A Preliminary Study of IoT Multidisciplinary View in the Industry

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RÉSUMÉ. Cet article présente une étude menée auprès de professionnels afin d'extraire leur perception de la pluridisciplinarité impliquée dans des projets pour l'Internet des Objets. Les résultats préliminaires montrent que toutes les facettes proposées (qui représentent la multidisciplinarité) ont été identifiées comme pertinentes. La Connectivité, le Comportement et l'Interactivité étant signalées comme les facettes les plus pertinentes. De plus, il a été suggéré de définir Données séparément de la facette Comportement.

ABSTRACT. This short article presents a study conducted with professionals to extract their perception of the multidisciplinarity involved with the Internet of Things projects. Preliminary results show that all proposed facets (that represent the multidisciplinarity) were identified as pertinent, being Things, Connectivity, Behavior, and Interactivity pointed out as the most pertinent ones. Moreover, it was suggested to define Data separately from the Behavior facet.

Mots-clés : Internet des objets; génie logiciel fondé sur des preuves

Keywords: Internet of Things;evidence-based software engineering

1. Introduction

IoT Internet of Things (IoT) allows composing software systems from uniquely addressable objects (Things) equipped with identifying, sensing, or actuation behaviors and processing capabilities that can communicate and cooperate to reach a goal (Motta *et al.*, 2019). Being a multidisciplinary domain, it comprises many areas from technical to societal and business. This multifaceted view of IoT was captured in the IoT Conceptual Framework with IoT Facets' concept (Motta *et al.*, 2018). This paper presents a study based on interviews with IoT professionals to observe their perception of the pertinence of the defined IoT facets and recover their current concerns.

This article is part of more comprehensive research. Its main contribution is validation of the IoT Facets to strengthen all this research, paving the way for other experimental studies and directing evidence-based software engineering in this research.

2. The IoT Conceptual Framework

The IoT Conceptual Framework was proposed based on the evidence of different experimental studies (Motta *et al.*, 2018; Motta, 2019). The Framework organization has three core concepts adapted for the IoT context: (i) the IoT Facets (Motta *et al.*, 2018), (ii) the Systems Engineering Life Cycle (BKCASE Governing Board, 2014), (iii) and the Zachman Framework (Sowa and Zachman, 1992). The organization aims to give an overview of IoT requirements and activities considering the knowledge areas and disciplines related to different engineering phases. Having such a conceptual structure provides a clear view of relevant information to support IoT engineering.

This article is concerned only with the IoT Facets defined in the first concept that is the one to deal with the IoT multidisciplinarity. The Facets emerged from data analysis from inputs of technical literature, practitioner's workshops, and a Government Report (Motta *et al.*, 2018) being flexible enough to cover IoT particularities. The two other concepts are out of the scope of this article.

The first concept is often overlooked during the development but is crucial for successful IoT solutions (Giusto, 2010). Considering a specific problem domain, different knowledge areas, and disciplines involved in IoT engineering. We named those areas and disciplines IoT Facets. We define Facets as "one side of something many-sided" (Oxford Dictionary), "one part of a subject, a situation that has many parts" (Cambridge Dictionary). From a literature review (Kitchenham, 2004) that considered 15 secondary studies, we defined the following IoT Facets (Motta *et al.* 2018): Connectivity, Things, Behavior, Smartness, Interactivity, and Environment. Figure 1 presents the IoT Facets definition.

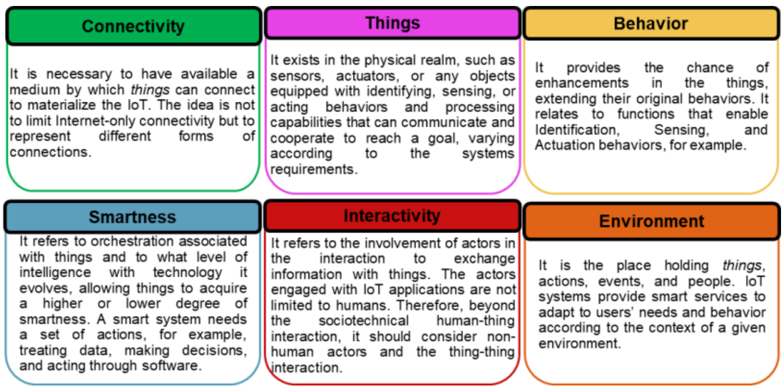

Figure 1. IoT Facets.

3. A Study in Industry: Structured Interviews

After defining the IoT Facets, we wanted to confirm this proposition and strengthen it with an industry perspective. Therefore, we conducted a study to understand the pertinence of the facets identified according to software practitioners' perception of IoT software systems' engineering. The pertinence was observed through the applicability, influence, and usage of each facet. For this, we interviewed professionals working on the early stages (problem definition, requirements analysis, and initial planning) of IoT software systems projects to observe their perception. We decided to focus on the early stages since translating a problem into a software solution is the primary challenge. During this conception phase, decisions and directions affect the overall solution (Pfleeger and Atlee, 1998).

