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From use-case to scenario: a proposal for an Ergonomical methodology facilitating an interdisciplinary dialogue in a digital twin design process

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According to ISO 23247, a digital twin (DT) is a digital system that monitors a physical entity or product by constantly updating its operational and environmental data. Developing a digital twin requires the mobilization of various digital stakeholders and experts in the field (process engineers, end users, etc.). Interdisciplinary collaboration, with shared common objectives, is crucial to the success of DT design project. However, few methods are currently available to facilitate dialogue. In this article, we propose methodological tools to foster an interdisciplinary design process to develop digital twins that are frugal, accessible, and adapted to future uses. Ergonomics and Human Factor design methods include work and project analysis. Few studies demonstrate how to share the results of these analyses to validate project objectives and scope. The features developed may, as the project progresses, diverge from the initial objectives without being shared and re-examined. It is often recommended to define use cases and scenarios, but these terms don't have the same meaning depending on the designer's profiles. This article aims to provide a shared definition of the terms 'use case', 'Typical Action Situation' (TAS), and 'scenario', and a method for their application. Our method was applied to two digital twin design projects: 1. the TERRA project for traceability in dairy production, and 2. the GEMINI 3D project for prediction, or even correction, of part defects and failures in additive manufacturing. From the beginning of the projects, use cases were used to specify the scope of the DT in its different versions. Then the Typical Action Situations made it possible to define the cooperation between humans and the digital twin (e.g., allocation of functions and transparency in communication between the two partners). Beyond sharing a common definition between users and designers, the methods aim to support a comprehensive change management approach.

Keywords: Ergonomics, Design, Digital Twin, Human-centered Design, interdisciplinarity Use case, Typical Action Situation

1. Introduction

This article proposes to focus on the early design phases of innovative digital tools, particularly Digital Twins (DTs). We consider the DT as the set of data and models linked to an object throughout its lifecycle Grieves (2005). It allows the dynamic virtual representation of an object (product, process or service) (Julien and Martin 2021).

Previous work has already demonstrated the contribution of project and activity analysis for the design methodology of a DT (Guennoc et al. 2024). This paper aims to further clarify the tools that can be used to precisely define the features of DT. A feature is understood as a capacity or characteristic of the twin that allows it to perform a specific task. Development choices are frequently driven by technical feasibility. Although the importance of adopting a user-centered vision from the early stages is well established (da Conceição et al. 2020), the articulation of techno-centric and anthropo-centric approaches remains difficult. This requires the pooling of methods and tools from various disciplines, including ergonomics, design, and engineering (Puig-Poch et al. 2025; Village et al. 2014).

One challenge is to overcome the design paradox as stated by Theureau (1996). He wrote that "*in order to develop design proposals for a future work situation based on knowledge of the activity, it is necessary to know with certainty the activity in that future situation. Within the framework of a design process, the activity in this future situation can only be known with certainty when the future situation is fully known. But then, the scope of the contribution to the design will be considerably limited since the design will be entirely complete.*"

The design of digital twins has particular characteristics in relation to this paradox. Firstly, it is a developing technology that remains relatively unknown to the general public. The ability of future users (and sometimes designers) to envision the use of a DT is particularly limited by its innovative nature. Furthermore, the design of DT is often conceived in terms of versions that generally start with a mirror, then a shadow, before becoming a DT (Julien and Martin 2020). The choice of features and their development can progress concurrently with subsequent versions. Finally, the design of the DT requires the expertise of a large number of design contributors (software engineers, data scientists, UX designers, cyber engineers, etc.) and experts in the field (process engineers, end users, etc.). Multidisciplinary work is often impacted by the mixing of these worlds, which are not accustomed to interacting. The lack of a common methodological framework and intermediary tools to facilitate dialogue constitutes a significant difficulty (Colin et al. 2022; da Conceição et al. 2020).

