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Abstract

This communication describes research and development directionsthat are being explored for the creation of a maintenance system for home appliances. The solution will enable a faster and more accurate automation of after-sale services for home appliances. It will be based on three tiers: data acquisition, data analysis and business tiers. The communication provides a contextfor the work, both regarding the application area in general and the three tiers,and then describes the objectives of the system being designed.

Current advancements on maintenance for household appliances

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Abstract. This communication describes research and development directions that are being explored for the creation of a maintenance system for home appliances. The solution will enable a faster and more accurate automation of after-sale services for home appliances. It will be based on three tiers: data acquisition, data analysis and business tiers. The communication provides a context for the work, both regarding the application area in general and the three tiers, and then describes the objectives of the system being designed.

1 Introduction

This work considers the creation of a system to detect failures on home devices (refrigerators, air conditioning, washing machines, etc.) by monitoring them with respect to different parameters, such as: energy consumption, sound, temperature, among others. By means of the collected data, the system will analyse the device's status and its usage patterns to detect current or future operational anomalies. Furthermore, the system under design will give feedback to the user, by showing useful information about the device and, if a failure is detected, by indicating what is wrong with the device, while also suggesting possible reasons for the failure and actions to be taken. Based on these goals, the distributed system under design (see Figure 1) is articulated into three major components (tiers): a) a Data Acquisition tier, which collects data from the user premises, and takes care of transferring the data to where they can be processed, i.e.: a cloud; b) a Data Analysis tier, which stores device data and produces useful device information regarding energy consumption and potential malfunctions; c) a Business tier that receives devices data (e.g.: energy consumption) and processed information (e.g.: alerts regarding potential failures), to present them to the user and to other stakeholders, while also allowing access to information to facilitate device maintenance.

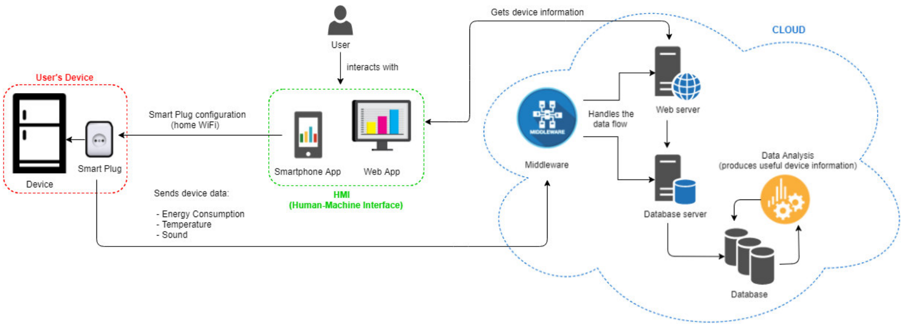

Figure 1 – System architecture

1.1 Data Acquisition tier

The data acquisition has the dual goal of collecting data in the user premises, and to transport the data to where processing can take place, while guaranteeing the security of the communication. Thus, the tier contains two sets of devices, smart connectors and gateways. The smart connector contains sensors to collect data in the user premises, which is usually connected to the user's home appliances. It can monitor the appliances' energy consumption (mandatory), temperature, and sound, through built-in sensors. Moreover, the smart connector must enable Demand Response (DR) strategies by allowing a remote application to switch on/off the power feed of the appliance controlled by the smart connector. This is an important feature since it allows the smart connector to be used in multiple functions, thus reducing its costs and increasing the perceived value of the system to the home owner. At installation time, the smart connector will have to be configured by the user via a smartphone app. The gateway takes care of centralizing the data exchanged between the smart connectors and the Data Analysis tier in the cloud, and realizing secure communication between them.

