Development of a matching platform for the requirement-oriented selection of cyber physical systems for SMEs

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Abstract. This paper addresses the challenge of a systematic requirement-oriented configuration and selection of cyber physical systems (CPS) for SMEs. As the key technologies of realizing the digitalization and interconnection of production processes, manufacturing companies have realized the potential benefits brought by CPS. However, due to the complexity and fast development of CPS technology, it is difficult for SMEs, which lack expertise and financial resources, to select the appropriate CPS technologies meeting both functional and financial requirements. To overcome the issue, an online matching platform is developed to let SMEs express their needs and assist them conceptualize the individual CPS. This paper presents the matching methodology of the matching platform, which can not only match technical characteristics but also evaluate economic potentials. Then, it was demonstrated by a tracking and tracing use case in the end-of-line assembly of a small-sized German electric automobile manufacturer.

Keywords: cyber physical systems, matching, evaluation, SMEs

1 Introduction

Faced with the growing digitalization trend, manufacturing companies have realized the potential benefits of adopting cyber-physical systems (CPS) in their production processes. The function of CPS is characterized by the connection of physical and computational entities usually with feedback loops, which enables higher efficiency and flexibility in production monitoring and control [1-5]. However, due to lack of overview of all available CPS technology in the market and technical expertise, it lasts especially for SMEs a long time until CPS are conceptualized and implemented. In this

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paper, a matching platform aimed at SMEs is developed and demonstrated, which supports the requirement-oriented selection of CPS.

2 State of the Art

In the literature, there are no specific methods but several general methods, which can be adopted to conceptualize CPS such as the guideline to design and construct technical systems and products (VDI 2221) [6]. However, it focuses a new development of technical systems, while implementation of CPS is usually a retrofit of existing infrastructure and a selection of available solutions. Thus, frame conditions and matching methodology need to be supplemented. Value benefit analysis and technical-economic evaluation method according to VDI 2225 [7–10] can contribute to functional or economic evaluation of CPS technologies. However, they fail in considering the two aspects in one framework. Therefore, a combined methodology to match technical features and evaluate economic potentials of CPS needs to be developed.

3 Development of CPS Matching Methodology

In this chapter, the developed CPS matching methodology including functional matching logic and economic evaluation model is presented. The methodology is then implemented in an online CPS matching platform: goo.gl/UmV7n8. The CPS matching platform will be introduced in more details through the case study in Chapter 4.

3.1 Functional Matching Logic

The approach to match user requirements and CPS technology functions is developed according to the VDI guideline 2221 [6] (see Figure 1). CPS technologies are broken down into six categories (actuators, sensors, transmission technologies, IT-Infrastructure, data processing, and HMI) to structure the components of CPS [11]. The functional fulfilment of available CPS technologies is assessed by a structural evaluation scheme containing all requirement specifications with a grading from 0 to 4 (see Figure 1) [12]. It enables user requirements and CPS technologies to be evaluated in a uniform scale, so that the matching of a CPS technology (or technology combinations) and requirements can be easily identified.

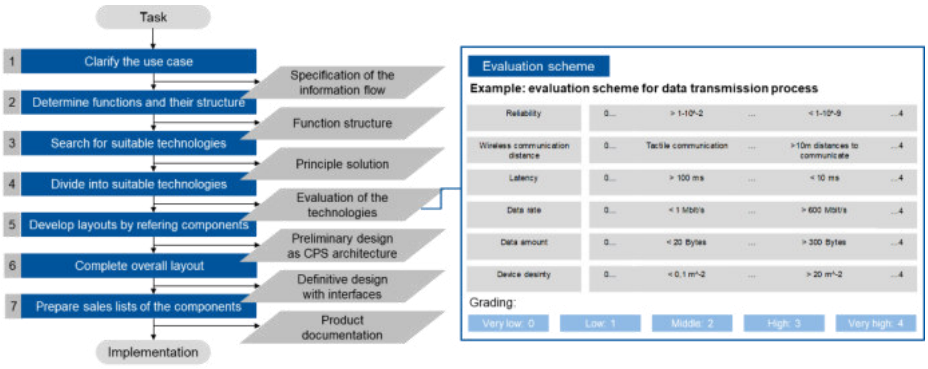

Figure 1. The overview of matching process and evaluation scheme for CPS functional fitting

