Technological Solution to Optimize the Alzheimer's Disease Monitoring Process, in Metropolitan Lima, using the Internet of Things

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Abstract: The use of information technologies (IT) in the health sector has allowed to optimize monitoring processes for diseases such as Diabetes or Parkinson's. For this reason, the incorporation of IT into the monitoring of neurological diseases, such as Alzheimer's, will enable remote monitoring solutions on the patient's health. This study will develop a mobile and web application that will monitor, through an IOT device, changes in the patient's vital signs (oxygenation and blood pressure), impairment of cognitive functions (memory, calculation and concentration) and the patient's sleep status with Alzheimer's. In addition, with this solution the patient's doctor will be able to record recommendations on the progression of Alzheimer's disease. The study was validated with 3 physicians and 3 caregivers, who participated in the validation process by comparing the time before and after using the technology solution. As a result, the optimization of the monitoring process has been validated, allowing real-time control of the progress of the disease and having the appropriate considerations of the doctor in case of any incident that may happen with the patient

1 INTRODUCTION

According to the Peruvian College of Physicians (CMP), it is estimated that approximately 200,000 Peruvians could currently suffer from Alzheimer's disease, and the figure is estimated to be quintupling by early 2050 (CMP - https://bit.ly/3lmkHEF).

Alzheimer's is a disease that increases with age, starting with subtle symptoms such as memory problems, disorientation in time/space, and difficulty naming objects. The World Health Organization (WHO) classifies the signs and symptoms of early-stage, intermediate- and late-stage dementia. The early stage; often goes unnoticed, presenting as more common symptoms the tendency to forgetfulness, the loss of the notion of time and spatial desubication (WHO - https://bit.ly/35lG6Z7).

As dementia evolves into the intermediate stage, signs and symptoms become more apparent. In view of this, in order to have greater knowledge about the impact of this disease, it was proceeded to analyze the information presented by radio program of Peru (PTR), in which they indicated that in the Ministry of Health in 2015 alone the number of Peruvians with Alzheimer's were 3,207; in 2016, from 3,309 to 2017 increased to 3,665, among new and old cases of people over the age of 60 (RPP - https://bit.ly/2UuZXiB) from Figure 1.

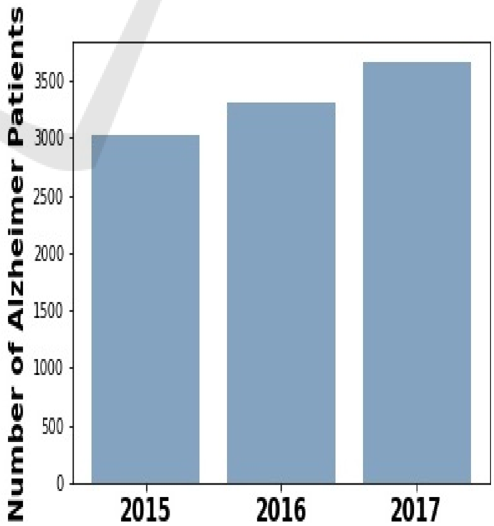

Figure 1: Indicator of people over the age of 60 diagnosed with Alzheimer's according to the Ministry of Health of Peru.

This information shows the importance of incurring monitoring the progression of Alzheimer's dis-

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ease, in order to support the monitoring of patients with the aforementioned disease.

Faced with this need to find some kind of technological solution, a study conducted in Catania and Messina, Sicily, developed a telemedicine system that involves three approaches: nutritional status, biometric data monitoring and cognitive status; focused on the care of the elderly in order to prevent neurodegenerative diseases. This system uses a device with internet access, which contains a web platform on which consultations are made to a doctor.

In addition, this system allows to provide cognitive training sessions to the patient and all the collected data are sent to the corresponding medical units to assess the patient's situation. At the end of the validation of this project, an improvement was observed regarding the nutritional status of the person, cognitive functions and the execution of daily activities of the participants (Maresca et al., 2019). By identifying this type of solution, it has been validated what to know about the health status and impairment of a patient's cognitive functions makes it easier for the doctor to generate accurate recommendations regarding the advancement of the patient's disease.

For this reason, this study answers the following question What technology is available, what technological devices should be taken into account to develop a mobile and web application that optimizes the monitoring of Alzheimer's disease, in the city of Lima, Peru? In response, it is proposed to develop a technological solution that allows to optimize the process of monitoring Alzheimer's disease, in Metropolitan Lima, using the Internet of Things.

