TagItSmart

Smart tags driven service platform for enabling ecosystems of connected objects

Grant agreement 688061

D1.1 Use Case Requirements and Conceptual Architecture

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Executive Summary

This document reports about the user requirements and the conceptual architecture of Qualytics system. The work is based on an intensive analysis of the problems existing manufacturing process (assembling), esp. from the quality control point of view and available technologies which can be used for improving that process.

The main problem is related to the problems with the quality of delivered devices: a) testing in the factory is incomplete but costly and b) customers are sometimes experiencing bad quality of delivered devices (although testing phase was positive).

On the other hand, as a part of a closed-loop value chain, the business can benefit very much from the (feedback) information about customer experience. This is especially valid for the home appliances due to an ever increasing expectation of customers regarding the quality (for even lower price). However, getting such information is usually a costly activity (e.g. done through different marketing campaigns).

The vision of the system is to enable, through the usage of dynamic QR codes, a closed-loop information chain in the home appliances domain, connecting and correlating the data from supplier/delivery, manufacturing/testing, utilization and maintenance/service. The goal is the improvement of customer satisfaction/experience, through improving the production quality control and maintenance process, based on the results of data analytics on the collected information.

The specification and requirements are an abstraction of expectations set forth through the communication with industrial partners interested in applying envisioned system. The starting point is the communication with Whirlpool (refrigerators domain), but we already started the discussion with some other interested parties in order to create as more exploitable as possible solution.

We use the formalisms of user stories for the requirement specification, as an informal, natural language description of one or more features of a software system. Based on the requirements elaborated in the previous section, we define the conceptual architecture of the system, which will be used as the blueprint for the development of the Qualytics platform.

An important issue which can influence the development of the system is the smart tagging technology which will be applied. However, we don’t see this as a (huge) risk since the system will be designed in a modular way and whatever technology will be used for smart tagging, the rest of the system will be communicating through a predefined software interface (API).

1. Introduction

1.1 Scope of the deliverable

This deliverable is part of the WP1 (Concept and Development M1-M3), which goal is to understand the requirements for the envisioned service and to provide the conceptual architecture of the Qualytics Platform.

The deliverable elaborates on the work done on understanding the problem, specifying the requirements and the conceptualization of the solution for the data-driven in-usage quality control in the domain of home appliances.

1.2 Contributions to other WPs and deliverables

This deliverable will serve as basis for the work in Task 1.3: Development, month M2 – M4.

In addition, this work will influence WP2, Task 2.1: Preparation/Piloting, month M2– M4.

1.3 Requirement engineering methodology and known constraints

The specification and requirements engineering process is based on the initial structure defined in the proposal. The specification of requirements in WP1 uses this as a starting point and details the environment from a logical and development point of view, whereas in the context of the work presented here, the development view concerns conceptual artefacts of software architecture design.

We use the formalisms of user stories for the requirement specification, as an informal, natural language description of one or more features of a software system.

The specification and requirements, as defined in the following, are an abstraction of expectations set forth through the communication with industrial partners interested in applying envisioned system. The starting point is the communication with Whirlpool (refrigerators domain), but we already started the discussion with some other interested parties in order to create as more exploitable as possible solution.

In contrast to classical or scientific requirements engineering techniques, WP1 aims at establishing an agile interaction when a) deriving the specification and b) implementing the solution. It means that the defined requirements can be refined in the further communication with potential partners during the system development phase.

An important issue which can influence the development of the system is the smart tagging technology which will be applied. However, we don’t see this as a (huge) risk since the system will be designed in a modular way and whatever technology will be used for smart

tagging, the rest of the system will be communicating through a predefined software interface (API).

1.4 Structure of the deliverable

The deliverable is structured in the following way:

In the second section we provide a detailed overview of the relevant business process that can be improved by the proposed approach, including the AsIs and ToBe situation. The main goal of that section is to understand the general structure of the processes/services where the Qualiytics approach can be applied

In the third section we provide the set of user stories that should be supported (for selected stakeholders), as well as the list of requirements the system should realize.

In the fourth section, based on the requirements elaborated in third section, we define the conceptual architecture of the system, which will be used as the blueprint for the development of the Qualytics platform.

In the fifth section we provide details about the business case.

In the sixth section we provide concluding remarks.

2. Business process dimension

In the second section we provide a detailed overview of the relevant business process that can be improved by the proposed approach, including the AsIs and ToBe situation.

2.1 As Is scenario

2.1.1 Introduction

There are many case studies that indicate a huge potential for cost saving (ranges of $ millions) by improving process control in modern manufacturing systems, http://asq.org/manufacturing/why-quality/case-studies.html. Process monitoring and diagnosis are widely recognized as important techniques for improving quality and (proactively) detecting abnormal behaviour, leading to more efficient approaches for predictive maintenance (e.g. detecting some problems ahead of time). In manufacturing systems, statistical process control (SPC, https://en.wikipedia.org/wiki/Statistical_process_control) methods have improved process capability through reliable online monitoring and diagnosis, esp. by detecting variations in the process (e.g., Shewhart charts, X-bar and R charts, etc.) that can indicate the appearance of some quality problems.

However, the process control can benefit very much from the improved sensing on the process (shopfloor) and product level, which makes not only the monitoring of the manufacturing process (production), but also other phases in a product life cycle (like the maintenance) more open for innovations.

2.1.2 Business processes involved

Introduction

The envisioned approach can be applied on any industrial case where the quality control and maintenance can/should be organized in a more efficient way in order to improve the customer satisfaction.

In order to illustrate the approach, in this section we present the details from the industry use case, which has been performed for Whirlpool in the domain of the ZHQ (Zero Hour Quality), a quality management approach that aims in having a valid product (high quality) from the beginning of the usage (zero hour) of a product/device. In order to achieve this, there is a very strict process of functional testing after assembling process that consists of 10+ measurement stations where different parameters of the operation of the assembled devices are checked.

The quality control process is done using a traditional threshold-based process, producing so called out-of-limits (OOL) alarms. It consists of defining an upper and lower threshold so that when a measurement goes above the upper limit or below the lower one, an alarm is triggered. Then engineers will inspect the parameter that is out of limits and determine whether it is an anomaly or not and decide which action to take (for example, run a procedure).

The main issue is that the thresholds are defined by experts and might be suboptimal, i.e. they could be refined, but the data for the refinement is missing.

