SAPA Technology: An AAL Architecture for Telemonitoring

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Abstract: Ambient Assisted Living (AAL) aims to allow frail older adults to stay safe at home, partly through remote monitoring which offers clinicians a means to prevent and manage risks. AAL needs an architecture to support the large set of data emanating from multiple sensors dispatched in several smart homes. These data must be processed in real-time to take the appropriate decisions in time. In this article, we propose an Event-Driven Architecture according to the publish-subscribe pattern. The proposed architecture is the core of our system, named SAPA Technology. It is composed of three layers: data gathering, data ingestion, and data processing. To ingest the data stream, we choose Apache Kafka, an open-source broker, and Apache Spark, a streaming system to process the ingested data. The SAPA Technology architecture respects scalability, homogeneity, and modularity. It supports at least thirty-eight smart homes.

1 INTRODUCTION

The aging of population in Canada and elsewhere in the world changes the way social and health services must be delivered (Organization, 2015). Only 10% of Canadian over 65 years-old live in a retirement home, or in a nursing home if their health status necessitates more medical services (Roy et al., 2018). But the number increases when incapacities and management of multiple chronic disease necessitate moving into a nursing home, or relying on increase home-care services. Even in the context of disability, older adults express the will to stay at home for as long as possible. However, some diseases can lead to severe cognitive, physical, and sensory deficits such as neurodegenerative diseases, strokes, arthritis, or macular degeneration. These conditions can have significant impacts on functional independence, especially in Activities of Daily Living (ADL). They may cause multiple risk situations whether immediate, such as falls, or on the long term, such as social isolation, malnutrition, or poor hygiene (Boulos et al., 2017; Robinson, 2018).

Research into Ambient Assisted Living (AAL) focuses on automated methods or processes to support safe performance in ADL, particularly for older adults with multiple health conditions while being supported by family, friends and medical staff (Rashidi and Mihailidis, 2013). ALL involve a sensitive, adaptive, and responsive software system to changes in the conditions of the persons living in the smart homes.

One of the AAL system aims is to support the clinical decision-making of clinicians delivering home

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care services (Lussier et al., 2020c; Lussier et al., 2020a). To do this, the AAL system monitors ADL performance and changes in habits and produce reports to inform clinicians. Clinical decisions related to the services that should be delivered to the older adults are then based on objective information (Lussier et al., 2020c). Offering periodic reports thus requires mechanisms for collecting and analyzing real-time data coming from smart homes.

Usually, data collection is done using sensors, connected objects and Internet of Things (IoT) devices capable of responding to an environmental stimulus. Thanks to this equipment, monitoring (Kanis et al., 2013; Zaric et al., 2015), context awareness (Wood et al., 2008; Schilit et al., 1994) and activity recognition (Charlon et al., 2013; Álvarez-García et al., 2013) can offer real-time services. The continuous flow of data emanating from the smart home requires computer methods to process them within a reasonable time frame. Above all, rapid data processing provides to the clinicians means to take informed decisions.

The great diversity of sensors and smart devices available implies to set up an infrastructure that manages heterogeneous data. Each device may contain several sensors with one or more parameters, which results in the creation of heterogeneous data. The AAL architecture must then manage the real-time streaming data emitted by these sensors as well as applications for data ingestion and processing to provide appropriate services to the older adults and the clinical staff.

To support the independence of older adults, the health care system in Québec, Canada, has implemented a program called SAPA (Soutien à l'Autonomie des Personnes Âgées; Support for the Autonomy of the Older Adults). SAPA Technology is a project conducted by our team in close collaboration with SAPA programs in Québec, that aims to promote home care services for isolated older adults with cognitive deficits through the use of remote monitoring of ADL. It aims to assess use cases and usability of the monitoring system. Ultimately, the project aims to support home care services in delivering the right services, for the right person, at the right time. This article mainly deals with the technological aspect of the SAPA Technology project. It presents, through software and hardware architecture, how remote monitoring is constructed, to facilitate home care through the analysis and treatment of ADL.

This article presents a scalable architecture optimized for real-time and batch data processing. Based on the Lambda architecture approach (Kiran et al., 2015), the proposed architecture combines the capabilities of collection, ingestion and batch and flow processing to recognize ADL, such as hygiene, meals preparation, rest, outings and inactivity. Lambda architecture is a data-processing architecture designed to handle massive quantities of data by taking advantage of both batch and stream-processing methods. Driven by events, the proposed model subscribes to IoT equipment events to offer to clinicians an ADL analysis interface.