Our ambition is to offer an approach and tools that allow for the definition of features for different versions of the DT, in a way that is shared among the different members of a design team. This involves, in particular, facilitating dialogue between ergonomists, future users, and software designers. To this end, we will present approaches used in the field Human-Centered Design (HCD) and the design methodology developed in French-speaking ergonomics. Building bridges between methods will involve clarifying certain terms (Use cases, Typical Action Situation, and Scenarios) and proposing a methodological approach to use those tools. We will support our approach with two projects: 1. the GEMINI 3D project for predicting, or even correcting, part defects and failures in additive manufacturing, and 2. the TERRA project for traceability in dairy production.

2. The human factor in the design process

2.1 Human-Centered Design method: how close to user needs?

Human-Centered Design methods have gained increasing attention over the last two decades, particularly within Agile methodologies (Sy and Miller 2008; Schwartz et al. 2009; Kadir and Broberg 2021; Schön et al. 2017). The ISO 9241-210 framework aims to « create software that both meets user and organizational needs and gives a great user experience » (Maguire 2013). HCD methods involve integrating end users into the very process of designing a device (Safin 2021).

Although HCD is often associated with software design, particularly Human/Machine Interfaces (Caliste and Dejean 2012), it can also be applied to other devices such as products, building tools, services, etc. It aims to guide development by the needs and characteristics of users (anthropocentric logic) and thus avoid a design solely driven by technical possibilities (technocentric logic). The ISO NF EN ISO 9241-210 standard provides for four human operator-centered design activities that interact with each other: 1. Understand and specify the context of use (i.e., defining user groups, personas); 2. Specify user requirements (i.e., identify needs, formulate recommendations); 3. Develop design solutions (i.e., scenario, prototype); 4. Evaluate the design (i.e., write usability test reports, user study report).

Maguire (2013) lists different methods for exploring the context of use. First, all types of users must be identified. This may involve conducting a **contextual inquiry** based on interviews and observations. Without using the term "ergonomics" or "real activities analysis", he suggests "*studying the user's current activities in their own natural environment – at the user's workplace, at home, on the move, etc. The researcher watches users perform their own work tasks and discusses with them any artefacts they generate or use*" (p.189). This practice actually seems to be quite uncommon. He also mentions the use of **scenarios** (Informal narrative descriptions) (Carrol 1999) and **personas**. They are intended to act as stimulus for the design team of different user characteristics and situations that should be designed for. Furthermore, **user journeys** involve describing all the steps to achieve a goal and redefining it as an "*ideal user journey*." Finally, the **user story** method can be used. These are generally written by the product owner to define the features to be developed (Rocha Silva et al. 2020). User stories serve to sort and prioritize the features to be developed. They aim to clarify user needs and the reasons for those needs. A common way of writing user stories is "*As a <role>, I want <some intention>, so that <some reason>".* Wang et al. (2022) established quality criteria for user stories: 1. Completeness (well-formed, uniform, full sentence); 2. Testability (Atomic, minimal, unambiguous) et 3. consistency (conflict-free, unique, estimable, conceptually sound, independent).

We observe that IT development methods make effort to interact with future users but requirements analysis is generally limited to task analysis. The consequences of introducing the technology are poorly understood. One of the fundamental principles recalled by French-speaking ergonomics is to analyze real activities and so to "*put technology back in its place as a mediator of activity carried out by a capable subject*" (Barcellini et al. 2025).

2.2 The design approach in French-speaking ergonomics

This section aims to present methods from the French-speaking ergonomics literature for the design of spaces and equipment (Béguin and Cerf 2004; Daniellou 2004; Martin 2000; Barcellini 2015; Duarte and Lima 2012). Ergonomics project management has therefore gradually become structured to address these two challenges simultaneously: transforming work organization and involving company stakeholders in the intervention (Coutarel and Daniellou 2007; Dutier et al. 2015). Key steps have been defined, such as: 1. Analysis of real work situation or reference situations. Reference situations are workspaces with similar characteristics to the one being designed (Daniellou 2005) ; 2. The development of Typical Action Situations (TASs). These are considered intermediate objects in the design process. They serve to describe the existing actual work and to prepare scenarios to simulate future activity (Daniellou 2004; Coutarel and Daniellou 2007). TASs are commonly defined by the tasks to be carried out; the associated criteria and constraints related to the achievement of these objectives; the workers involved; the sources of information, means and tools needed; the internal or external factors that may influence the achievement of these objectives (Galey et al. 2022) ; 3. The definition of settings of usage (usage configurations) and design guidelines that allow the generalization of activities covered by the new system (Duarte and Lima 2012; da Conceição et al. 2020). And 4. The design of prescription and action scenarios for the simulation of future work (Daniellou 2007; Garrigou et al. 2001). These steps have been formalized in particular in the updated diagram of Barcellini (2015).