The main contributions in this solution:

- it allows to generate a constant communication between doctor and caregiver,
- establish a medical control without moving the patient to the medical center,
- provide real-time information of blood pressure, oxygenation, the generation of alerts to the doctor about the signs of health of the patient.

Finally, this research is structured as follows: in Section 2, brief definitions of the concepts used in the development of the project will be indicated, Section 3 will include the analysis, design and construction of the project, in Section 4 the comparison will be made between technological solutions developed against our proposed proposal, Section 5 will explain what has been done at the programming level, validation and results, finally Section 6 will present the conclusions and recommendations.

2 RELATED WORKS

During the development of our proposal, various contributions from studies were considered as references such as (Rostill et al., 2018), in which authors indicated that including IoT devices for home monitoring and vital signs, allow to lead to important interventions in which serious complications could occur without the use of technology.

Furthermore, in (Alexandru and Ianculescu, 2017), the authors present another assisted technology that helps people affected by dementia, such as the MSI-MDD digital platform.

Nevertheless, it is also evidenced that the authors of (Jain et al., 2018), through a mobile application evaluate and improve the emotional state of caregivers, allowing to optimize the stimulation process for the caregiver, applying medical metrics.

Finally, in (Gilson et al., 2019), the authors showed that web-based video services can be used on tablets, allowing to improve mood in people living with dementia and improve perceptions of caregivers about the daily interaction that older adults may have with their caregivers.

It should be noted the works aforementioned focus on improving the mood of patients and caregivers, however, the solutions presented do not allow to establish a medical control to monitor the disease of the patient with Alzheimer's, through the capture of sleep state data and vital signs, which will allow to generate constant communication between the doctor and the caregiver that empowers them to make decisions about the patient's health.

3 METHOD

The development of the project was divided into 2 of the main dimensions of design thinking: desirability, which will be explained in the analysis and feasibility section, which will be explained in the design section.

3.1 Analysis

In this phase, an initial survey of the problem was carried out, focusing it on the first dimension of design thinking: desirability.

- The first step consisted of sharing surveys with three doctors and ten caregivers of patients with Alzheimer's disease (AD), in order to obtain the relevant data during the AD monitoring process. In this survey, the relevance and frequency of taking vital signs of Alzheimer's patients was evaluated. The final result made it possible to identify

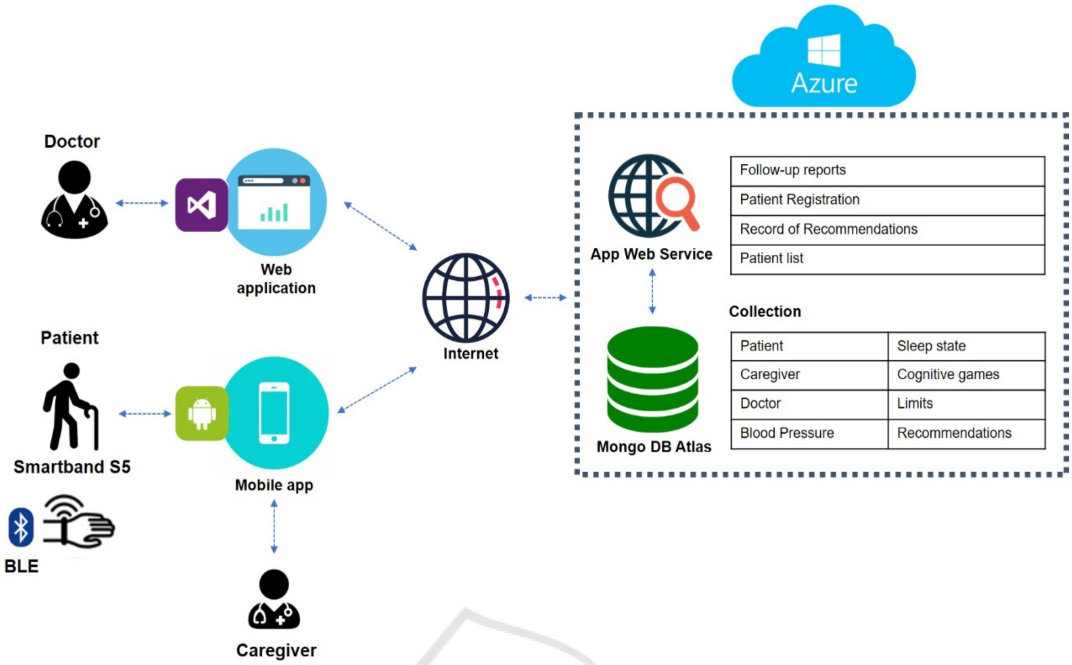


Figure 2: Architecture of integration of the proposed technological solution.

that blood pressure, oxygenation level, sleep status and cognitive functions are the relevant data.