Use case settings and preliminary analysis

We briefly list the most important elements from the Whirlpool use case:

- For each refrigerator that Whirlpool produces, a functional test is performed by attaching sensors and measuring a number of parameters
- Functional tests validate that a refrigerator works as it should and represent one of basic measures of quality control
- For the dataset provided following 6 (behavioral) parameters are measured (see Figure 2 for an example):
  - Temp. Destra (Rossa), Temp. Sinistra (Nera), T EV Cap Fz., T EV Cap. Fr., Cos Fi, Potenza
- There is a need to include contextual parameters into analysis as well. Following contextual parameters can be provided:
  - Time when the functional test was performed
  - Temperature of the environment in which functional test was performed
  - Location (part of the factory) where the functional test was performed
- The dataset is too large to be processed on a single machine and that is why we need a scalable, distributed solution which is able to bare with Big data.
- The feedback from customers, (esp. through maintenance process) is missing
- The dataset should be extended with the customer-driven information

The data

Length of time series parameters differs for a number of tests (see Figure 1 for an example of the histograms for one parameter). However, this issue can be easily resolved using DTW as a distance measure and padding as a preprocessing technique. DTW allows us to compare functional tests of different length, while we use padding to get all parameters of a single functional test to the same length.

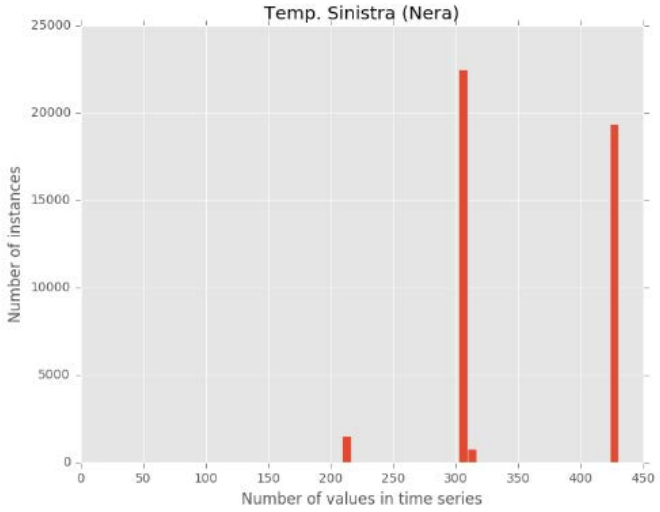

Figure 1. Length of Temp. Sinistra parameter for instances in the dataset

In addition, the values of one parameter are changing during the usage, as depicted in Figure 2. This implies the need for having an expressive formalism for monitoring the changes in the value of parameters relevant for the quality control.

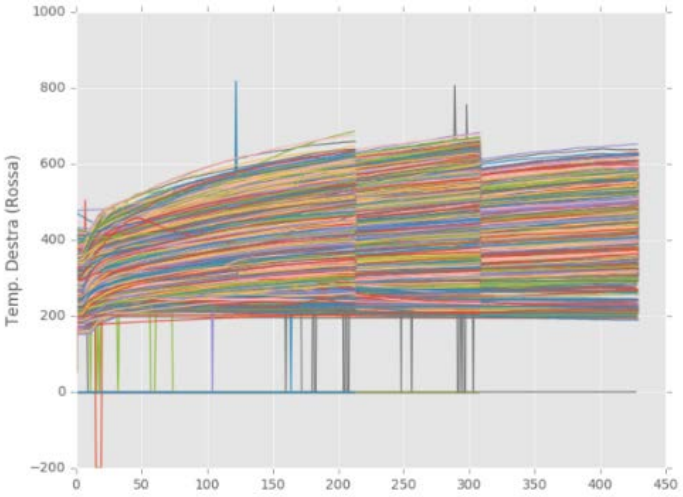

Figure 2. Temp. Destra (Rossa)

2.1.3 Challenge

Ensuring process quality is especially critical for manufacturing of home appliances due to an ever-increasing expectations of customers regarding the quality (for even lower price). Research shows that most of vendors lose between 5%-15% of sales revenue because of the lack of attention to quality. This is very important for the manufacturing of major appliances

(large machine in home appliance used for routine housekeeping tasks such as cooking, washing laundry, or food preservation) which are based on an extensive assembling process of parts produced by various suppliers. This is why the control of the final product (so called functional test) is of the critical importance for the quality perceived by the customers (so called zero hour quality, ZHQ). In a functional test a set of specific test rules is activated that either starts the automatic test process or instructs an operator about the measurements he/she has to perform on the tested device (e.g. washing machine).

One of the very important factors that makes the process more complicated is the cost of the functional testing. It is estimated that the testing takes up to 10% of the total costs and there is a huge effort in making the functional testing as plain as possible, i.e. to make only those tests which are necessary to be performed. Usually, this knowledge cannot be defined by experts themselves, but rather generated through the analysis of the past data from that process. For example, different correlations between measured parameters in the past tests can indicate that some of the parameters shouldn't be measured since they are strongly positively correlated. Another important source is the maintenance process that can give new information about the issues which happened. By having the possibility to measure parameters using dynamic QR codes, we will open a new opportunity to correlate parameters and in that way to get new optimization regarding the testing process.

The whole process is presented in the following figure. Set of monitoring rules is defined by experts (quality supervisor).

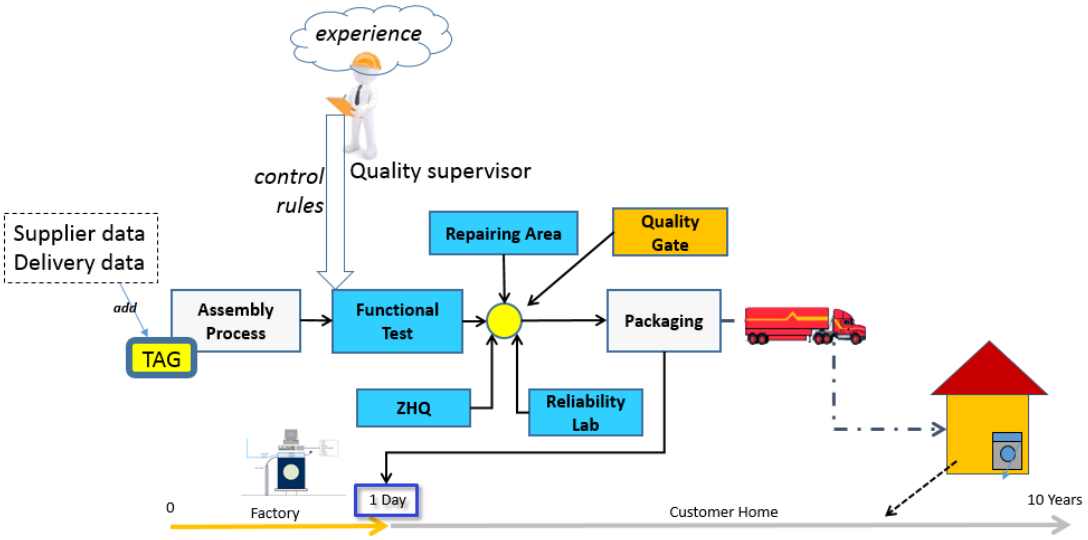

Figure 3. AsIs quality control process

The main motivation for the proposal is coming from the problems with the quality of delivered devices: a) testing in the factory is incomplete but costly and b) customers are sometimes experiencing bad quality of delivered devices (although testing phase was positive).