The remainder of the article is structured as follows: the clinical needs for telemonitoring are presented in Section 2; the SAPA Technology architecture model based on Lambda architectures is presented in section 3; the tools used to implement the architecture are presented in section 4; the whole SAPA Technology system and some clinical elements are discussed in Section 5; and, finally, our conclusions are given in section 6.

2 CLINICAL NEEDS FOR TELEMONITORING

AAL is a promising alternative to promote aging at home and prevent risks. Remote monitoring offers means to the clinicians to be warned when a hazardous event occurs, and to determine social and medical services needed when the health status of the older adults evolves (Lussier et al., 2020b). Thanks to the sensors scattered around the person's home, precise information about their everyday life routine is collected. They can be combined with information reported by the older adults themselves, and/or their family, about how ADL are performed. Among those, the most important ADL are meals preparation, hygiene, sleep and outings (Rashidi and Mihailidis, 2013; Pollak and Perlick, 1991; Roy et al., 2016). The global level of indoors activity complements these ADL, since inactivity informs on the potential need of interventions regarding a health condition or motivation.

The expectations of the SAPA stakeholders taking part in the study is to be able to better understand the everyday life routine of the older adults with cognitive deficits and to obtain specific information about some of the activities they are engaging in. To do so, the SAPA Technology provides reports on the activities occurring at the older adults home to the clinician who may then decide to modify, or not, their intervention plan. Thereafter, the clinician can follow the intervention plans' implementation through regular reports offered by SAPA Technology (Figure 1). This remote monitoring of ADL is based on an AAL environment deployed at the older adults' home and gathering continuous information about activities occurring at home (i.e, meal preparation, hygiene, sleep, outings and periods of inactivity).

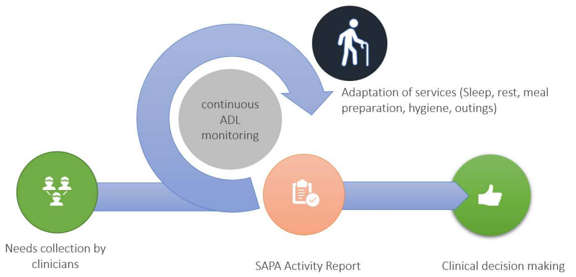

Figure 1: SAPA Telemonitoring process.

3 ARCHITECTURAL MODEL

By their nature, AAL systems are real-time systems that monitor the performance of ADL with the aim to assist when needed. An AAL system therefore involves the modeling of a real-time architecture.

This real-time prerequisite implies that the ambient sensors operate most often in event mode, namely in publish-subscribe patterns. According to this pattern, every detection of an action in the smart home triggers a sensor event (Kenfack Ngankam et al., 2020). An architecture that follows the publish-subscribe pattern is named Event-Driven Architecture (EDA) (Chandy, 2006). This approach contrasts with the SOA architecture approach that gathers data for responding to requests (Hanson, 2005).

The subscription model is better suited to push events to consumers rather than to offer passive data read mechanisms. With each significant change in the home, EDA promotes production, propagation and reaction to events. Thus, an event architecture favours responsiveness of the AAL system, as systems based on events are designed purposely for unpredictable and asynchronous environments (Hanson, 2005). Released from the data storage constraint imposed by requests, an event architecture greatly contributes to the scalability and adaptability of AAL systems. The remainder of the section first presents the criteria taken into account for modeling the EDA and, thereafter, the three components constituting the SAPA Technology architecture: data gathering, data ingestion and data processing.

3.1 EDA Requirements

The SAPA Technology architecture must deliver information to the clinicians, and assistance to the older adults, on a real-time basis, but it must also guarantee reliability and security for all the analyses and processes realized. Therefore, the EDA must satisfy three types of specifications:

1. Respond to the needs of final users
   - (a) Adaptable to the different needs of the older adults.
   - (b) Non-intrusive to facilitate the acceptability.
   - (c) Easy to use and offer real-time data stream processing capability.
2. Be devices independent
   - (a) Homogeneous to support different manufacturers and protocols in the same network.
   - (b) Generic enough to be independent of communication technology.
   - (c) Suitable for different smart environments.
3. Be extensible to integrate new services
   - (a) Modular, stand-alone and based on reusable components.
   - (b) Scalable to allow new sensors and components to be added or removed.

