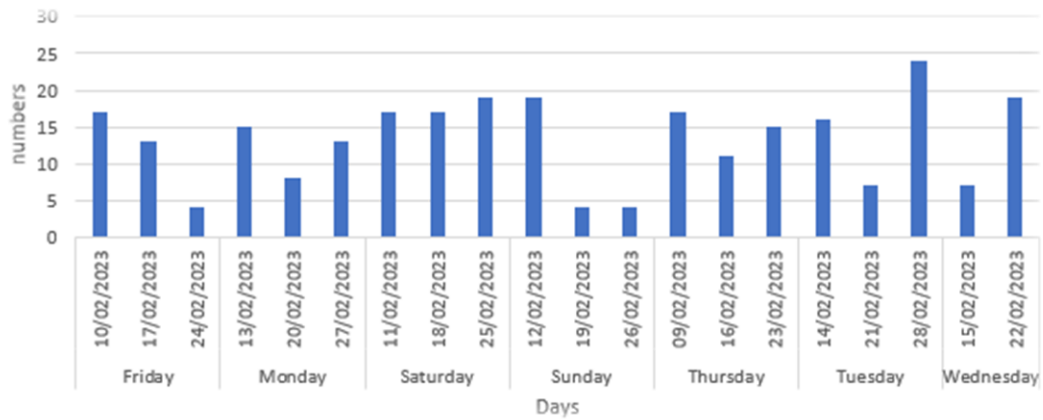


Figure 7. Number of times refrigerators are opened in one month

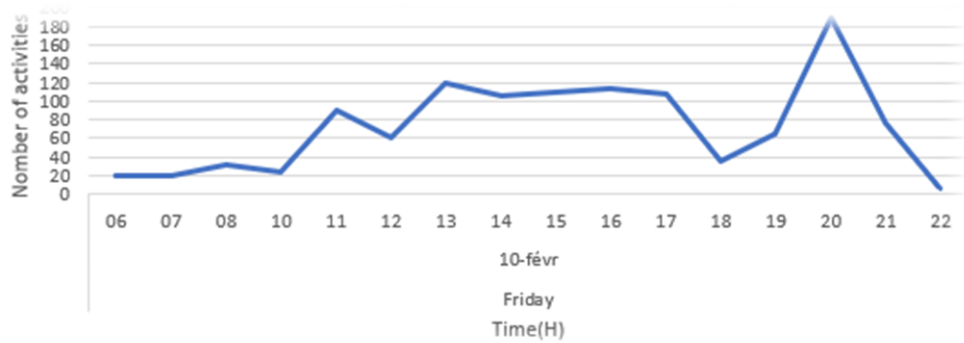


Figure 8. Time spent in the kitchen in one day

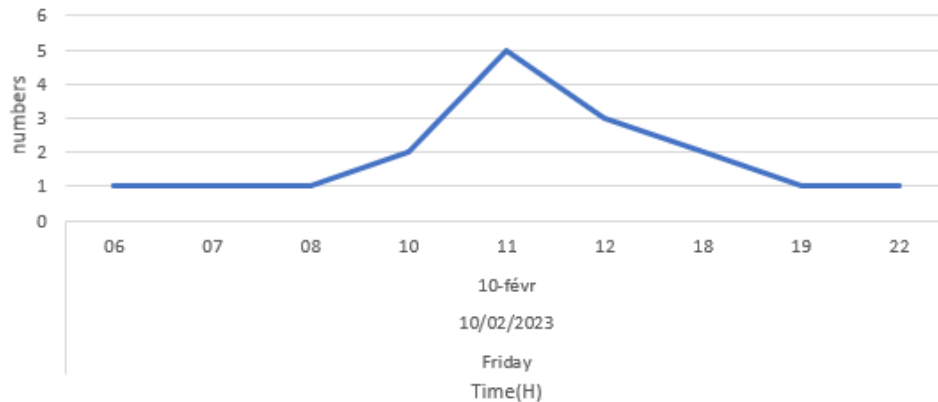


Figure 9. Number of times refrigerators are opened in one day

V. CONCLUSION AND PERSPECTIVES

CART France is a research and development project that aims to improve the quality of life of the elderly in their living environment thanks to the wealth of information related to meal intake and mobility provided by different types of sensors. The preliminary results we obtained allow us to identify correlations between mobility data and meal intake. Changes in habits can be easily detected and understood through the use of biological biomarkers coupled with digital biomarkers..

The results and analyses remain individualized, i.e., they change from one person to another. Our goal is to provide a digital analysis to the physician, who then correlates these objective digital results with data from clinical evaluations performed in the more global INSPIRE project. This study ultimately aims to build a nutritional model (including biological and digital biomarkers) that combined with AI algorithms will provide automatic diagnosis and can be included in the care pathway system.