2.1.4 Weaknesses and bottlenecks

The current quality process has several drawbacks:

- *testing inefficiency*: control rules are defined by human experts and might be suboptimal which leads to increased production costs. Especially imprecise are rules that introduce fixed/static thresholds (e.g. the temperature should be less than 80˚C) since usually the models have more "smoothly" defined limits. However, the usage of these rules is a useful indicator if some ranges of the early warning can be defined in addition (they can be also defined using statistics, like 3σ)

- *high costs*: functional tests are performed in an uniform way across all produced objects, which means that some of the measured parameters are redundant and introduce additional costs

- *customer dissatisfaction*: control rules may be inaccurate (e.g. out of date) which means that even a device passed the test, it can be malfunctioning at customer's home (low ZHQ). This is usually the case when some of the parameters in the testing phase were "close to the upper/lower limit" but not classified as "lower quality" due to the usage of the threshold-based approach (as described in 1)

- *there is no feedback* from the user about the usage of the devices (and potential problems)

The main cause of these problems is the testing "silo": test procedure isolated from any information/experience about the usage or maintenance of devices. The "silo" effect is disabling the process of integrating the values of measurements along the life-cycle of the product. Consequently, by applying the data analytics on the data collected in the whole life-cycle we will be able to generate new knowledge about the factors which influence the quality of a product.

3. Use case requirements

In this section we present the results from the requirements analysis which is done in a more general way in order to incorporate the needs from different use cases which can benefit from the new quality control approach.

The formalism of user stories is used for the requirements specification. In software development and product management, a user story is an informal, natural language description of one or more features of a software system. User stories are often written from the perspective of an end user or user of a system.

3.1 Stakeholders

The process of collecting requirements begins with identifying the set of stakeholders involved.

We found two main and one additional stakeholder, as presented in Table 1.

Role	Description
Maintenance personal	Owner of the maintenance process. Responsible for visiting customers and reacting on complains The main challenge is the detection of the main cause of the problems (as reported by a customer)
Quality control engineer	Owner of the quality control process in the production Responsible for ensuring that only product with desired (predefined) quality will be delivered to customers Two main challenges are: 1) the accuracy of the control rules that are applied in the quality control process 2) the lack of integrated information related to the quality control, like about the problems which happened at customers sites
Customer	Buyer Interested in having the product properly working all the time, with minimal maintenance costs

Table 1. List of stakeholders

3.2 User stories

A common approach used in agile software development methodologies is the ‘user stories’ collection format.

A user story is a sentence in the form of “As a [who], I want [what], in order to [why]”. These short stories allow the users to express requirements grounded in business needs, and are used to start a discussion on specific requirements. At the same time, requirements are simple to analyze and understand, since they come from single sentences. During the discussion, the requirements can be confirmed or rejected.

The purpose of these stories is to capture the business need of the user and communicate this need, and it’s rationale to the platform architect. The last part of the sentence provides the backstory and eases the analysis of requirements. The following set of tables is the original set of those stories that were collected during brainstorming sessions by project partners. Functional requirements listed in the next chapter refer to these stories.

Since the requirements have different scope, we introduced the notion of the priority of the requirements in order to make the development as feasible as possible. We use the MoSCoW method (https://en.wikipedia.org/wiki/MoSCoW_method) for defining requirement priorities.

The categories are typically understood as:

Must have

Requirements labeled as *Must have* are critical to the current delivery timebox in order for it to be a success.

Should have

Requirements labeled as *Should have* are important but not necessary for delivery in the current delivery timebox. While *Should have* requirements can be as important as *Must have*, they are often not as time-critical or there may be another way to satisfy the requirement, so that it can be held back until a future delivery timebox.

Could have

Requirements labeled as *Could have* are desirable but not necessary, and could improve user experience or customer satisfaction for little development cost. These will typically be included if time and resources permit.

Won't have (this time)

Requirements labeled as *Won't have* have been agreed by stakeholders as the least-critical, lowest-payback items, or not appropriate at that time. As a result, *Won't have* requirements are not planned into the schedule for the next delivery timebox. *Won't have* requirements are either dropped or reconsidered for inclusion in a later timebox.

3.2.1 Maintenance personal stories

User story ID	**UID-M1**
Story	As a Maintenance personal I want to get as much as possible information about the usage of the product by the customer in order to be able to find the root cause of the customer problem in a fast and efficient way

User story ID	**UID-M2**
Story	As a Maintenance personal I want to insert monitoring probes in the customer product in order to observe some aspects of the product behaviour after doing some reparations (in a shorter period of time)

User story ID	**UID-M3**
Story	As a Maintenance personal I want to define own monitring rules for the probes in order to be able to check some specific behaviour of the product

Table 2. Maintenance personal stories

3.2.2 Quality control engineer stories

User story ID	**UID-Q1**
Story	As a Quality control engineer I want to get as much as possible information about the problems in usage of the product by the customer in order to be able to tune the quality control rules in the production process

User story ID	**UID-Q2**

Story	As a Quality control engineer I want to integrate information about the usage of the product with other collected data in order to get a better understanding of the efficiency of the current quality control process

User story ID	**UID-Q3**
Story	As a Quality control engineer I want to insert monitoring probes in the customer product in order to observe some aspects of the product behaviour (in a shorter period of time)

User story ID	**UID-Q4**
Story	As a Quality control engineer I want to define own monitring rules for the probes in order to be able to check some specific behaviour of the product

Table 3. Quality control engineer stories

3.2.3 Customer stories

User story ID	**UID-C1**
Story	As a Customer I want to get more information about the behaviour of the product (in usage) in order to be able to react before having maintenance problems

3.3 Requirements

We have divided requirements in two groups, based on the parts of the systems they are related to.

- First is In-usage quality monitoring (QM) and it refers to the possibility to monitor some of parameters of a product during is usage easily. It is mainly supported by the Maintenance personal.