- As a second step, through the testimonies obtained, we proceeded to develop the customer journey of the patient with Alzheimer's in its three phases of the disease, in which the moments through which the patient passes in their day to day were obtained as a result, identifying eight moments, which are: grooming, dressing, eating, cognitive entertainment, relaxation, rest, medication and physical activity. The development of the Customer Journey also made it possible to identify the actors in the monitoring process, which are: doctor and caregiver, while, on the other hand, the costs and times associated with the monitoring process were identified.
- In the third step, the wearables available for data collection were evaluated. Therefore, the evaluation was carried out based on the information collected in the previous steps and on the device characteristics such as water resistance, cost, battery life, built-in sensors and weight.
- The fourth step is the value proposition canvas was developed which allowed to reaffirm the initial approach of the project, through the identification of gain creators, pain relievers, gains, pains.

Finally, the wearable Smartband S5 was selected (S5 Bluetooth Heart Rate Fitness Smart Bracelet - https://bit.ly/36nQfEc). This device allows the capture of data such as heart rate, oxygenation level, blood pressure, step counter, calories and sleep status. The wearable's margin of error is 10% in case the person or patient who uses it is in constant motion . This value was indicated to the physicians who carried out the initial survey and they said that the margin would not significantly affect the values obtained from the patient, since they don't usually perform high physical activity

3.2 Design

For the design phase, a logical and physical architecture was developed in order to identify the relationships between the project components. Furthermore, the development of a mobile application that would interact with the wearable and a web application was established.

In addition, the interface design was developed based on the requirements defined in the analysis phase (see Figure 2). Likewise, an integration architecture was developed to identify the relationships between the participants (doctor, caregiver and patient), processes (patient monitoring) and information (patient health report) that compose the technological solution.

Additionally, the interface design was developed based on the requirements identified in the analysis phase.

3.3 Elaboration

During this stage, the applications that compose part of the technological solution were developed: mobile and web.

On the one hand, the coding of the mobile application included the libraries android-smartband-sdk-sxrblejy2aidl-release.aar and android-smartband-sdk-sxrblejy2library-release.aar to establish the connection with the wearable Smartband S5. Likewise, this library allowed obtaining data related to vital signs (arterial pressure and blood oxygenation) and sleep status. Additionally, stimulation games aimed at the following cognitive functions were included: memory, concentration and calculation. The data related to vital signs, sleep status and scores in the cognitive stimulation games were stored in the MongoDB Atlas database and the visualization functionality was integrated through reports with the support of the AAChartCore-Kotlin library.

On the other hand, the code of the web application includes the development of functionalities for displaying reports related to the patient's health status with support of the Chart JS library. Likewise, the functionality of recording recommendations for each patient was incorporated (see more details in the demo video).

4 EXPERIMENTS

For validating the system for patients with AD, surveys were conducted focused on evaluating the impact on time and costs in the monitoring process.

4.1 Experimental Protocol

A virtual meeting was held with a doctor and two caregivers to consult on the functionalities of the web and mobile solution, it should be noted that before starting the meeting a pre-validation survey was shared, which allowed obtaining the indicators related to costs and time that involves monitoring the disease.

After presenting the solution, insights were obtained about the system and with a post-validation survey the information was collected to identify the variation in the initial indicators. Likewise, the same dynamic was carried out with two additional caregivers, but in this case, the virtual meeting was replaced with a demonstration video (see more detail in this meeting).

4.2 Experimental Results

The focus of the validation is analyzing the results obtained in the pre-validation and post-validation survey that was carried out as a final step of the desirability dimension. The results of the aforementioned surveys allowed to verify the reduction of costs and time related to the monitoring of Alzheimer's disease (see more detail of these surveys).