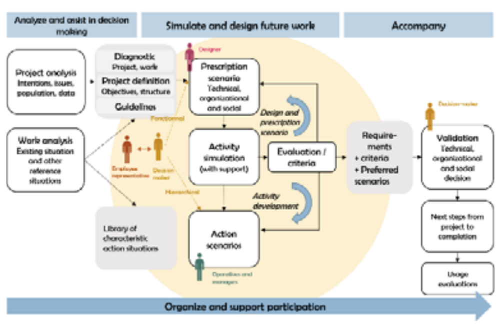

Fig. 1: Project management approach proposed by the ergonomics of activity (Barcellini, 2015)

2.3 Articulating HCD and French-speaking ergonomics during the first steps of Digital Twin design

Digital twins are complex cyber-physical systems, and defining the features to be developed presents a challenge. This was the case for the two projects presented below. Combining the HCD methods with the French-speaking ergonomics method can have a great value (Lauton et al. 2025). The HCD method described in ISO 9241-210 offers tools for considering users at each stage. Different user types are taken into account based on their characteristics and their goals and tasks. HCD also includes task allocation between users and the system. However, we have identified limitations, in particular in the two first stages: understanding and specifying the context of use (1) and specifying the user requirements (2). Ergonomic design method can help to overcome these limitations.

First, in HCD approach, the project analysis is integrated into the context analysis. The project objectives are assumed to be already defined by the client. Thus, the challenge is to understand these objectives. In ergonomics, the project analysis includes a strategic analysis of the stakeholders. It is fueled by the initial analyses of the relevant work situations (or reference situations). The ergonomist can help the client clarify or even to co-create the project's objectives.

Then, in HCD, identifying needs can involve interviews, observations, and workshops to take into account the context of use. One limitation is that it is assumed that users can clearly express their needs, and even prioritize them. Ergonomics distinguishes the task and the real activities. Analyzing real activities gives access to individual and collective strategies, some of which are "embodied" and therefore difficult to verbalize. Taking these strategies into account in the development of the tool avoid hindering certain forms of activity.

Finally, in the HCD approach, the transition from task analysis to the selection of features to be developed is not very detailed. Requirements must be translated into specifications and trade-offs must be made. Choices are based on the designer's understanding. Orientations are then only discussed during the testing phases. Tools proposed in ergonomics, particularly the TASs and their translation into design guidelines (or features), are especially relevant for enriching the dialogue between designers and future users before producing design solutions.

To summarize, in this article, we propose to enrich the initial stages of the DT design of digital twins using methods developed by French-speaking ergonomists. Our proposal is, in particular, to reposition use cases and TASs as a tool for dialog and coordination with field experts as well as with designers. Beyond simply providing specifications, the goal is to further engage designers in understanding the activity that will be created or modified. The choices regarding the scope of the DT and its features in its different versions, would be more refined. Furthermore, we provide examples to illustrate our operationalization of the approach.

3. Proposed approach for defining the scope and features of a digital twin

3. 1. Definitions of key terms

At the start of the Gemini 3D project (about predicting part defects and failures in additive manufacturing), a collective effort was made to define the terms. Nearly 70 terms were defined and categorized according to their generic nature or their application to a specific field (3D printing, Computer science, Ergonomics, Digital twin). This work, carried out in the form of workshops, helped to reveal potential misunderstandings. For example, the term “use case” is used in computer science and ergonomics. However, the definitions remain vague in their application in both disciplines. This work on concepts provided an opportunity to engage in discussions on what is the real job of the various partners. The definitions adopted are as follows. 1. A **use case** formalizes the objectives of the socio-cyber-physical system and the interactions between its components. The generic components of a use case are: socio (the users or beneficiaries), cyber (the digital twin and other software), physical (all the hardware related to the product and the production equipment); 2. **Typical Action Situations** aim to account for the elements that are expected to be present in the future situation. A TAS is a combination of those elements: the prescribed context (task to be performed, objectives, resources), the logic of action, and the events that may impact the future activity (variability). TASs are a tool for design projects.