- Second is Integrated analytics (IA) and it is related to the analysis of the collected data using data analytics methods. It is mainly used by Quality Control Engineer

The first part is the main one since it assumes the usage of smarttags.

In addition, there are three types of control activities which can be supported

- Tracing: Monitoring specific changes in the temperature
- Alarming: Detecting anomalous changes (based on clustering, or anything what is not normal is anomaly)
- Logging: Recording all changes in the temperature

In the following text we provide list of requirements

ID	**R-QM1**
Requirement	The data gathering should be done in an as automated as possible process
Priority	Should Have
Actor	Maintenance Personal
Source story	UID-M2
Description	Main rationale is the need for making the process of data gathering (measurement) - Accurate - Regularly performing - Easy for the interpretation - Easy to be integrated with the rest of the system
Related business KPIs	Improving maintenance service

ID	**R-QM2**
Requirement	The interpretation od gathered data should provide useful insight for the analysis

Priority	Must Have
Actor	Maintenance Personal, Quality Control Engineer
Source story	UID-M1
Description	Interpretation should enable: - the classification of the gathered data - several classes are defined o Status is normal o Status is anomalous o Status is unusual
Related business KPIs	Improving maintenance service

ID	**R-QM3**
Requirement	The possibility to install monitoring probes (smarttags) on customer product
Priority	Could Have
Actor	Maintenance Personal, Quality Control Engineer
Source story	UID-M3, UIQ–Q3
Description	Monitoring probes can be installed on a product in an easy way
Related business KPIs	Improving maintenance service Improving quality control process

ID	**R-QM4**
Requirement	The possibility to change monitoring probes (smarttags) on customer product
Priority	Should Have

Actor	Maintenance Personal, Quality Control Engineer
Source story	UID-M3, UIQ–Q3
Description	Change monitoring probes (physically) on customer product in an easy way
Related business KPIs	Improving maintenance service Improving quality control process

ID	**R-IA1**
Requirement	Define monitoring rules for a customer product (modelling issue)
Priority	Must Have
Actor	Maintenance Personal, Quality Control Engineer
Source story	UID-Q4
Description	Monitoring rules should be defined by experts in advance
Related business KPIs	Improving maintenance service Improving quality control process

ID	**R-QM5**
Requirement	Situation analysis should enable a proper real-time reaction
Priority	Should Have
Actor	Maintenance Personal
Source story	UID-M2

Description	Alarming: Detecting values which are indicating anomalies (or anything what is not normal is anomaly)
Related business KPIs	Improving maintenance service

ID	**R-QM6**
Requirement	Situation analysis should enable tracing for a selected parameter
Priority	Must Have
Actor	Maintenance Personal
Source story	UID-M1
Description	Monitoring specific changes in the values of a selected parameter (e.g. temperature)
Related business KPIs	Improving maintenance service

ID	**R-QM7**
Requirement	Situation analysis should enable logging values for a selected parameter
Priority	Must Have
Actor	Maintenance Personal
Source story	UID-M1
Description	Logging: Recording all changes in values of a selected parameter (e.g. temperature)
Related business KPIs	Improving maintenance service

ID	R-IA2
Requirement	Data analytics should provide new knowledge
Priority	Must Have
Actor	Quality control engineer, Maintenance personal
Source story	UID-Q1
Description	Based on collected past data the system should derive new knowledge that can be applied in the quality control process
Related business KPIs	Improving quality control in the production process Improving maintenance service

3.4 Scenarios and advantages

There are many scenarios which can be supported by the proposed system. We see two main application in maintenance service:

1. To record that a device behaved (at home) in an anomalous way
    - QR code colors indicate the existence of the anomalous temperatures
    - This data is used for matching with the functional tests of that device in order to create a basis for analytics

2. To check how a device will behave
    - To check the behaviour of the devices which has been repared (maintenance service done on demand)
    - Such a device is equiped with several QR codes which records the behaviour of the device in a limited time period (1-2 days)
    - The data (colors) from QR code are analyzed in order to check if some anomalous behaviour
    - An approach similar to the „holter“ for patient monitoring (eHealth)

The main advantages are:

- A very efficient way for improving:
  - Maintenance service
    - Better diagnostics (more data to be used)
    - Less experience personal can be used
  - Functional test process
    - Data from the anomalies at home-usage will be used in the data analytics to find causes of some potential problems in the usage of devices
  - „Self-alarming“ service
    - A customer can check on his/her own if the device behaved anomalously (related to the values for the temperature)

4. Conceptual architecture

4.1 Introduction

Based on the requirements elaborated in the previous section, we define the conceptual architecture of the system, which will be used as the blueprint for the development of the Qualytics platform.

From the technological point of view, the system should enable the monitoring of complex situations during the usage of a device in a nonintrusive way

This is what we call **Complex remote device monitoring: in-usage testing**

It requires:

- Formalism for modelling of complex situations
- Mechanism for measuring/detecting complex situations
- Storing monitoring data

It will enable the analytics on the monitored data.

4.2 High-level architecture

Following figure depicts the main elements of the architecture (high-level view).