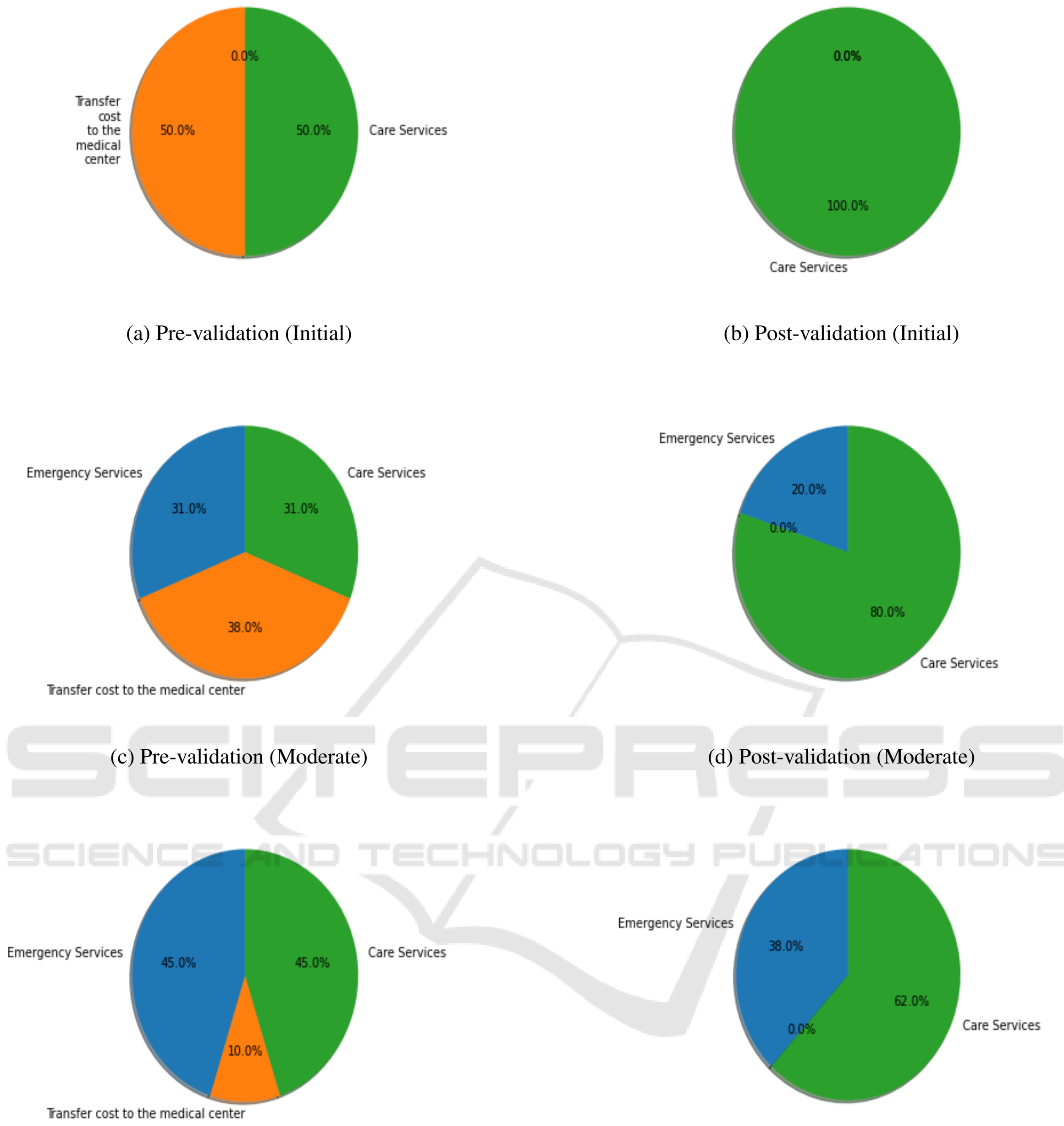
The following is what has been identified with respect to cost reduction (see Figure **??**):

- **Initial Phase:** it was identified that 50% of the people surveyed in the pre-validation, indicated as costs related to the monitoring process of Alzheimer's disease, the transfer to the medical center. However, in the post-validation this percentage was reduced to zero, leaving only the costs related to the care service (see Figures 3a and 3b). The reduction in the mentioned cost was achieved by the use of telemedicine, which doesn't require a constant physical transfer by the patient to the medical center.
- **Moderate Phase and Severe Phase:** it was identified that, on average, 38% of the people surveyed in the pre-validation indicated as costs related to the monitoring process of Alzheimer's disease two main sources: a) emergency services and b) transportation costs to the medical Center. However, in post-validation, this percentage was reduced to 29% (see Figures 3c, 3d, 3e and 3f). The reduction of the cost of the emergency service was achieved due to the fact that there is constant monitoring of the patient's health by the doctor, who gets daily information about the variation of the patient's vital signs. This allows the doctor to make immediate decisions about the medications that the patient may require.

