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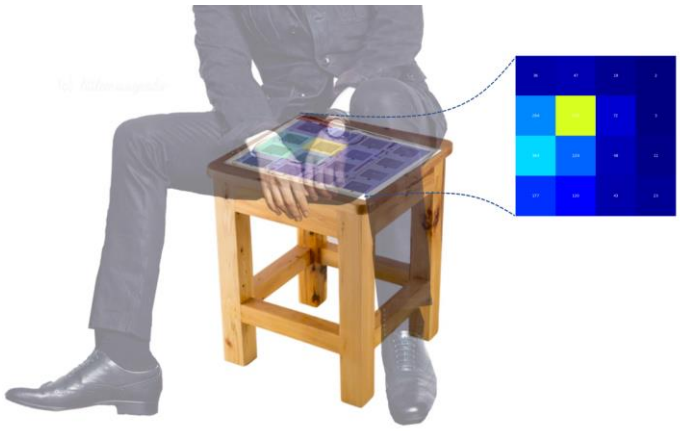
1SHARE

Executive summary

The present research objective is to develop a human activity recognition (HAR) system by exploiting in-memory computing (IMC) and machine learning technologies. However, while most of the developed HAR systems have been focused on the identification of macro activities, little attention has been addressed to systems with a narrower scope. After analyzing market potential and challenges, the development of a sitting posture recognition system emerged as the most promising route. From a literature review study, passive solutions (office chairs with ergonomic design) were proved to be scarcely effective, active solutions (posture identification through sensors) have not been developed to define a scalable product. In order to address such research gaps an integrated system will be created, composed by a smart office chair and a smartphone application providing warnings to the user. The HAR system will be integrated with the office chair, by using a sensors matrix integrated on the seat. This innovative product could lead to drastically improve the effectiveness of office chairs in maintaining a correct position as well as reducing the impact of backaches on users' health condition.

Key Words

In-Memory Computing, Human-Activity-Recognition, Machine Learning, Posture Recognition



1SHARE smart chair concept.

Project description written by the Principal Academic Tutor

Human activity recognition (HAR), or the ability to learn and classify a certain behaviour based on sensor data and algorithm, is a growing topic in artificial intelligence (AI) for monitoring health, industrial processes and security. A key objective for HAR is the ability to learn/recognize the activity locally on the edge and in real time, thus minimizing the energy consumption and maximizing data privacy. The objective of this project is to develop edge-computing HAR hardware accelerators based on in-memory computing (IMC), which are capable of one-step acceleration of machine learning algorithms thanks to in-memory computing. The project focused on posture recognition as a case study, designing a novel smart-chair to classify the posture and give feedback to the user. The prototype chair and the computing system have been developed by off-the-shelf components and tested in the lab (TRL around 3). An IMC random-forest circuit has been designed and simulated. The results are extremely promising with respect to the state of the art in terms of accuracy of recognition and energy consumption, thus supporting IMC as an attractive alternative to digital systems for HAR smart sensors on the edge.

Team description by skill

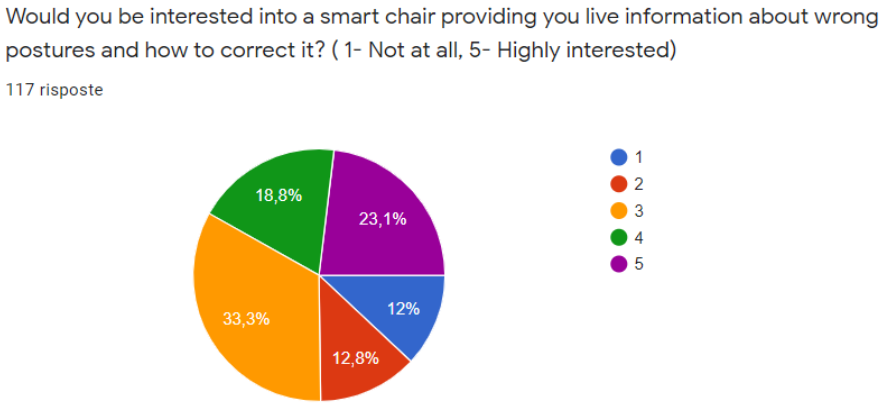
Irene Chiocchia	Management engineer	Project management, market analysis, cost analysis, production processes
Gian Luca Dolso	Physical engineer	Physics of devices and laser systems, optics, quantum mechanics
Riccardo Galvani	Biomedical engineer	Biomedical devices and instrumentation, electronics of biomedical sensors
Kevin Montano	Nanotech engineer	Physics of nanostructured devices, micro- and nano-electronics, hardware design
Marcello Neri	Electronic engineer	Electronic devices, sensors and circuits, hardware design
Andrea Scotti	Computer engineer	Computer programming, machine learning, digital systems, algorithms, databases

Goal

In-memory computing (IMC) is a very promising approach, that could effectively tackle the limitations in terms of speed and power consumption affecting current electronic devices. Indeed, computation and storage of data are physically separated in modern computers, and this significantly hinders performances, since a significant portion of the computation time and energy are actually employed to transfer the data. Furthermore, the computation time itself can be enormously shortened with this kind of approach: the analog data storage and physical in-memory computation enables IMC devices to perform a complex operation, such as the inversion of a matrix, in just one step, independently of the matrix size.

The goal of this project is to exploit the in-memory computing approach in the context of human activity recognition (HAR). Specifically, the goal is to conceive and develop a cutting-edge technological application that fully exploits the potentialities of this novel electronic paradigm to perform HAR in a more effective and reliable way. Human activity recognition is principally used as an assistive technology for healthcare and elder-care, empowered by extensive data collection from sensors, data-set construction, and machine-learning-based classification methods. Many players in this field have already made large investments, and the main categories of market-available devices are smartphones on one hand, and smartwatches and other wearables on the other. Despite the considerable size of the HAR market, it cannot be considered mature.