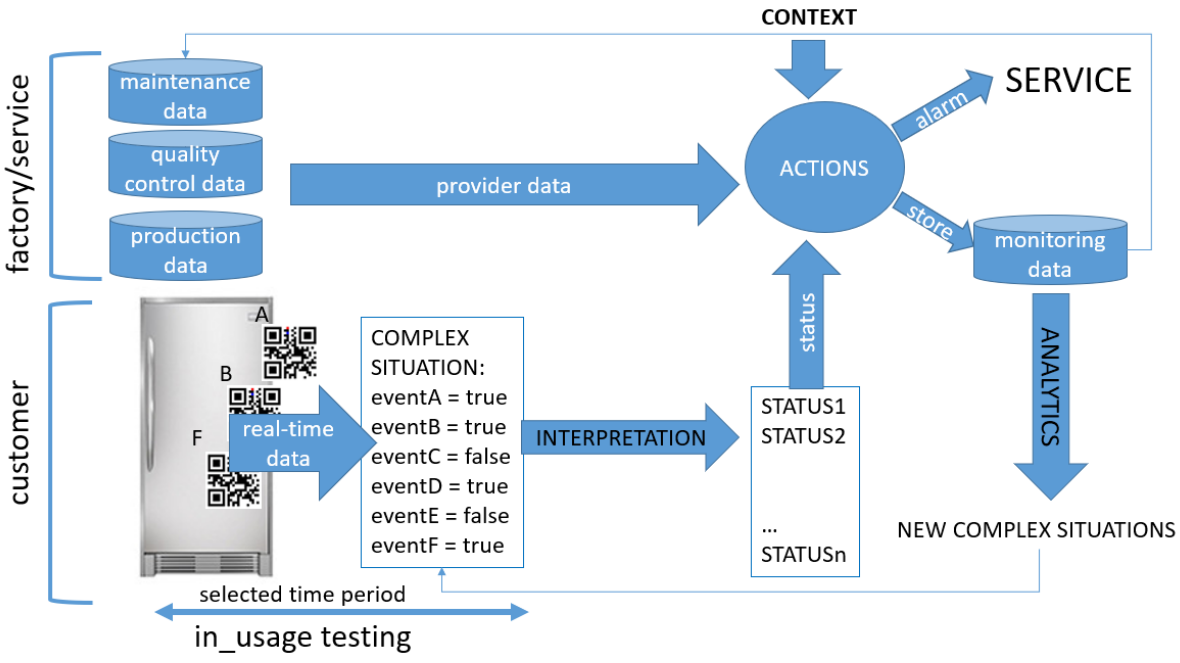

Figure 7: High level architecture

There are three main functionalities supported:

- Using smart tagging for the integration of the values of measured parameters along the life-cycle of the product
- Applying the data analytics on the data collected in the whole life-cycle in order to generate new knowledge about the factors which influence the quality of a product.
- Enabling the use of the generated knowledge as close to the edge/device in order to increase the reactivity of the system (and make the maintenance more affordable)

There are two parts of the architecture:

- One is related to the collection of in_usage data, which should enable the monitoring and control process.
    - The main part is related to the monitoring of changes in the temperature of a part of a device using smart tags (QR code)
- Second is related to the analytics on the integrated data, which should be done in efficient way due to the connection with the manufacturing/assembling process
    - There are three types of monitoring:
        - Tracing: Monitoring specific changes in the temperature
        - Alarming: Detecting anomalous changes (based on clustering, or anything what is not normal is anomaly)
        - Logging: Recording all changes in the temperature

The following figure illustrates the relations between two above mentioned phases

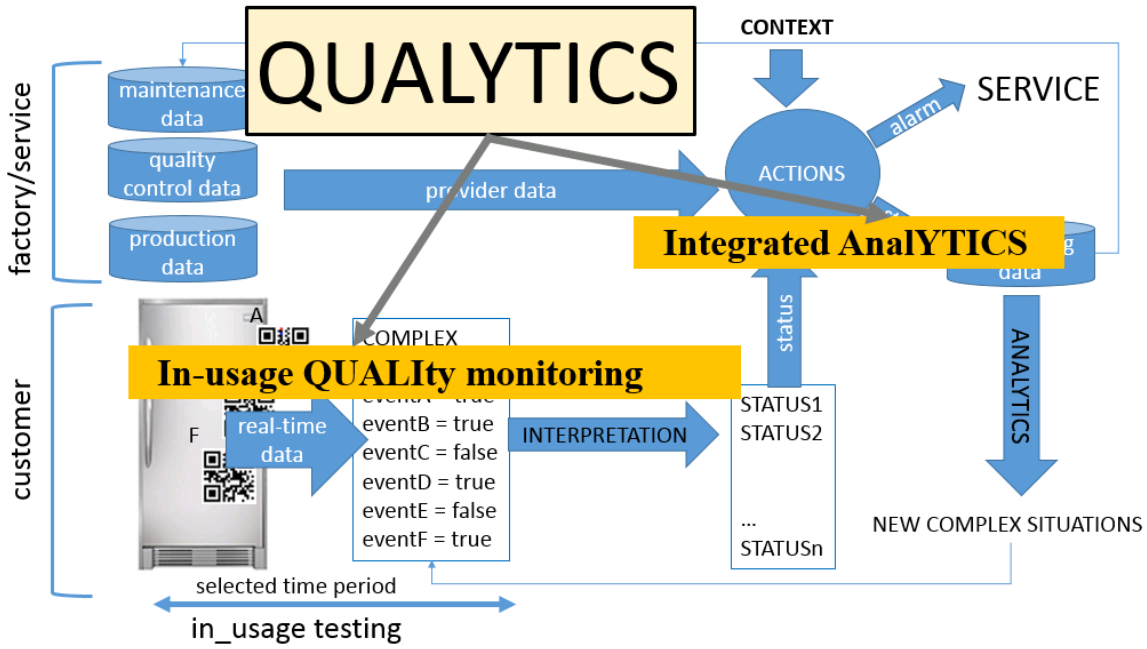

Figure 8. Qualytics approch

4.3 Mapping of requirements

From the data processing point of view, there are several phases which should be supported:

1. Data Gathering is related to the collection of data from different data sources
    - Covers requirements R-QM1, R-QM3, R-QM4, IA-1
2. Data Interpretation is related to understanding the status of the controlled parameters
    - Covers requirement R-QM2
3. Data Integration is related to the integration of the data from various sources
    - Covers requirement R-QM6
4. Situation analysis is related to the detection of different situations of interests
    - Covers requirements R-QM5, R-QM7
5. Data Analytics is related to the creation of new knowledge relevant for the monitoring process
    - Covers requirement R-IA2

Figure 9 illustrates the position of the phases in the conceptual architecture.