  Nevertheless, the reduction in the cost of transportation to the medical center, as in the mild phase, was achieved due to the use of telemedicine, since the doctor has the information required for the evaluation of the patient.

Regarding the reduction in the time of the tasks associated with the monitoring of Alzheimer's (see Figures 4,5,6,7 and 8), it was identified that various tasks are usually performed in a range greater than 20 minutes, it should be noted that, when using mobile app, web app, and wearable, task time is reduced by a maximum of approximately 19 minutes in total.

- **Measurement of Blood Pressure and Oxygenation:** we identified that this task (see Figure 4) was previously performed between 5 to 10 minutes (80% of the time) and between 21 to 60 min-



(a) Pre-validation (Initial)

(b) Post-validation (Initial)

(c) Pre-validation (Moderate)

(d) Post-validation (Moderate)

(e) Pre-validation (Severe)

(f) Post-validation (Severe)

Figure 3: Pre- and post-25cm.

utes (20% of the time) (see Figure 4a), however, it can now be all performed in a maximum of 10 minutes (see Figure 4b). The reduction in time to perform this activity was achieved due to the use of the wearable, which generates the measurement of blood pressure and oxygenation automatically, without the need to prepare the patient with the devices that were used to control the mentioned vital signs.

- **Transfer the Patient to a Medical Center:** we identified that this task (see Figure 5) was previously performed between 21 to 60 minutes (80% of the time) and more than 60 minutes (20% of the time) (see Figure 5a), however, it can now be all performed in a maximum of 20 minutes (see Figure 5b). The reduction to carry out this activity was achieved due to the use of telemedicine, which reduces the need to travel to a medical center periodically.

(a) Pre-validation (b) Post-validation

Figure 4: Measuring Blood Pressure and Oxygenation (in minutes).

(a) Pre-validation (b) Post-validation

Figure 5: Transferring the Patient to a Medical Center (in minutes).

(a) Pre-validation (b) Post-validation

Figure 6: Supporting Cognitive Stimulation Activities (in minutes).

- **Activities to Support Cognitive Stimulation:** we identified that this task (see Figure 6) was previously performed between 21 to 60 minutes (80% of the time) and more than 60 minutes (20% of the time) (see Figure 6a), however, it can now be all performed in a maximum of 20 minutes (see Figure 6b). The reduction to carry out this activity was achieved by the use of the mobile application, which includes games aimed at the following cognitive functions: memory, calculation and concentration. For this reason, the search time for activities related to cognitive functions decrease, according to the values indicated above.
- **Supporting Physical Exercise Activities:** we identified that this task (see Figure 7) was previously performed between 11 to 20 minutes (20% of the time) and around 21 to 60 minutes (80% of the time) (see Figure 7a), however, it can now be all performed in 30 minutes in average (see Figure 7b). The reduction to perform this activity,

(a) Pre-validation (b) Post-validation

Figure 7: Supporting Physical Exercise Activities (in minutes).

(a) Pre-validation (b) Post-validation

Figure 8: Communication with an Specialist in case of complication (in minutes).

like the previous activity, was achieved by the use of the mobile application, which includes recommendations for physical exercises, which is suggested by the patient's doctor. For this reason, the search time for physical exercises decreases, according to the values indicated above.

- **Communication with an Specialist in Case of Complication:** we identified that this task (see Figure 8) was previously performed between 11 to 20 minutes (60% of the time) and around 21 to 60 minutes (40% of the time) (see Figure 8a), however, it can now be all performed in 22 minutes in average (see Figure 8b). The reduction to perform this activity, like the last two mentioned before, was achieved by the use of the mobile application, which includes a section on "Generate alert" for the doctor, in case the ranges of the variation of the patient's vital signs are outside the limits established by the doctor and by the information that the he maintains on the website of the patient's results. For this reason, the time taken to explain to the doctor how the patient's health behavior has been in a given period is reduced because the doctor has all the variation generated day by day.