They are used as a basis for building scenarios for simulation; 3. The **design scenario** is a tool used during the simulation phase of a project. There are two types of design scenarios: The prescription scenario is proposed by designers and specifiers. It describes the prescribed future. An action scenario is based on the elements of a TAS. It is a sequence of events, a storytelling exercise, designed to facilitate exchange between designers, specifiers, and future operators or users. TASs are derived from use cases, specifying them. They allow to consider several different scenarios (cf. Fig. 2).

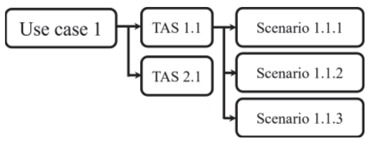

Fig. 2: Hierarchy between use cases, TASs and scenarios

3.2. Positioning of use cases and TASs in the DT design process

The proposed approach is adapted from that of French-speaking design ergonomics to meet the specificities of our DT design projects. It can generally be applied to the design of innovative digital devices. In our cases, the projects did not originate from needs formalized by a company. They are research projects carried out by consortia including industrial partners. They seized an opportunity, sometimes before clearly defining the initial need or problem. For the Terra project (traceability in dairy production), the tool developed has a generic scope since it is intended for all small dairy producers. Thus, in this context, the ergonomist shifts from understanding the need to one of co-construction.

The Fig. 3 illustrates the initial phases preceding the definition of the future tool's features. The **project analysis** aims to understand and formalize the intentions of the various project team members. The **analysis of existing situations** begins in the first stage and continues throughout the development phases of the first demonstrator. An initial project **scope** is established using **use cases**. Once discussed and validated collectively, the use cases are further defined using **TASs**. The TASs vary in detail depending on the complexity of the activity and the project's scope. They are presented to the project team and should enable the selection of situations in which human agents will be assisted by the DT. TASs can precise the scope (in an iterative way) and are a support for discussion about the desired **future work situation**. The "desired futur" can be formalized in the form of future TASs. Once the future situations are validated, it is possible to define and select the features to develop.

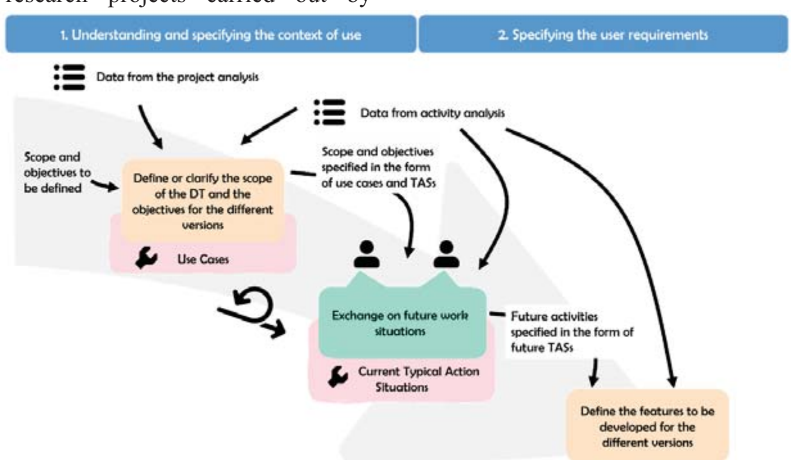

Fig. 3 : Methodological proposal for clarifying the scope and features of a Digital Twin

3.3. Examples of use cases and TASs in the Gemini 3D and TERRA projects

The **GEMINI3D** project aims to enable prediction, traceability, and correction of defects in additive manufacturing. The GEMINI3D platform is intended to become a dedicated space for demonstrating and experimenting with 3D printing and DT for industrial users. Additive manufacturing is a promising technology for the wide range of products geometries it can produce, generating minimal waste and utilizing recycled and recyclable materials. The ambition of the DT is to enable the production of high-quality parts, while reducing development time, thus meeting the needs of industrial users. Four use cases have been defined: production, platform maintenance, educational use, and sizing of the DT. An example is presented in Fig. 4.