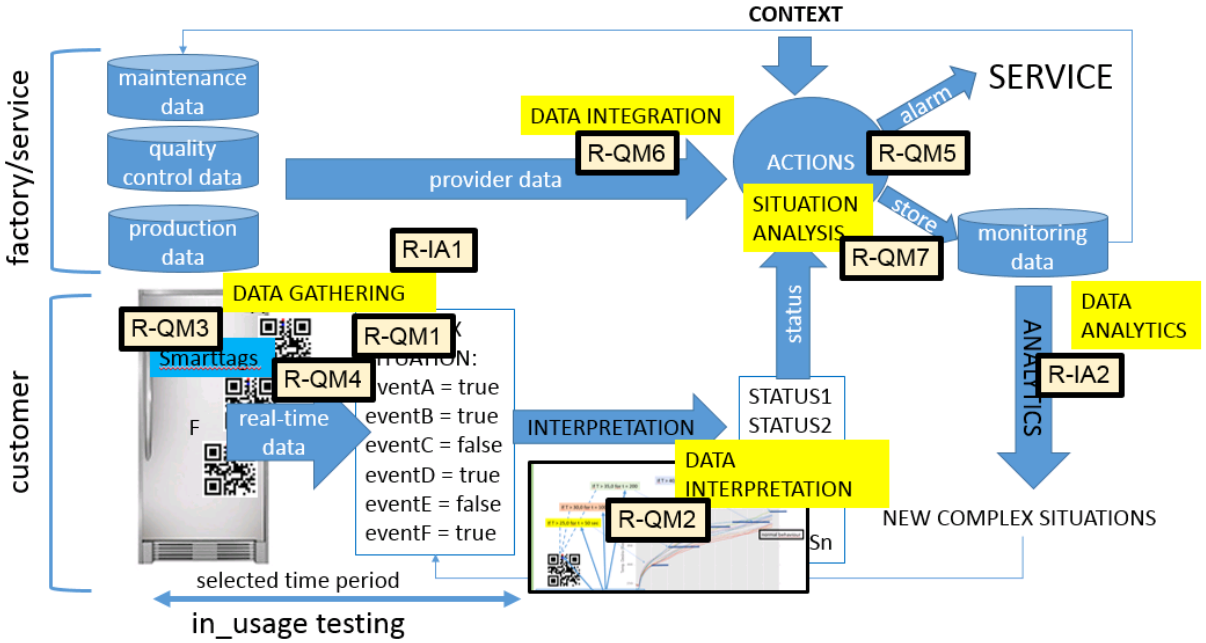

Figure 9: Mapping of the requirements to the architecture

4.3 Technical architecture

4.3.1 Overview

In order to provide more information about the technologies which will underlie the system, we provide in this section some more technical details about the integrated data analytics architecture

Core D2Lab components modified for the purpose of specific are given on Figure 10.

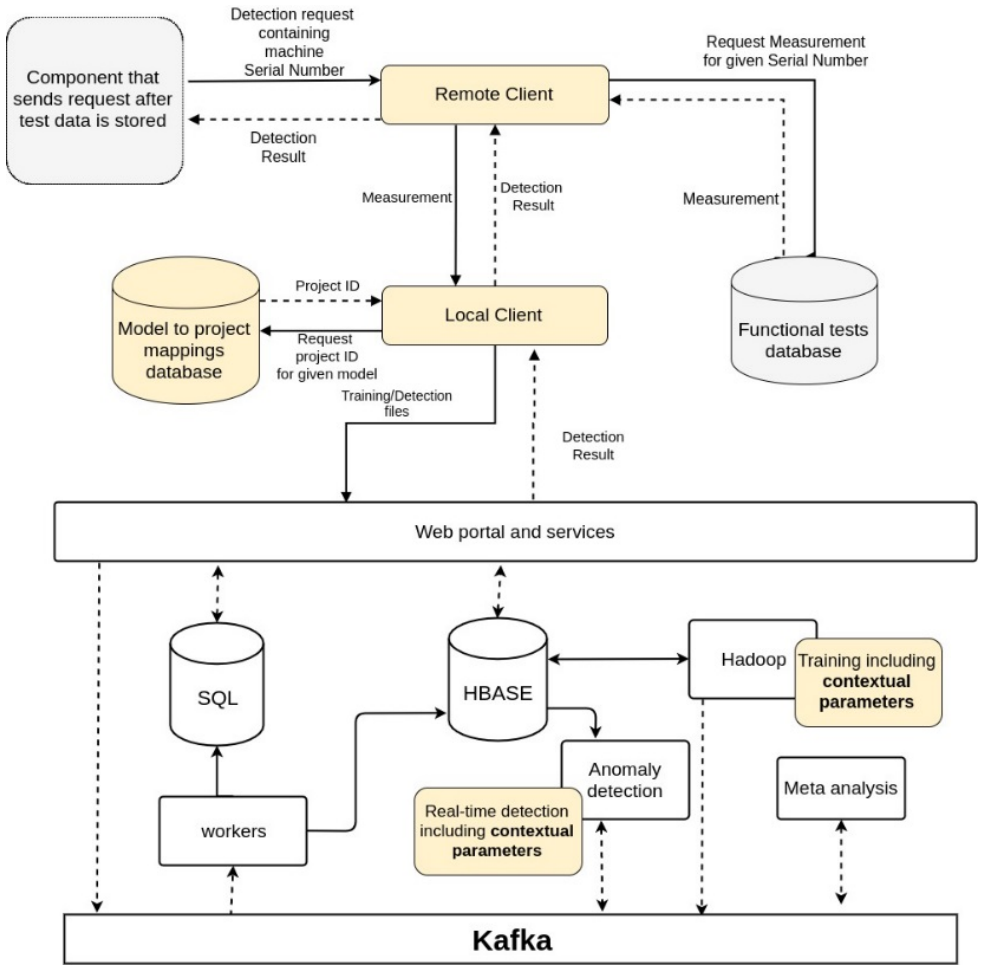

Figure 10. Integrated data analytics architecture

D2Lab represents a highly scalable system, based on Big data technologies such as Hadoop, HBase and Kafka. In this case all components will be deployed inside facility (private cloud) with no need for external communication. Core features of the system, specific to this use case are:

1. *Remote Client*

Represents the entry point for anomaly detection. When a functional test is finished the remote client receives a request to analyze the functional test saved in the functional test database. It reads the measurements for the database, transforms the data according to specified format and contacts the local client. After it receives answer from the local client it returns the result to the component which initiated the procedure.

2. *Local Client*

Local client has access to a database which contains mapping between different types (models) of devices and specific domain entity used by D2Lab system. It maps the model of

the machine tested by the functional test to D2Lab project entity (in order to isolate analysis of different types of device) and contacts D2Lab service, passing the functional test.

3. *Model to project mappings database*

Contains mappings between different kinds of devices (machines) and D2Lab project entities.

4. *Training procedure*

Training procedure had to be extended to support analysis which includes contextual parameters. Specific steps were needed to determine the influence of contextual parameters and to emphasize it.

5. *Real time anomaly detection*

Influence of contextual parameters also had to be included in real time anomaly detection. Similar steps need to be performed during both phases, to have an identical workflow for a functional test, regardless of whether it comes for training, or in real time, for anomaly detection.