In addition to the aforementioned results, the medical specialists who participated in the survey indicated opportunities for improvement, such as:

- Add alerts for taking medications for the patient and caregiver.
- Include the wearable activation functionality from the caregiver interface.
- Include other measurement variables such as: step count and heart rate.

Likewise, the general opinions that the respondents commented regarding the project presented were the following:

- The solution not only improves the quality of life of the patient, but also of the family member and caregiver.
- Definitely the doctor's monitoring is more efficient with the results obtained from the patient.
- It is a good starting point, the solution has a lot of potential.

5 CONCLUSIONS

Based on the information indicated in the previous sections, the reduction of transfer costs, emergency service costs and time associated with monitoring Alzheimer's disease has been demonstrated, the optimizing the EA monitoring process.

Likely, as a continuation of this work, we plan to expand the scope of the solution by incorporating the elderly, without restriction of having Alzheimer's disease. This approach is done because of what this population should have constant monitoring about its vital signs, to prevent future diseases to which they may be vulnerable due to their age. Evenmore, store all the data using blockchain (Cueva-Sánchez et al., 2020) technology to ensure security and accesibility.

For this reason, adding more variables such as temperature control, stress management, step counting, will allow you to have accurate control over the current state of an elderly person, which the doctor will be able to make preventive decisions before your patient. Taking this platform into cloud (Xu et al., 2020) could be a interesting topic or with other kinds of wearables (Roopaei et al., 2018) or using a chatbot to detect the symptoms (Solis-Quispe et al., 2021), and therefore extract patterns from the obtained data (Ugarte et al., 2015).

REFERENCES

Alexandru, A. and Ianculescu, M. (2017). Enabling assistive technologies to shape the future of the intensive senior-centred care: A case study approach. *Studies in Informatics and Control*, 26.

Cueva-Sánchez, J. J., Coyco-Ordemar, A. J., and Ugarte, W. (2020). A blockchain-based technological solution to ensure data transparency of the wood supply chain. In *2020 IEEE ANDESCON*, pages 1–6.

Gilson, A., Dodds, D., Kaur, A., Potteiger, M., and II, J. H. F. (2019). Using computer tablets to improve moods for older adults with dementia and interactions with their caregivers: Pilot intervention study. *JMIR Formative Research*, 3(3):e14530.

Jain, F., Sikder, A., Yang, F., Schafer, R., Dowling, G., and Traeger, L. (2018). Mentalizing imagery therapy mobile application to enhance mood of family dementia caregiver: Feasibility and limited efficacy testing (preprint). *JMIR Aging*, 2.

Maresca, G., Cola, M. C. D., Caliri, S., Luca, R. D., Manuli, A., Scarcella, I., Silvestri, G., Bramanti, P., Torrisi, M., Calabrò, R. S., Bramanti, A., and the Sicilian Teleneurology Group (2019). Moving towards novel multidisciplinary approaches for improving elderly quality of life: The emerging role of telemedicine in sicily. *Journal of Telemedicine and Telecare*, 25(5):318–324.

Roopaei, M., Rad, P., and Prevost, J. J. (2018). A wearable iot with complex artificial perception embedding for alzheimer patients. In *WAC*, pages 1–6. IEEE.

Rostill, H., Nilforooshan, R., Morgan, A., Barnaghi, P., Ream, E., and Chrysanthaki, T. (2018). Technology integrated health management for dementia. *British Journal of Community Nursing*, 23:502–508.

Solis-Quispe, J. M., Quico-Cauti, K. M., and Ugarte, W. (2021). Chatbot to simplify customer interaction in e-commerce channels of retail companies. In *International Conference on Information Technology & Systems*, pages 1–6.

Ugarte, W., Boizumault, P., Loudni, S., Crémilleux, B., and Lepailleur, A. (2015). Soft constraints for pattern mining. *J. Intell. Inf. Syst.*, 44(2):193–221.

Xu, M., Feng, G., Ren, Y., and Zhang, X. (2020). On cloud storage optimization of blockchain with a clustering-based genetic algorithm. *IEEE Internet Things J.*, 7(9):8547–8558.