Lambda architecture is a data processing architecture, which takes the advantages of both batch processing and stream-processing to handle a large amount of data effectively (Kiran et al., 2015). The SAPA Technology architecture is a model based on Lambda architecture and consists of three layers. The data gathering layer is fully distributed and disseminated in the environment. Data ingestion occurs both at the edge and in the cloud to enable better interoperability. In the third layer, processing and application are performed in the cloud to benefit from the performance of compute tools.

3.2 Data Gathering

Sensors and IoT devices gather smart homes events to identify ADL. The interfacing of specific sensors/devices with the system is achieved by a local, distributed and autonomous data collection component. This component acts as an intermediate layer aimed at clearly separating IoT devices from the rest of the system. This separation makes it possible to increase the modularity and to increase the weak coupling between the components of the architecture, as shown in Figure 2. To facilitate context awareness, and promote the efficiency of exchanges, the privileged communications are of the machine-to-machine (M2M) type. The data collected by the sensors is transmitted to a local processing unit and to a data stream ingestion unit in real-time.

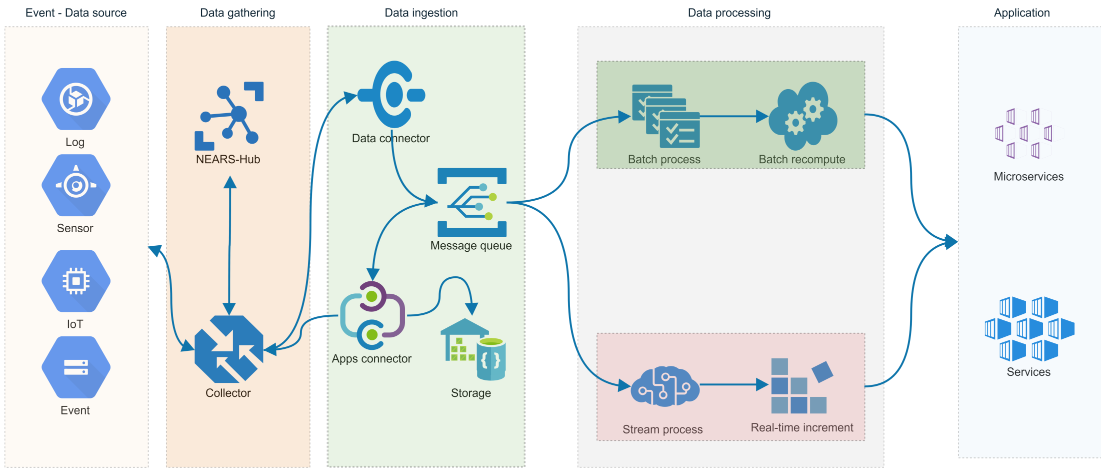

Figure 2: SAPA Lambda Architecture.

3.3 Data Ingestion

We propose a heterogeneous data ingestion model, as shown in Figure 2. The model can receive or extract heterogeneous data from multiple sources and save it in a unified format. Built to do data joins, aggregations, filters and transforms, the data ingestion model is based on distributed event streaming. Event streaming generates a continuous flow and interpretation of data to ensure that the right information is in the right place at the right moment. Four strategies based on high performance data pipelines are used to model the unit of ingestion. They are high availability, scalability, high throughput, and permanent storage.

In the SAPA Technology architecture, data is ingested from multiple different data sources at the same time. Each source submits new tuples on a stream, which are then received by the data ingestion mechanism. This data ingestion primarily serves as a mail queue. It routes the tuples to the correct destination while continuously triggering the appropriate Extract, Transform, and Load (ETL) process as new data arrives. The publish and subscribe process that analyses and transforms data ensures interoperability and reusability. The ingestion of each event does not require a response to the entity that delivered the data. It is a one-way data pipeline.

3.4 Data Processing

As a Lambda architecture, the SAPA Technology architecture was designed to ingest and process data in real-time (Figure 2). The data processing unit is a software component working either asynchronously or synchronously. It detects independent incoming events of different types and identifies a high-level event (e.g., ADL, by correlating these sensor events with the others). In this sense, high-level events can be defined as the output generated after processing many small IoT independent input data streams. High-level events can be: sleep, rest, meal preparation, hygiene, outings and periods of inactivity (Demongivert et al., 2021; Demongivert et al., 2020).