4.3.2 Processing pipeline

D2Lab processing pipeline is depicted on Figure 11. These are only the phases of analysis and for each phase there is a certain number of possibilities which can be used depending on the use case and concrete data. For example, in case of Whirlpool refrigerator use case data was stored in a relational database, from which it needed to be extracted using SQL queries, to be imported into D2Lab system for training. We performed exploratory analysis to find out about the influence of contextual parameters and to conclude that we will need a special learning method as the instances in dataset may differ in length. A lot of instances had missing values, which needed to be dealt with. Data was transformed using standardization method. There was no need to create windows as the data was not in a streaming form. PCA was selected as dimensionality reduction method, while Fast Fourier Transform (FFT) and statistical features were also considered. Similarly, Elbow method gave better results when trying to determine the optimal number of clusters than the Silhouette method. The whole procedure was unsupervised due to lack of labels, so we used our scalable clustering algorithm KmedoidsUsingFAMES during training. We inspected the clusters, cluster representatives and anomalies found during training. We compared clusters and anomalies to try to identify the root cause of anomalies. Along the way we produced a lot of 2D/3D plots (scatter plots, silhouette plots, box plots, histograms), and at the end produced a report called “Process Data Atlas”. Model produced during training (containing cluster representatives) was then used in real-time to detect new anomalies between functional tests, as they are performed.

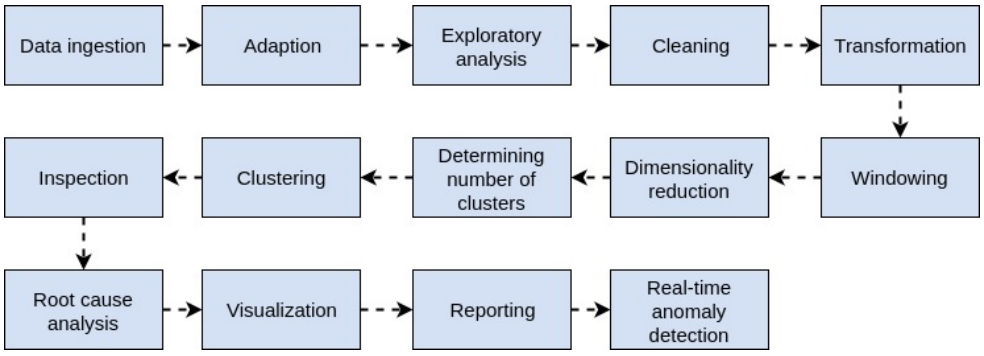

Figure 11. D2Lab processing pipeline

We use the notion of anomalies as something that is “significantly different than the past” without pretending that an anomaly is a mistake, but rather an outlier. Consequently, the detection process is related to comparing the real-time status of a system with a model of its normal behaviour, whereas the creation of this model is the most challenging task. Indeed, since there are, usually, many parameters influencing a process it is difficult to design/create (by an expert) the model of the normal behavior of the process (which enables model-based anomaly detection), as discussed in the previous section.

4.3.3 Mapping of phases

Figure 12 illustrates how the underlying technologies will be used for supporting the phases in the Qualytics approach

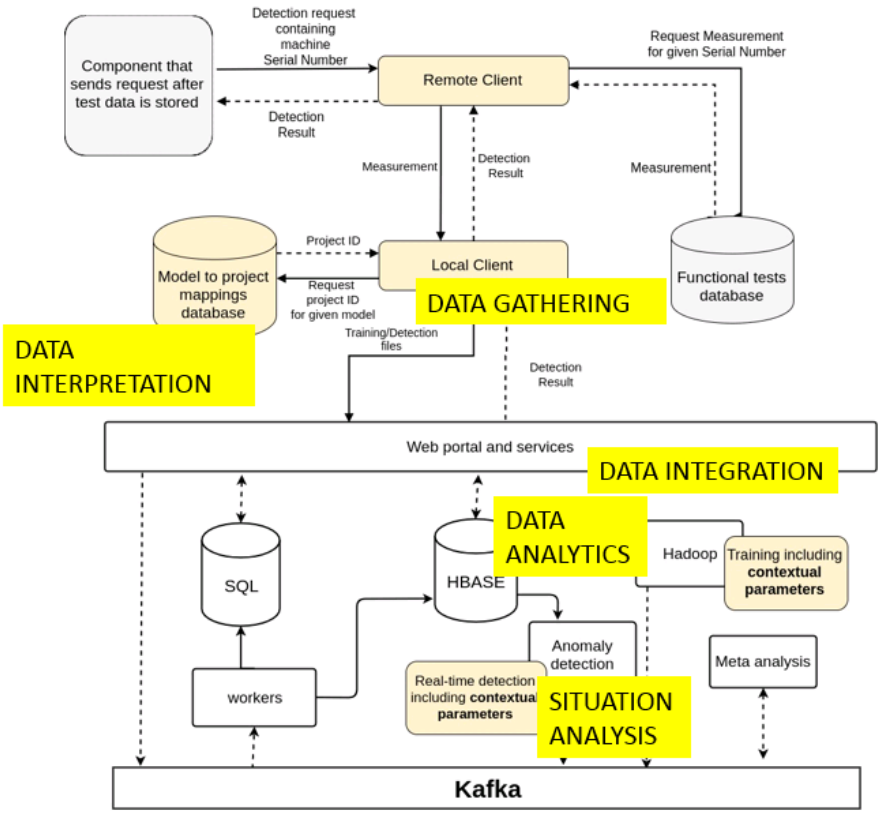

Figure 12. Illustration of the support provided by underlying technology

5. Business case

In this section we provide details of the relevant business scenario based on the requirements provided in Section 3.

5.1 Introduction in the relevant business process

We define the system with the idea of breaking the silos in the quality control approach by the usage of smart tagging approach.

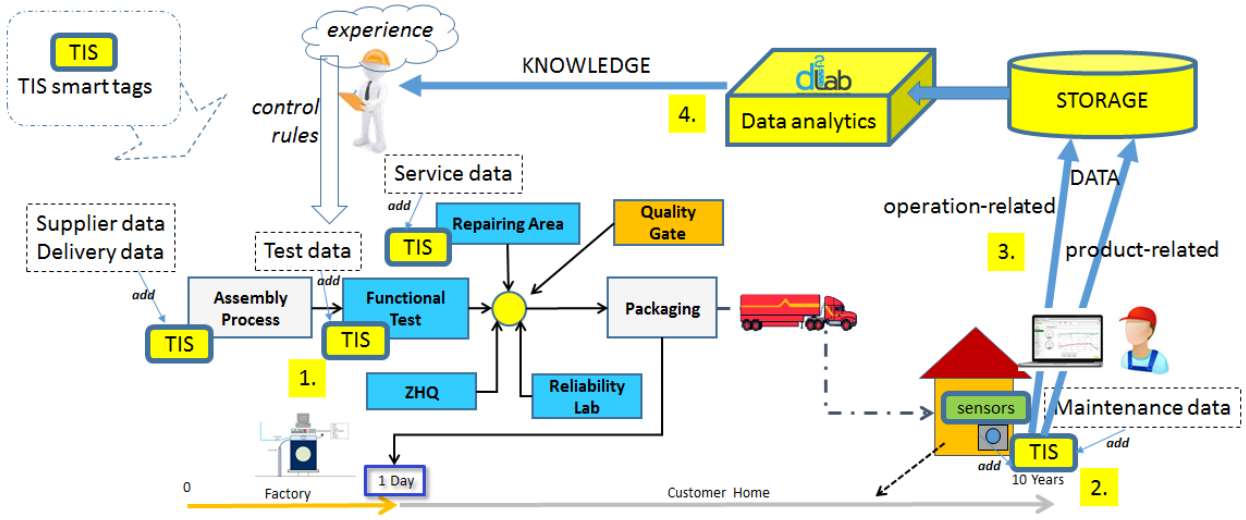

Figure 13. Proposed approach for tagging-supported quality improvement process – generic case

