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Conceptions of Man in Human-Centric Cyber-Physical Production Systems

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Abstract

The functionality of existing cyber-physical production systems generally focuses on mapping technologic specifications derived from production requirements. Consequently, such systems base their conception on a structurally mechanistic paradigm. Insofar as these approaches have considered humans, their conception likewise is based on the structurally identical paradigm. Due to the fundamental reorientation towards explicitly human-centered approaches, the fact that essential aspects of the dimension "human" remain unconsidered by the previous paradigm becomes more and more apparent. To overcome such limitations, mapping the "social" dimension requires a structurally different approach. In this paper, an anthropocentric approach is developed based on possible conceptions of the human being, enabling a structural integration of the human being in an extended dimension. Through the model, extending concepts for better integration of the human being in the sense of human-centered approaches, as envisioned in the Industrie 5.0 conception, is possible.

Keywords: Industry 5.0, Cyber-Physical Production System, Conception of Man, Human-Centered

1. Introduction

Due to external and internal changes, such as the COVID-19 [1] and the climate crisis, as well as societal changes [2], cyber-physical production systems (CPPS) are transforming from purely technical systems to value-based systems [3]. In addition to resilience and sustainability, human-centricity represents one key concept at the center of the new Industrie 5.0 paradigm [4, 5]. Thus, peoples' central needs and interests must be placed at the center of the production process [4]. This fundamental change in perspective requires a substantive and conceptual engagement with people as central actors, especially for modeling and designing systems. Consequently, answering either implicitly or explicitly the following questions is paramount.

- What constitutes humans?
- According to which causal structures, primarily actions and decisions, can be derived?
- How, if necessary, essential information from and about humans can be obtained?

Depending on the answers, the requirements for CPPS will vary. In their approach for value-oriented and ethical technology engineering, Longo et al. [6] derive standards from a total of 14 general values and use these as a template for the design requirements. Self-actualization, accountability, autonomy, privacy, identity, welfare, and stimulation are among these values. A bidirectional relationship between the values, standards and design requirements is established.

Graessler and Poehler [7] use Character, Skills, and Mood to represent humans in scheduling and assignment tasks for CPPS. While Character and Skills are relatively time-invariant

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or stable over time, Mood or emotions are conceptually integrated as a shorter-term expression.

Romero et al. [8] developed a typology with eight classes based on the type and extent of physical and cognitive interaction in the Operator 4.0 approach. Besides the more technology-oriented types, such as the Super-Strength Operator, Augmented Operator, Collaborative Operator, and the Virtual Operator, the socially-oriented types Heahlty Operator, Social Operator exist, as well as the cognitively centered types Smarter Operator and Analytical Operator.

Tan et al. [9] focus on collaboration in the Anthropocentric Approach for Smart Assembly and do not have their own conceptualization of humans, but point out that human-specific problems such as stress or limitations such as misuse, false indication, and mode confusion [10] occur in collaboration.

The different approaches show a wide range of conceptualizations of humans within CPPS. Although all of the conceptualizations use a human-centered or anthropocentric approach, they do not always explicitly refer to the underlying conceptions of man.

Therefore, first Section 2 briefly describes the different conceptions of man. The classification of the human images concerning their use and integration in CPPS follows in Section 3. Finally, Section 4 gives a summary and an outlook on further research and related questions.

2. Conception of Man

Conceptions of man are used in many disciplines with very different meanings. In the human sciences, such as medicine or psychology, the concepts represent an essential point of reference, and, depending on their positioning, they refer to different schools of thought in the respective discipline. The conceptualization within the social sciences regards mainly interaction and communication aspects and therefore rather refers to external than internal structure. The economic theory approaches primarily contain exact positions on the conceptions of human beings or their action-guiding conception to use them as a basis for explanatory approaches and the design task. The technical sciences usually fall back on the conceptions of the other disciplines. An exception here is, for example, the concept of "home creators" by Poser [11].

Consequently, for the use and integration in CPPS, man's psychological and economical conceptions are briefly introduced. For the use and integration in CPPS, the psychological and economic conceptions of man are therefore briefly presented. Both find explicitly or implicitly usage in the application domain and are in principle structurally connectable.

2.1 Conceptions of Man from a Psychological Perspective

Psychology science uses the following approaches to human models:

- Bio-Psychological Model
- Psycho-Dynamic Model
- Behavioristic Model
- Humanistic Model
- Cognitive Model

In the *Bio-psychological* Model, human behavior, experience, and consciousness are understood based on physical and biochemical processes. Based on this approach, corresponding conceptions are implemented with neuroscience, e.g., in robotics [12].

The *psycho-dynamic model* explains human behavior mainly by drive control. Important representatives of this direction are Sigmund Freud, Alfred Adler, and Gustav Jung. Different models are then derived from this basic explanatory paradigm to explain and, above all, to shape it. For example, Freud focuses on libido and Adler on power. Psycho-dynamic models are usually used implicitly; for example, personality classifications such as the Big-Five use Jung's basic psycho-dynamic concept [13] .