Use case: Production

Objective: The system aims to produce a part while anticipating adhesion defects between the filament strands in the event of an extrusion flow rate problem, and to propose corrective actions to be applied during printing.
Users: Engineer specializing in materials science or additive manufacturing
Cyber: Digital twin, connector with Vision5D and EGM
Physical: Platform with robotic arm, extruder, hopper where the material is stored, temperature and pressure sensors, product currently being printed

Current Typical Action Situation: To produce a part with a complex geometry in a semi-crystalline material

Context: Crystalline and semi-crystalline materials require very precise temperature adjustments of the environment and extrusion. Carbon-filled semi-crystalline materials are being developed for aerospace. Optimal strength quality is required.
Objective: Manufacture the part in a single print.
Logic of action: Manufacture a part with guaranteed strength without post-printing rework, prevent defects to avoid their occurrence
Tools Used:
- EGM record sensor data
- VISIO 5D record visual defects

Recorded Information:
- extrusion screw rotation speed, printing speed, extrusion screw pressure, temperature of the 4 extruder zones, temperature of the last printed layer, room humidity

Variability of the situation: problems with extrusion flow rate issues at any point during manufacturing, geometry of the part produced, number of supports required, manufacturing time, type of manufacturing material (amorphous, semi-crystalline, or crystalline), material composition

Fig. 4 : Use case "production" of GEMINI3D project and an example of TAS

The **Terra project** aims to give small dairy producers (working in short supply chains) access to digitalization. Small producers do not have the same resources as large agri-food companies to manage their data on the quality of finished or semi-finished products, the presence or absence of allergens, energy consumption and so on. Yet managing data throughout the production cycle helps to ensure transparency on the origin, processing and quality of products, thereby attracting, reassuring and retaining consumers. The digital twin is one of the tools developed within this framework. Three use cases for the twin have been defined: product traceability, production planning, and monitoring of water and energy consumption. Fig. 5 present the traceability use case and a TAS concerning the recording of information.

Use case: Traceability

Objective: The system aims to assist producers in managing the traceability of manufactured products. It must allow for the recording of information related to raw materials, manufacturing processes, and production contingencies.
Users: Dairy producers
Cyber: Digital twin, connector with Socléo, which manages customer orders and invoicing
Physical: Pasteurizer temperature sensors (Version 1), Workshop temperature sensor (Version 2)

Current Typical Action Situation: Recording information for a batch of skyr

Context: The producer produces skyr using a lactic acid fermentation process. The lactic acid will be used in other products.
Objective: Record all data related to the product and the process to ensure batch traceability for all customers.
Logic of action: Real-time recording of production data ensures nothing is overlooked, saves time later, and allows for easy retrieval of all batch information in case of a customer return.
Tools Used:
- Product batch information is recorded in OneNote. It is accessed via a tablet in the workshop.
- Quantities produced for each customer are recorded in Socléo.

Recorded Information:
- Milk collected: Quantity, protein content, fat content.
- Processed product: Quantity of skimmed milk, quantity of cream obtained, quantity of skimmed milk added, destination of the milk, pasteurization start and end time, time reaching 3°C, calcium added, etc.

Variability of the situation: Number of different products to record, number of different customers

Fig. 5 : Use case "traceability" of Terra project and an example of TAS

The features associated with this TAS have been defined for different versions. Version 1: The tool allows easy retrieval of information, product characteristics, and relevant customers. Version 2: The tool allows easy import of information on raw materials, including photos of starter culture and rennet packages.

Conclusion

This article is the result of ongoing discussions between ergonomists and psycho-ergonomists working on innovative DT design projects. It has been integrated into a DT design methodology to guarantee proficiency in use throughout the projects. The approach was developed in parallel with the execution of several projects. However, it may still evolve with experience gained from new projects. We highlight the positive feedback from designers regarding the integration of these ergonomic methods. Work is currently underway to analyze the effects of this approach on designers' perceptions within the Gemini 3D project.

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