Here we give a brief description:

1. Factory/Manufacturing: By tagging (cf. TIS in Figure 13) in the Functional test phase, all important data related to results from various tests will be kept with the corresponding device. The same is valid for the data from a potential in-factory service.

The advantage comparing to AsIs process is that all relevant manufacturing data will be stored on the device (tag).

2. Home/Operation: The data related to the operation of the device will be collected. This data can be collected in different ways, primarily using dynamic QR codes that change according to the selected environmental parameters (temperature, humidity, intensity of lights), potentially enhanced with printed NFC tags and sensors. Additionally, if existing, a home automation system, which can be even a simple energy consumption monitoring, can bring more data about the operation of the device.

In that way the data about the operation of the device will be collected and stored locally.

The advantage is that operation-related data will be available for further analyses.

3. Home/Maintenance: In the case that any maintenance service is needed, the tag will be updated with the corresponding data. All data, product- and operation-related data will be transferred to the extern storage.

The advantage is that experience from the maintenance will be collected and associated with production data in order to enable a proper root-cause analysis of the problems which might happen.

4. Cloud/Data Analytics: Using data analytics, very important/interesting correlations between production, testing and operation can be found. Especially important is the knowledge related to functional tests, which can be used for updating control rules (cf. Figure 1).

One of the most important parameters that should be measured is the temperature of appliance/product during the operation. If the temperature will be increasing in an “unusual” way, it can be interpret as an early warning for some defect in the operation. This is especially important for the appliance that are in operation for a long time or intensively (like refrigerators or ovens).

Therefore, we see the usage of the sensor for the measurement of the several types of the temperatures (e.g. related to refrigerators) very promising.

There are 6 parameters measured in the functional tests of refrigerators, whereas four of them are related to the temperature: Temp. Destra (Rossa), Temp. Sinistra (Nera), T EV Cap. Fz, T EV Cap. Fr. We assume that the sensors (initially dynamic QR codes, later thinfilm), which will enable measurement of these temperatures, will enable the collection of the information about the changes in these two temperatures. This information can be used in two ways:

- standard: if the device (refrigerator) is malfunctioning, this information can be correlated with the information from the functional tests (step 1) in order to enable correlation between the outcomes from the functional tests and the malfunctioning devices (incl. the changes in their temperatures);
- advanced: by assuming that we can collect a significant amount of this data, we can learn the normal model of the temperature-related behaviour (data analytics) and if the real-time temperature is behaving “unusually” we can initiate a maintenance process.

Therefore, the advantage is that silos: manufacturing (factory), utilization (home) and maintenance (service) will be connected and analysed in order to find “hidden” correlations, which can be very important for the update of existing control rules and generation of new ones

Nissatech has developed a framework for data analytics D2Lab, D2Lab.nissatech.com, that is specialized in unsupervised pattern mining, which leads to the detection of so called “unknown unknowns” - the situations of interest (can be anomalous ones) that the process/system owner was not aware of.

5.2 Business Scenario: Improving quality control by managing temperature fluctuation patterns based on smart tags

5.2.1 Scenario Settings

The goal of the scenario is to define the procedure for checking the quality of the maintenance service performed on a part of a product/machine that depends on the temperature fluctuations. In this case it is the cooling part of a refrigerator.

The particular problem in the maintenance process is an unstable behaviour of the cooling part after reparation, which is reflected on the fluctuation of the temperature in the fridge, usually happening in the first days after reparation. However, our approach is based on connecting data, so that the data from maintenance process will be combined with the data from manufacturing (assembling) process.

Indeed, the fluctuations are also observed in the functional tests performed after assembling process, so that the knowledge about the shape and duration of some fluctuation are known. Since there are different types of the fluctuation, we will focus on those which range corresponds to the characteristics of the smarttags we will be receiving (thinfilm).

As Is – current problem

The existing procedure does not enable remote checking of the fluctuations in the temperature.

The main motivation is coming from the problems with the quality of delivered devices:

a) testing in the factory is incomplete but costly and

b) customers are sometimes experiencing bad quality of delivered devices (although testing phase was positive).

To Be – Additional requirements (gathered for the second iteration of this deliverable)

- The solution should be easy to install / de-install and if possible to be reused;
- It should be installed by the non-experts;
- It should serve as the quality check for the maintenance process.

5.2.2 Functionalities

The system combines IoT and Data Analytics for Quality Control. The main goal is to integrate:

- Information about the behaviour of a model (data analytics from functional tests)

- Requested for the definition of the range in the fluctuation of the temperature (data analytics);

- Measurements after service/repair based on the customer complaint
  - Checking the validity of the fluctuation in the temperature (tagging technology);
  - Customer is reporting the measurements outcome.

6. Conclusion

This document reports about the user requirements and the conceptual architecture of Qualytics system. The work is based on an intensive analysis of the problems existing manufacturing process (assembling), esp. from the quality control point of view and available technologies which can be used for improving that process.

The vision of the system is to enable, through the usage of dynamic QR codes, a closed-loop information chain in the home appliances domain, connecting and correlating the data from supplier/delivery, manufacturing/testing, utilization and maintenance/service. The goal is the improvement of customer satisfaction/experience, through improving the production quality control and maintenance process, based on the results of data analytics on the collected information.

The specification and requirements are an abstraction of expectations set forth through the communication with industrial partners interested in applying envisioned system. The starting point is the communication with Whirlpool (refrigerators domain), but we already started the discussion with some other interested parties in order to create as more exploitable as possible solution.

An important issue which can influence the development of the system is the smart tagging technology which will be applied. However, we don't see this as a (huge) risk since the system will be designed in a modular way and whatever technology will be used for smart tagging, the rest of the system will be communicating through a predefined software interface (API).