In this context, our team had to define a specific objective for the project. Particularly, we had to adequately select a single Human-Activity-Recognition task with a high importance to society and consumers, which could be effectively addressed by our IMC approach, in a way that would eventually confer us a significant competitive advantage over existing, non- IMC-based, solutions. This choice, of course, gave shape to the entire outcome of the project and took place in the very early stage, laying the foundations the subsequent phases.

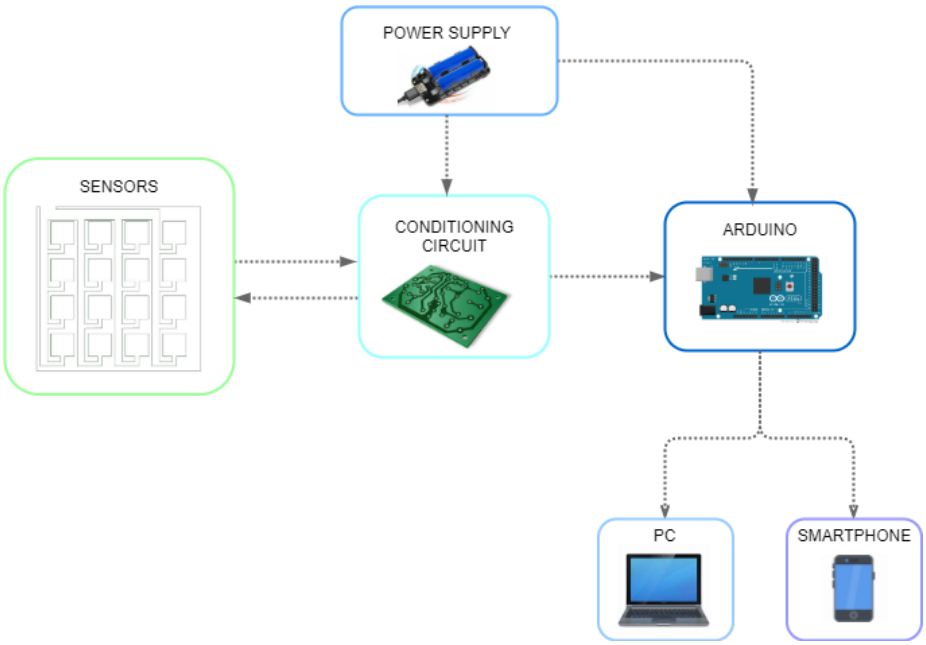


Relevance of the problem of an incorrect sitting posture, addressed by 1SHARE.

Understanding the problem

In the first phases of the project activity, the team selected a single HAR task or problem that the IMC approach could solve with superior performances. For this choice of scope, the first, relevant observation to be made is that the majority of existing HAR devices are focused on the identification of macro-activities, such as walking and running, while little attention has been addressed to systems with a narrower scope. The team therefore performed an extensive research on existing HAR systems, taking into account both the technical aspects related to such technologies and also the more social and economic side of HAR, including consumer trends and market potential. Due to the high importance, the high market potential and the highly-advantageous applicability of the IMC technology, the team decided to focus on a very specific field related to healthcare and health prevention: we decided to address the issue of an incorrect sitting posture as a cause of back pain and other health problems.

The importance of this issue is beyond doubt. Our bodies and our anatomy were never designed for long sitting hours and office work, and the current Coronavirus outbreak only worsened our lifestyle, making even more sedentary. Since the first industrial revolution, work tasks have constantly reduced the amount of physical effort they require. Leisure activities as well are often carried out while seated: playing video-games, watching films and reading are just a few examples. The ill-effects of a poor sitting posture and sedentary life are well-known for leading to different chronic diseases. A first category of health issues affects the musculoskeletal system, and includes low-back pain (LBP) and sciatica. Experts estimate that up to 80% of the US population will experience back pain at some time in their lives. An incorrect sitting posture can also lead to cardiovascular problems, an important example being impaired circulation in the higher-pressure zones. In turn, cardiovascular problems may affect also the digestion process, leading to a general stagnant, fatigued feeling. Therefore, the overall well-being of the person is affected by an incorrect sitting posture, with implications that reach the physiological sphere. These health issues also translate into direct and indirect costs for business organizations.



Smart chair hardware.

Exploring the opportunities

The team chose to address the problem of an incorrect sitting posture, due to this issue's unquestionable relevance and high market potential. The identification of this scope allows the strengths of the IMC approach to be fully exploited: indeed, posture recognition is a computationally expensive task, which typically requires significant amounts of time and energy on a standard, non-IMC electronic device. For this reason, this computation is cloud-based in most of the solutions already in the market. Our solution is characterized by a higher efficiency, both in terms of computation time and energy requirement: this allows for the computation to take place in the device itself, with no need for an internet connection, with a higher speed and no privacy-related issues due to cloud operation.

Generating a solution

Once the scope of the project was suitably chosen, the team had to design the solution that could perform the required task, and perform real-time sitting posture recognition, with the goal of correcting the user's posture. Among the possible parameters to be monitored, the most effective for posture

determination is the pressure map of the area on which the person is sat. Within this choice, several design solutions were considered. For instance, the first design solution to be considered was a cushion, that was however discarded due to the difficulty of adapting it to the wide range of commercially-available chairs, and also because its mobility hinders the accuracy of the measurements. The final concept we propose consist in a smart chair, with real-time recognition of the user's posture and real-time feedback, so that ill-postures and bad sitting habits can be corrected for, by means of a constant flow of advice.

Main bibliographic references

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