Subsequently and based on our results, a comparative study between CART US and CART FRANCE could be proposed to identify the cultural or environmental factors that may affect nutritional behaviors between these two populations.

REFERENCES

- [1] S.B. Junaid et al., 2022 . Recent Advancements in Emerging Technologies for Healthcare Management Systems: A Survey. In *Healthcare*, 10(10), 1940. MDPI. doi: 10.3390/healthcare10101940.
- [2] Y. Song et al., 2022. Pathological Digital Biomarkers: Validation and Application. *Appl.Sci.*2022,12,9823. <https://doi.org/10.3390/app12199823>
- [3] A. Piau et al., 2019. Current state of digital biomarker technologies for real-life in-home monitoring of cognitive function for MCI to mild AD and implications for clinical care: systematic review. *Med Internet*, doi: 10.2196/12785.
- [4] J.P. Bakker et al., 2019. A systematic review of feasibility studies promoting the use of mobile technologies in clinical research. *Nature Portfolio J. Digit. Med.*, 2(47), doi: 10.1038/s41746-019-0125-x
- [5] M. Jung et al , 2009. Fulfilling the promise: A model for delivering successful online health care. *J. Med. Marketing*, 9(3), 243–254.
- [6] A. Piau et al., 2019. Current state of digital biomarker technologies for real-life, home-based monitoring of cognitive function for mild cognitive impairment to mild Alzheimer disease and implications for clinical care: systematic review. *Journal of medical Internet research*, 21(8), e12785.
- [7] Z. Beattie et al., 2020. The collaborative aging research using technology initiative: an open, sharable, technology-agnostic platform for the research community. *Digital Biomarkers*, 4(1), 100-118, doi.org/10.1159/000512208.
- [8] P. Thaitatkul et al., 2022. Mobility, activities, and happiness in old age: case of the elderly in Bangkok. *Case studies on transport policy*, 10(2), 1462-1471, doi.org/10.1016/j.cstp.2022.05.010.
- [9] A. Garcia-Agundez et al., 2019. Recent advances in rehabilitation for Parkinson's Disease with Exergames: A Systematic Review. *Journal of neuroengineering and rehabilitation*, 16(1), 1-17, doi: 10.1186/s12984-019-0492-1.
- [10] E. Gambi et al., 2020. Food Intake Actions Detection: An Improved Algorithm Toward Real-Time Analysis, *Journal of Imaging*, doi: 10.3390/jimaging6030012.
- [11] H. Lohne-Seiler. et al., 2014. Accelerometer-determined physical activity and self-reported health in a population of older adults (65–85 years): a cross-sectional study, *BMC Public Health*, doi: 10.1186/1471-2458-14-284.
- [12] S. Coradesch et al., 2014. GiraffPlus: A System for Monitoring Activities and Physiological Parameters and Promoting Social Interaction for Elderly, *Journal Abbreviation: Advances in Intelligent Systems and Computing*, doi: 10.1007/978-3-319-08491-622.
- [13] N. W. Thomas et al., 2021. Home-Based Assessment of Cognition and Health Measures: The Collaborative Aging Research Using Technology (CART) Initiative and International Collaborations, in *IEEE Instrumentation & Measurement Magazine*, 24(6), 68-78, doi: 10.1109/MIM.2021.9513638.
- [14] Z. Beattie et al., 2020. The collaborative aging research using technology initiative: an open, sharable, technology-agnostic platform for the research community, *Digital Biomarkers*, 4(1), 100–118.
- [15] N.W. Thomas et al., 2020. An ecologically valid, longitudinal, and unbiased assessment of treatment efficacy in Alzheimer disease (the Evaluate-AD trial): proof-of-concept study, *JMIR Res Protoc*. 27;9(5):e17603. doi: 10.2196/17603.
- [16] I. Elmadfa et al., 2008. Body composition, changing physiological functions and nutrient requirements of the elderly. *Annals of Nutrition and Metabolism*, 52(Suppl. 1), 2-5, doi: 10.1159/000115339.
- [17] P. de Souto Barreto et al., 2021. The Inspire Research Initiative: A Program for Geroscience and Healthy Aging Research going from Animal Models to Humans and the Healthcare System. *Frailty Aging*, 10(2):86-93. doi: 10.14283/jfa.2020.18.
- [18] A. Piau et al., 2020. When will my patient fall? Sensor based in-home walking speed identifies future falls in older adults. *J Gerontol A Biol Sci Med Sci*, 75(5):968-973. doi: 10.1093/gerona/glz128.