Data coming from data ingestion is sent both to the batch processing layer and the speed layer for processing. Batch processing uses a batch query to generate analyses and to identify high-level events. The main function of the batch layer is to use a historical archive to keep all the data collected. The speed layer is similar to the batch layer. It computes also similar analyses, except these analyses are realized in real-time and concern only the most recent data. To achieve this, it uses the queuing and streaming mechanisms. The flexibility of such an architecture makes it easy to adapt to the scalability of the older adult's needs.

4 IMPLEMENTATION

The implementation of the SAPA Technology architecture was primarily driven by the real-time nature of IoT systems. It integrates hardware and software components to support telemonitoring services. All the sensors of the SAPA Technology architecture use the Z-Wave and ZigBee communication protocols to transmit data.

Mainly due to the event-driven nature of IoT sensors, the implementation favored transmission in publish and subscribe mode. The publication and subscription mechanism involves three types of components: a client that sends messages, called a publisher, a second client that receives messages, called a subscriber, and a broker, responsible for managing the communication. MQTT (Message Queuing Telemetry Transport) (Hunkeler et al., 2008) is a lightweight network publish and subscribe protocol based on the Transmission Control Protocol (TCP). MQTT is open, simple, and easy to implement on devices with limited resources, in environments such as M2M communication and IoT. The MQTT broker is the main component of the data collection unit. A hub module is used as edge computing for local processing and ambient decision making.

A streaming system needs a messaging infrastructure at the start of its pipeline to feed the system with data. In the context of AAL systems, messages typically indicate the state of an IoT device at any given time.

Apache Kafka (Kreps et al., 2011) is an open-source message broker and highly scalable publish and subscribe messaging system capable of handling thousands of clients and hundreds of megabytes of read and write per second. Kafka emphasizes high speed messaging, scalability and sustainability. Kafka supports both batch consumers which may be offline and online consumers which require low latency. Well suited to equipment, subject to strong resource constraints, Kafka can manage long message delays to provide periodic system ingestion. It allows consumers to replay messages as needed, it is capable of queuing new tuples or pushing new ETLs to the streaming processing unit. This functionality is important for our architecture that is shared by multiple services. Kafka was chosen for these two reasons.

The automatic failover is realized by failure detection and active node election mechanism implemented on a distributed configuration service with Apache Zookeeper. Currently, in the SAPA Technology implementation, Kafka serves exclusively as a message queue for individual tuples, each of which is routed to the appropriate data flow graph in the streaming processing engine.

The Lambda architecture was proposed by Marz and Warren (Warren and Marz, 2015) to provide a scalable and fault-tolerant architecture for processing real-time and historical data in an integrated manner. It is the pillar of the SAPA Technology architecture to analyze large amounts of data in an efficient, fast, and fault-tolerant manner.

The SAPA Technology architecture uses Spark (Zaharia et al., 2010), a modern streaming system offering highly scalable processing with low latency. Spark provides data-driven processing, batch processing, and streaming primitives, all of which seem like a natural fit for SAPA Technology.

Spark is specially designed for latency sensitive applications that involve large volumes of data streams with time stamps, such as trading systems, fraud detection and surveillance applications. Spark provides the ability to perform in-memory calculations using resilient distributed data sets (RDDs), allowing it to provide faster compute times for iterative applications. Spark streaming processes data streams in micro-batches, where each batch contains a collection of events that occurred during the batch period (regardless of when the data was created).

The SAPA Technology is currently installed in thirty-eight smart homes. In each of these smart homes, an older adult is followed by a clinician who regularly carries out home care services follow-ups to adapt the range of services needed. The SAPA Technology has been validated and deployed in accordance with the Ministry of Health and Social Services' rules and regulations regarding data security and protection. Each house contains an average of thirty-eight connected devices. Typically, devices are composed of one to six built-in sensors. The SAPA Technology architecture currently supports more than three thousand sensors and processes, eight hundred raw events per minute for the detection of more than twelve high-level events (rest, meal preparation, outings, etc.) per minute (Figure 3).