The *behaviorist model* assumes that environmental conditions primarily influence human behavior. The approach does not include the modeling of an internal representation. Accordingly, behavior is entirely deterministic, and interactions from the outside or the existing framework allow for determining behavior respectively. Within the deterministic approach, a distinction can be made between classical behaviorism (Watson), neobehaviorism (*Tolman*, *Hull*, *Guthrie*), and radical behaviorism (*Skinner*). This basic approach applies to specific elements within CPPS systems, such as learning [14], or the entire conceptualization [15] of Industry 4.0 or 5.0.

The *humanistic model* approach assumes that humans are neither driven by strong, biologically determined drives or instincts nor manipulated by pervasive environmental determinants. Accordingly, humans are active beings who are inherently good and capable of choosing their own path. Key features [16, 17] of the conception of man are (1) autonomy and social interdependence, (2) self-actualization, (3) goal and meaning orientation, and (4) wholeness. Wholeness is understood as a holistic approach in which the human being has various sides, aspects, levels, and processes that are simultaneous components of the unity in their interactions. Important representatives of this approach are *Bühler*, *Rogers*, *Maslow*, *Fromm*, and *Frankl*.

The cognitive model views humans as active information processors. Human cognition can be seen here as the process of perceiving, reasoning, remembering, thinking, problem-solving, and decision making [18]. Around these processes, humans "construct" their interpretation of the world. As Humans are seen as active information processors, decisions are made based on experience, stored knowledge, and perception of external stimuli. Education, experience, and group norms are the basis for forming individual values, life goals, and motivation to act. The conception of man sees man accordingly as a learning system to satisfy functional, psychosocial, and emotional needs [19].

2.2 Conceptions of Man from an Economic Perspective

From economics, the following human images are derived empirically [20]

- Homo Oeconomicus
- Scientific Management - Taylorism
- Factor-theoretical Approach
- Human Relation Approach
- Decision-oriented Approach

The *homo oeconomicus approach* is a well-known and frequently used approach among the economic concepts of man. The approach assumes that humans act based on a selfish principle of utility. Economic theories (*Smith*, *Bentham*, *Mill*) build on this entirely rational basic principle. Thus, according to Smith, the pursuit of profit is introduced as a universally valid rational principle and the fundamental axiom of economics to increase the welfare of all [20].

In *Scientific Management,* Taylor similarly builds on humans' completely egoistic basic attitude and connects it with man's disinterest in the company's goals. Here, the motivation to work is ensured only by financial incentives. On this basis, Taylor introduces the separation of managerial and executive work.

On the other hand, the human being is regarded as a social being with the human relation approach. This means that humans are motivated predominantly by social needs and not predominantly by monetary incentives. In particular, humans are not viewed in isolation but as social beings in a community with others. Therefore, people's behavior is guided by their membership in workgroups and the social regulation and norms that exist within those groups. Incentives and controls by management are thus less important or influential. Thus, according to Nicklisch [21], man is conceived as a spiritual being with the basic needs of conservation, creation, and free will.

Humans are also viewed from a social and behavioral science positioning in the *decision-oriented approach*, but rationality is limited by bounded information intake and processing capacity [22]. Due to this limitation, instead of optimal solutions to problems, humans also accept solutions that meet certain aspiration levels.

3. Integration into the CPPS

The variety of approaches presented above indicates that very different positions for human models are possible. The decision for or against a specific model would not be objectively decidable due to different normative characteristics and different premises. In order to anchor the conception of man structurally and contentwise, in CPPS, categories can be derived from the conceptions of man based on which the positioning can be made. In order to anchor the concepts of human beings structurally and in terms of content in the CPPS, the corresponding dimensions were derived from the conceptions of man, taking into account the requirements of CPPS. The dimensions cover, on the one hand, static constitutive structures and on the other hand processual dimensions that relate to decision-making and adaptability. (Fig. 1)

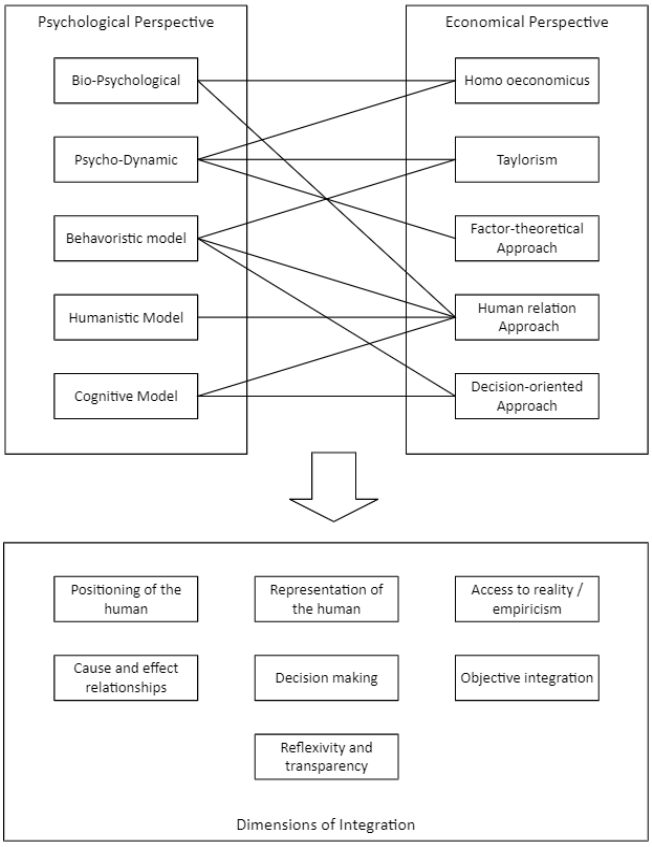

Fig. 1: Integration-Model

For the integration of the human being into a CPPS or for an anthropocentric approach, the following different levels can be derived:

- Positioning of the human being
- Representation of the human being
- Access to reality/ data basis
- Contexts of action
- Decision making
- Objective integration
- Reflexivity and transparency

3.1 Positioning

Positioning defines whether or not humans exist as an entity in the CPPS. The positioning dimension determines how people are taken into account conceptually. Approaches with a purely technical focus either do not depict people at all or depict them as a resource with the same structure. The resource-oriented mapping may refer to a group of people or to the individual himself. In pure technology-centric approaches, humans are either not represented at all or represented as a structurally identical technical element, something like a resource. In human-centric approaches, humans have an explicit position in the CPPS and are a system component.

3.2 Representation of the human being

An essential characteristic of human integration in CPPS is the kind of the human’s representation in the system. One

possible way of involvement is to select one or very few limited role models. For example, one or a few role models provide a uniform holistic representation. Thus, all individuals are assigned to one role, and further integration is then done via this role. This generic approach has the advantage of reducing complexity through standardization. In contrast to this is the representation of the human being as an individual instantiation. Especially in humanistic approaches, a reduction to an abstract uniform representation is not permissible since the explicit reference to the individual is established here.

3.3 Access to reality/ data basis

Another important aspect is the underlying empirical data that grounds reality creation. Capturing reality can refer to the individual, a group, or a specific role. Furthermore, generalized approaches are possible, which support a unified view. For example, in the case of selection decisions in the CPPS, the utility function can be considered the same for all employees or just individually. Should the conception be based on the individual, then a distinction can be made between static and dynamic data access or the reality construction derived from it. With static data, (relatively) time-stable information such as character, skills, or preferences is recorded. On the other hand, dynamic data records information that changes frequently or is unstable over time, such as emotions or moods.

3.4 Contexts of action

In conceptualization, the underlying understanding of the interrelationships of action and effect is crucial. Assuming a fully deterministic system context, a complete evaluation of the interrelationships of action and effect in terms of their impacts is possible. On the other hand, assuming a not fully deterministic approach, the interactions of action and effect can only be derived conditionally or even probabilistically. The assumption has particular implications for the degree of automation in principle, especially in the case of task-specific substitution approaches.

3.5 Decision making

According to the definition of the cause-effect relationships and the design of the reality construction, different models for decision-making may result. Depending on the positioning, decisions can be automated, partially automated, or holistically hybrid. The underlying decision parameters, the objective, and the approach to decision identification are relevant to decision making. Particularly when considering artificial intelligence methods, a precise definition or positioning is necessary. One definition is what should or could be defined as an automated system or process, and another is where humans should or even must be involved. In the case of human involvement, the decisive factor is whether a decision cannot or should not be automated in principle or whether a decision should be made with human involvement for pragmatic reasons.

3.6 Goal integration

The decisive factor for the normative design is the involvement or structural position of the human being. Thereby, differentiating between an involvement on the individual or group level is possible. Especially in approaches that consciously see autonomy as an essential feature, it is crucial to determine what kind of integration should occur and where the boundaries of integration lie. Depending on the positioning, either a discursive process, a determination related to a defined overall goal, or a specific group or person, enables determining the type of integration.

3.7 Reflexivity and transparency

One characteristic of the conception of man within a CPPS is the transparency of the position, referring to the degree or extent of reflexivity. The question is if the participants are aware of whether and how they are represented in the system and whether there is an opportunity for reflection. Reflection is understood in this case as a conscious consideration of the chosen position by means of a discursive process without normative pressure from the group or organization.

4. Conclusion and Outlook

As a result of the change in CPPSs toward human-centered systems, the human being as a relevant actor is increasingly becoming the focus of consideration. The previously underlying conception of man, primarily implicit in the conceptions, is now coming more and more into focus due to the paradigm shift. Especially regarding the task of explanation and the task of design, they become essential because, without the reference, neither an explanation nor a design can be realized in a well-founded and transparently comprehensible way. In the present approach, categories are derived based on the psychological and economical conceptions of man, which are descriptively necessary for the integration into the CPPS. A uniform solution for positioning cannot be made because the different premises of the actors do not allow this. However, through the expression of the categories, the conception of man can be explicitly defined and thus be used as a basis for the design task. The existing category system will be incorporated into a CPPS and thus become available as an active system element in the next step. This will enable an empirical evaluation and further development of the existing CPPS into actual human-centered systems that meet the new requirements better.

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