Material. The study package[1] is available online and included an invitation explaining its objectives, a consent form to be signed by the participants, and a questionnaire. The questionnaire was divided between a characterization section and an evaluation section with three main questions. The questions were:

- RQ1: Are the facets **pertinent** to IoT software systems engineering at the project's early stages?
    - RQ1.1: Are the facets **applicable** to IoT software systems engineering at the project's early stages?
    - RQ1.2: Do the facets **influence** decision-making in IoT software systems engineering at the project's early stages?
    - RQ1.3: Are the facets **used** in IoT software systems engineering at the project's early stages?
- RQ2: How are the facets taken into account in the early stages of IoT software systems projects?
- RQ3: Is there any additional facet pertinent to IoT software systems engineering at the project's early stages that is not present in this set?

The facets were evaluated individually. According to the dictionary, pertinent is to have clear decisive relevance to the matter in hand (Merriam-Webster) and can be observed through applicability, influence, and usage – as we used in this study. This part of the questionnaire contained the facet definition and a Visual Analogue Scale (continue line with labels in each extreme from "Not Applicable" to "Totally Applicable") to capture the perception expressed in subjective values for the applicability, influence, and usage of such Facet. The RQ2 and RQ3 were performed as open questions in a structured interview style. It could enable a freer discussion and capture information such as the impact of the facets in the development and which facet is harder to achieve or measure.

Pilot interview. Two collaborators with relevant experience in IoT and software development participated in the pilot. The purpose was to verify the materials and

[1] http://bit.ly/3sHDwq9

procedures before applying them. Their feedback was used to refine the process before the execution.

Structured Interview. Two researchers performed this series of interviews at the end of 2019. Six participants selected by convenience (using professional contacts) participated in the study from three different enterprises in France. All the participants received all the material from the study package. The interviews took place between the researchers and participants on different days regarding their schedules. The interviews lasted one hour, on average.

Results. The characterization section presented the participants' experience with IoT; as shown in Figure 2-A, the most presented role was a software engineer with three responses, but we also had researchers from R&D divisions (with 2 participants) and managers (with one participant). It is interesting to have different roles in capturing more insights on the topic (Figure 2A).

In Figure 2-B, we can briefly view the organization, with most of the participants reporting 15 projects. Figure 2-C shows the participant's experience in developing IoT projects. The most experienced participant had 15 years of experience, and the least had four years of experience. The media was more than seven years of experience. The last characterization is regarding their IoT-related projects. The most experienced had participated in 15 projects, and the least had worked three projects. The mean was more than 7 IoT projects. These results give our population a good maturity on the IoT subject.

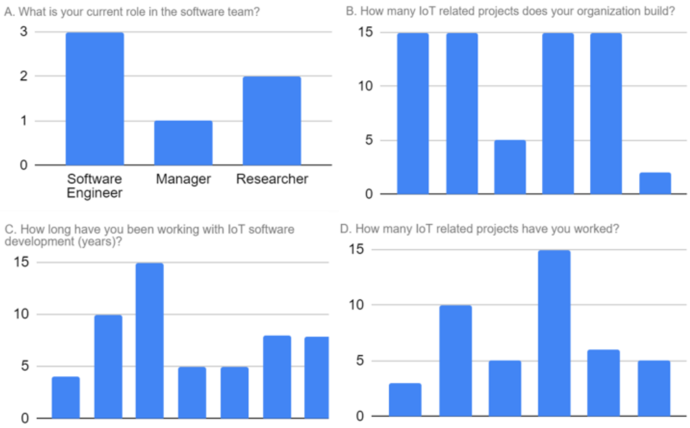

Figure 2. Characterization results.

The pertinence was observed through Applicability, Influence, and Usage (Figure 3). In general, the participants' perception is that all facets are pertinent for IoT projects. From the results, Connectivity, Smartness, and Behavior Facets are the most applicable. The Things and Connectivity are the facets the influence the most. Also, Things, Connectivity, and Behavior are the most used facets, according to the participants.

RQ2 and RQ3 were open questions to foster the discussions. With RQ2, we observed the technologies (methods, techniques, artifacts) used in practice. From their experience, we retrieved valuable information such as how to decide whether to build or adapt a new device, how the technical limitations (such as a battery) are taken into account during the development, and strategies to deal with the growing project complexity. With RQ3, we hoped to observe the completeness of the proposal that relies on the facets. One of the participants reported that "*all these concepts are relevant. I do not see anyone working with IoT saying anything different from that*". However, a crucial discussion was presented related to Data. "*The use, processing, what to do with what was received, how to present it to the user*" were some of the issues presented by a participant during the interview.

Our initial idea was that the data would be treated along with the system's behavior. For example, a system with environmental sensing should capture the relevant data and handle it to be valuable for the system. However, we separated behavior and data concepts from the interviews' results, thus creating the Data Facet.

Figure 3. Pertinence results.

With the study results presented, we propose an update in the IoT Conceptual Framework (Motta *et al.* 2018; Motta 2019) to include the Data Facet, as presented in Figure 4 with its description. Therefore, the final set has eight facets representing the multifaceted concerns for IoT software systems development, observed from experimental studies.

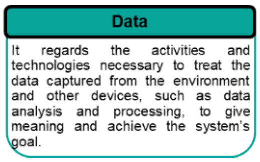

Figure 4. Definition for Data Facet.

4. Conclusion

This article presented the IoT professionals' perception of the pertinence of IoT Facets. One of this work's contributions is to clarify the need for a multifaceted view for IoT software systems and the adequate artifacts to deal with it. The research's next steps are to reinforce the results by performing more experimental studies and developing an artifact to support professionals working with IoT projects.

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