5 DISCUSSION

The passage from a SOA architecture to a Lambda architecture allows to process a large amount of data coming from multiple smart homes. Therefore, the analysis is made easily on real-time or on batch mode to provide in depth analysis. The scalability concerns the number of devices installed in the homes, the number of smart homes and also the number of clinicians who could observe the data. The SAPA Technology architecture is also less prone to faults as the archive offers means to recover false analysis. The three layers architecture offers interoperability as communications between the layers have been judiciously chosen to ensure that various components may communicate together through an intermediate layer.

The SAPA Technology architecture offers modularity thanks to the Kafka pipeline that enables services to share data and the analysis they have made. Clinicians are able to visualize five ADL on a secure web platform. Regular reports are available to give indicators on ADL to support their clinical decision-making regarding services needed. Thanks to the modularity, we also plan to add services to the older adults in order to assist them and to provide a safe en-

Figure 3: SAPA Lambda Architecture Performance.

vironment without changing the internal code structure or the underlying technology.

The deployment of the SAPA Technology in a smart home necessitates installing the physical devices at home and to linking them to the SAPA architecture. In our architecture, services for the installer facilitate and shorten the time to deploy the sensors at home.

6 CONCLUSION

This article has presented the architecture that provides remote monitoring in an AAL system for older adults. This research on computer architecture is part of a larger research program conducted by a transdisciplinary team composed of computer scientists, occupational therapists, psychologists and designers. It is the cornerstone of multiple services for older adults and clinicians as well as for the research program.

Without a reliable architecture that allows to gather accurate information and to provide appropriate reasoning in real-time, clinicians and researchers may not be able to conduct other research programs and to develop services. This architecture is the result of the transdisciplinary team as all the needs identified by each discipline have contributed to elaborate the specifications of the architecture to attain a common goal.

In a near future, we plan to add services to the older adults, such as a calendar to remember appointments and planned activities. Thanks to SAPA Technology it will be easy to link the additional services to the existing ones in order for the applications to share the same data. To identify the ADL occurring in the smart home, SAPA Technologies infer the ADL recognition from rules and cross-referencing of event data. It is planned to use data mining approaches, which are available in Spark, to better follow the evolution of the older adults autonomy.

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REFERENCES

Álvarez-García, J. A., Barsocchi, P., Chessa, S., and Salvi, D. (2013). Evaluation of localization and activity recognition systems for ambient assisted living: The experience of the 2012 EvAAL competition. *Journal of Ambient Intelligence and Smart Environments*, 5(1).

Boulos, C., Salameh, P., and Barberger-Gateau, P. (2017). Social isolation and risk for malnutrition among older people. *Geriatrics & Gerontology International*, 17(2):286–294.

Chandy, K. M. (2006). Event-driven applications: Costs, benefits and design approaches. *Gartner Application Integration and Web Services Summit*, 2006.

Charlon, Y., Bourennane, W., Bettahar, F., and Campo, E. (2013). Activity monitoring system for elderly in a context of smart home. *IRBM*, 34(1):60–63.

Demongivert, C., Bouchard, K., Gaboury, S., Lussier, M., Kenfack-Ngankam, H., Couture, M., Bier, N., and Giroux, S. (2020). Fuzzy Features for Quality Estimation of Activity Instances in a Dataset. In *Proceedings of the 6th EAI International Conference on Smart Objects and Technologies for Social Good*, pages 54–59, New York, NY, USA. ACM.

Demongivert, C., Bouchard, K., Gaboury, S., Lussier, M., Kenfack-Ngankam, H., Couture, M., Bier, N., and Giroux, S. (2021). Handling of Labeling Uncertainty in Smart Homes using Generalizable Fuzzy Features. In *Proceedings of the Conference on Information Technology for Social Good*, pages 248–253, New York, NY, USA. ACM.

Hanson, J. (2005). Event-driven services in SOA. *Javaworld, January*, 31.

Hunkeler, U., Truong, H. L., and Stanford-Clark, A. (2008). MQTT-S—A publish/subscribe protocol for Wireless Sensor Networks. In *2008 3rd International Conference on Communication Systems Software and Middleware and Workshops (COMSWARE'08)*, pages 791–798.

Kanis, M., Robben, S., Hagen, J., Bimmerman, A., Wagelaar, N., and Kröse, B. (2013). Sensor Monitoring in the Home : Giving Voice to Elderly People. *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2013 7th International Conference on*.