3.2 Economic Evaluation Model

After a functional fitting, the matching platform can further assist user companies with economic evaluation of CPS solutions. A model of Return on CPS (RoCPS) is developed specifically to quantify the potential profits by CPS applications, which is defined in Formula (1) with reference to the method of Return on Investment [13].

$$\text{RoCPS} = \sum_{i=0}^{n} \frac{p_i}{(1+r_i)^i} / \sum_{i=0}^{n} \frac{c_i}{(1+r_i)^i} \tag{1}$$

p_i is the total profit in period i, c_i is the total cost in period i, r_i is the discount rate in the period i, n is number of periods. The value of RoCPS indicates how much return can be gained after adopting CPS compared with its implementation costs. In the matching platform, a universal template sheet for cost and profit estimation is provided, in which all cost drivers and benefit types are identified and monetization rules are given, thus facilitating non-experts to make assessment (see more in [14] about our research work).

4 Application of the CPS Matching Platform

The developed matching platform was applied to conceptualize a CPS solution at a small-sized German EV manufacturer. The SME wishes to track the order status during the end-of-line assembly by a wireless identification and localization of the initial chassis place and the final mounting place, in order to bring more transparency in intralogistics.

Firstly, the production manager of the SME chose the use case type on the matching platform. Following information processes of the use case were suggested by the platform: identification, localization, raw data transmission, raw data processing, information transmission and data storage. Among them the identification, localization and data transmission are the mayor challenging selection task to construct the CPS.

Secondly, the matching platform asked the production manager to fill out a requirement catalog for each information process. The requirement specifications in the catalog are derived from the evaluation scheme introduced in 3.1. For this tracking and tracing

case, the resolution of the localization within less than one meter, the data rate larger than 1 Mbit/s and a scalable IT-infrastructure are some most decisive requirements.
Thirdly, the matching platform automatically filtered the suitable solutions, because all CPS technology specifications stored in the platform have been assessed in advance with the identic evaluation scheme as the requirement specifications (see Figure 2). In analogy to the morphological box [11], the platform can also generate CPS technology combinations, which fulfills the requirements of all information processes. Now the production manager can either take the optimal combination suggested by the platform or combine the technologies by himself and compare the functional fulfillment based on the grading.
Finally, the RoCPS was calculated with the given calculation sheet and the profitability of CPS concepts was evaluated. Figure 2 shows that the first CPS concept suitable for the use case consists of RTLS and LTE; the second concept suggests 5G as the transmission technology. Since the use of mobile communication systems in production requires a base station and customized networks, which is an expensive option, the SME decided to choose Bluetooth connections via Beacons by self-combination.

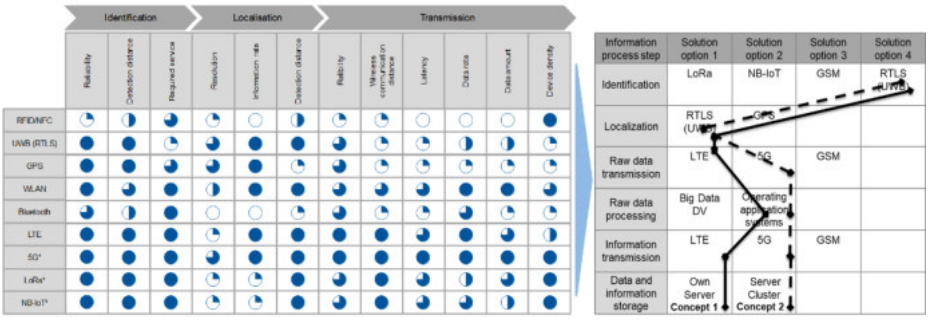

Figure 2. Two CPS concepts suggested by the matching platform for the use case

5 Summary and Outlook

This paper developed a matching platform for SMEs to select appropriate CPS solutions from both functional and economical perspectives. It was demonstrated by a small-sized German EV manufacturer, supporting them in CPS selection for tracking and tracing during the end-of-line assembly. The matching platform bridges the gap between inexperienced users and CPS suppliers, which can promote the digitalization transformation of SMEs. In future, it is expected to be optimized by more uses of public.

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