1.2 Data Analysis tier

Data collected by the Smart Connector tier is sent to a platform with enough computational power to process them, by means of a communication middleware. The goals of this tier are to enable predictive maintenance based on power consumption and other data collected by sensors in the smart connector, and in the user premises at large. The computation done in this tier can comprise an identification of the usage patterns for the appliances. Later on, this information can be used in conjunction with a remote control of the appliances to save on energy usage, for example by switching off Heating, Ventilation and Air Conditioning (HVAC) systems while the user is not at home, and by tuning the energy used in a refrigerator based on how much food is inside. The profiling of the usage pattern can also be compared to other similar devices to understand if the device is malfunctioning. For example, it is possible that a refrigerator is consuming too much for degradation of its insulation, and this can be identified by comparing energy consumption patterns with similar devices, e.g.: of the same brand and model. Communication between the Data Acquisition tier's devices and the computational platform is also part of this tier. We advocate the use of an event-based messaging bus to allow for high-performance in the communication activities. At the same time, the choice of the messaging bus must consider two issues that are of utmost importance for users: security and privacy. Both the issues are taken care of by most messaging bus, by using mature approaches such as TLS for data confidentiality and integrity, and PKI to ensure authentication/authorization of involved parties.

1.3 Business tier

This tier considers the utilization of data from the Data Acquisition tier, and information and alerts from Data Analysis tier, to enrich the experience of the users and the visualization capabilities of the platform. The main objectives are storage for data and processed information, to allow data to be always available in a timely manner, and HMI for the user. The data storage is aimed at providing fast access by the users. Thus, the deployment of this component depends on how data must be accessed, both as raw data and through HMIs. The HMI platforms are the main touchpoint of the service, and their purpose is to gather all useful information in one place. This part of the system can help users throughout the different phases of their products' lifecycle, such as the installation, maintenance and repair phases. When a registered device appears to be suffering from a malfunction, the user will be alerted by a notification. In this sense, the HMI platform makes use of the prioritization mechanisms of the Data Analysis tier, to deliver to the user urgent notifications as soon as possible, while transferring other visualization data by means of a batch process.

2 Maintenance of Appliances

Industry maintenance today focuses on several aspects related to economy, safety and profitability [1]. Companies want to improve availability, performance and quality of their machines, in order to supply better products, decreasing costs and increasing profitability and safety as much as possible. By leveraging on data, it is possible to provide diagnosis and prognosis information while rendering the underlying technology financially feasible. Diagnostic and prognostic actions allow machines or processes to be maintained in good conditions, provide more precise knowledge concerning the occurrence of failures, while also providing instructions on how to keep the equipment in optimal condition, or how to fix it. On the other hand, the servitization of maintenance and other marketing strategies must be considered in order to provide a greater added value to customers, retailers and producers of equipment, taking advantage of the potential savings offered by maintenance techniques. House appliances have both commonalities and differences with respect to the manufacturing industry. All components of machines and appliances necessarily suffer wear and tear during operation, and house appliances are no exception. Both a factory and a household can be connected to the Internet. Both the appliance users and the personnel of an industrial machine cannot be deemed experts on all the nuances related to the machine operation in faulty conditions, and can profit from advanced maintenance systems that automate or ease maintenance operations. On the other hand, the economic importance of house appliances is usually much lower than in a manufacturing context, additionally they operate in a much more open and diverse environment, than in a factory. Also, the number of connected appliances can be very large, and different proficiency levels with technology can be expected in different households.

Regarding current efforts, there is a plethora of research projects aimed at building platforms for predictive maintenance. SmartMaintenance [2] is an example of a project devoted to this problem. Its main objective was to develop a solution to collect data in real-time regarding the machines under analysis for maintenance management, taking the condition of machines into account as well as the latest production plans. Another interesting project is MANTIS [3], which was driven by industrial pilots from different contexts (energy production, railways maintenance, industrial machines, etc.). It also supports a three-tier distributed architecture, composed by a tier in the customer's premise made of CPS, a middleware to bring the data to the cloud, and an analysis tier that also provides visualization capabilities. In addition to these projects, there have also been other research efforts aimed at innovating in the process of detecting equipment failures through energy consumption records, such as [4], which explains that it is possible to detect such failures. However, the authors of [4] explain that they were not able to implement a solution, which, consequently, serves as further motivation for this work.

We can identify a few challenges to this work: i) how to increase the acquisition frequency of the smart connector, at the same time keeping the costs low; ii) how to give an adequate level of security for a very resource constrained smart connector; iii) how to make the system scalable to support a very large number of devices; iv) how to cope with GDRP regulations; v) which faults can be identified just by analysing energy consumption data.

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