Kenfack Ngankam, H., Pigot, H., Lorrain, D., Viens, I., and Giroux, S. (2020). Context awareness architecture for ambient-assisted living applications: Case study of nighttime wandering. *Journal of Rehabilitation and Assistive Technologies Engineering*, 7:205566831988786.

Kiran, M., Murphy, P., Monga, I., Dugan, J., and Baveja, S. S. (2015). Lambda architecture for cost-effective batch and speed big data processing. In *2015 IEEE International Conference on Big Data (Big Data)*, pages 2785–2792.

Kreps, J., Narkhede, N., Rao, J., and others (2011). Kafka: A distributed messaging system for log processing. In *Proceedings of the NetDB*, volume 11, pages 1–7.

Lussier, M., Aboujaoudé, A., Couture, M., Moreau, M., Laliberté, C., Giroux, S., Pigot, H., Gaboury, S., Bouchard, K., Belchior, P., Bottari, C., Paré, G., Consel, C., and Bier, N. (2020a). Using Ambient Assisted Living to Monitor Older Adults With Alzheimer Disease: Single-Case Study to Validate the Monitoring Report. *JMIR Medical Informatics*, 8(11):e20215.

Lussier, M., Aboujaoudé, A., Couture, M., Moreau, M., Laliberté, C., Giroux, S., Pigot, H., Gaboury, S., Bouchard, K., Belchior, P., Bottari, C., Paré, G., Consel, C., and Bier, N. (2020b). Using Ambient Assisted Living to Monitor Older Adults With Alzheimer Disease: Single-Case Study to Validate the Monitoring Report. *JMIR Med Inform 2020;8(11):e20215 https://medinform.jmir.org/2020/11/e20215*, 8(11):e20215.

Lussier, M., Couture, M., Moreau, M., Laliberté, C., Giroux, S., Pigot, H., Gaboury, S., Bouchard, K., Belchior, P., Bottari, C., Paré, G., Consel, C., and Bier, N. (2020c). Integrating an Ambient Assisted Living monitoring system into clinical decision-making in home care: An embedded case study. *Gerontechnology*, 19(1):77–92.

Organization, W. H. (2015). *World report on ageing and health*. World Health Organization.

Pollak, C. P. and Perlick, D. (1991). Sleep Problems and Institutionalization of the Elderly. *Journal of Geriatric Psychiatry and Neurology*, 4(4):204–210.

Rashidi, P. and Mihailidis, a. (2013). A Survey on Ambient Assisted Living Tools for Older Adults. *Biomedical and Health Informatics, IEEE Journal of*, PP(99):1.

Robinson, S. M. (2018). Improving nutrition to support healthy ageing: what are the opportunities for intervention? *Proceedings of the Nutrition Society*, 77(3):257–264.

Roy, N., Dubé, R., Després, C., Freitas, A., and Légaré, F. (2018). Choosing between staying at home or moving: A systematic review of factors influencing housing decisions among frail older adults. *PloS one*, 13(1):e0189266.

Roy, N., Misra, A., and Cook, D. (2016). Ambient and smartphone sensor assisted ADL recognition in multi-inhabitant smart environments. *Journal of Ambient Intelligence and Humanized Computing*, 7(1).

Schilit, B., Adams, N., and Want, R. (1994). Context-aware computing applications. In *1994 First Workshop on Mobile Computing Systems and Applications*, pages 85–90.

Warren, J. and Marz, N. (2015). *Big Data: Principles and best practices of scalable realtime data systems*. Simon and Schuster.

Wood, A. D., Stankovic, J. A., Virone, G., Selavo, L., He, Z., Cao, Q., Doan, T., Wu, Y., Fang, L., and Stoleru, R. (2008). Context-aware wireless sensor networks for assisted living and residential monitoring. *IEEE Network*, 22(4):26–33.

Zaharia, M., Chowdhury, M., Franklin, M. J., Shenker, S., Stoica, I., and others (2010). Spark: Cluster computing with working sets. *HotCloud*, 10(10-10):95.

Zaric, N., Radonjic, M., Pejanovic-Djurisic, M., and Radusinovic, I. (2015). An example of monitoring system with reasoning module for ambient assisted living applications. In *IEEE EUROCON 2015 - International Conference on Computer as a Tool (EUROCON)*, number 610658, pages 1–6. IEEE.