



HAL
open science

Exploring the notion of situation for responsive manufacturing systems specification issues

Frédérique Mayer

► **To cite this version:**

Frédérique Mayer. Exploring the notion of situation for responsive manufacturing systems specification issues. 16th IFAC INCOM, Jun 2018, Bergamo, Italy. hal-01841822

HAL Id: hal-01841822

<https://hal.univ-lorraine.fr/hal-01841822>

Submitted on 9 Oct 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Exploring the notion of situation for responsive manufacturing systems specification issues

Frédérique Mayer

Université de Lorraine, ERPI, EA 3767, Nancy, F-54000, France

frederique.mayer@univ-lorraine.fr

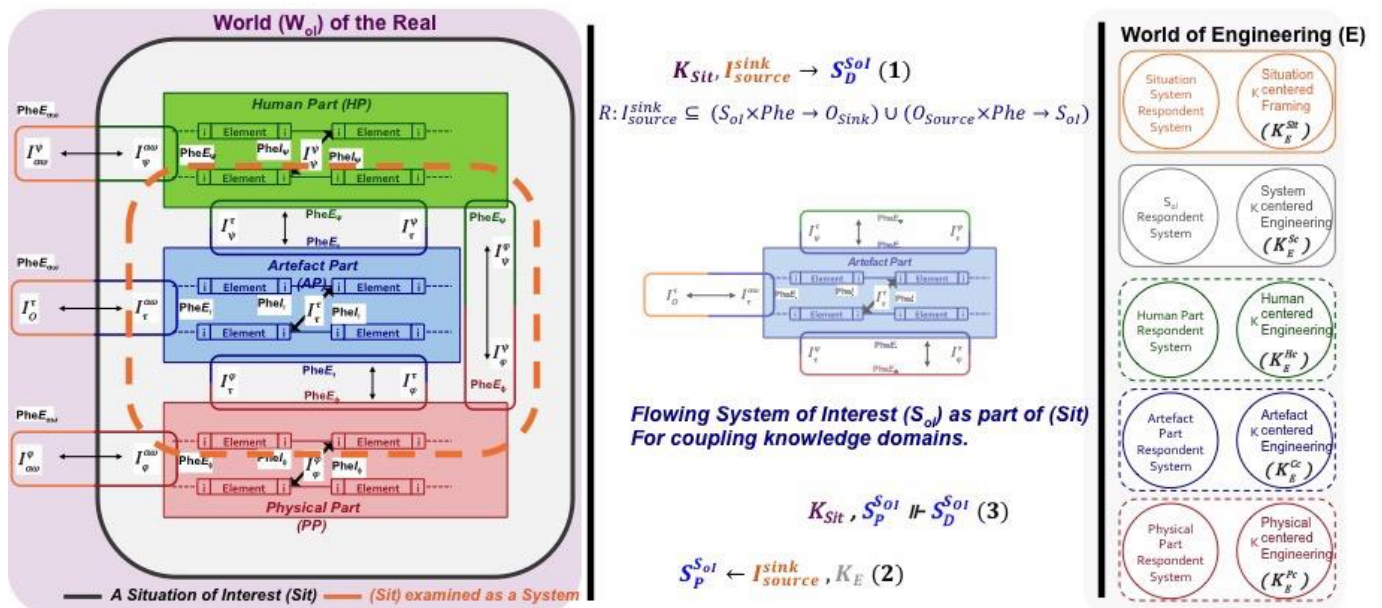
Abstract: Responsiveness in manufacturing is a key challenge for facing open-ended changes more and more enhanced by the increasing development of easy-to-use digital technologies. However, the control of a given situation into wholeness by a respondent system is raising design issues to make cooperating together the many entities of the Human, digital and physical parts interleaved in a related world-of-interest in order to reach and maintain common goals. This paper provides an overview of some relevant works for attaining a situated perspective of the responsiveness of a system to be engineered with simplicity. This property of living beings is more particularly explored for the cognitive orchestration of the interdisciplinary knowledge assets, which are cooperatively involved in a project system in order to frame a given situation examined with a system perspective.

Key Words: situation, system, responsiveness, simplicity, knowledge-enhanced interoperability, systems engineering

1. RESPONSIVENESS TO A SITUATION

Responsiveness is presented by (Monostori et al. 2015) as one of the key challenges that manufacturing systems have to face for coping the complexities of manufacturing environment. In (Vánca et al. 2011), the authors argued that responsiveness is one of the cornerstones of a resilient manufacturing system that (Levalle et Nof 2017) recommend being rather than being robust to deal with unforeseen events perceived “a posteriori” in the real as systemic failures (Boardman et Sauser 2013).

Examining the circumstances under which manufacturing systems must be responsive leads to an interest in situations in which humans are involved and for which they required services to them. Thus, our main hypothesis is that situations shape the responsiveness of manufacturing systems and their study involves control knowledge assets beyond traditional ones to a priori design them for the unexpected (Valckenaers et Van Brussel 2015) (Noran, Romero, et Zdravkovic 2014) as well for the resilience in order to face these complexities revealed too often a posteriori.



2. SITUATION FRAMING KNOWLEDGE

The aim of this section is to give an overview of the notion of situation available in the scientific literature in order to provide key knowledge elements for responsiveness issues.

2.1. Scientific context of the notion of situation

The awareness of situation has been brought into the foreground when system design paradigms had to shift from artifact-centered to user-centered (Boy 2005) and now to cognitive frameworks (Rolls 2013) in order to better understanding a priori situations in which Humans are involved. For example, situation is a central unit of analysis for information science in order to better understanding the behavior of humans when seeking information (Cool 2001). Situation awareness (Endsley 2016) is an important construct for practitioners in human factors in order to be aware of how a human involves in his environment (Millot 2015). In the manufacturing domain, the awareness of situation is rather considered for safety reasons as a requirement for automating system (Cormier, Phan, et Ferrie 2015).

2.2. Designating a situation

The notion of situation refers to a timely combination of objects whose states are becoming available, in particular circumstances, for humans. Thus, the meaning is that a situation commits in its totality a set of objects for achieving some goals as required by humans. Situations are of different kinds as argued by (Boy 2015). Thus, if states of objects are available but not yet perceptible by human, the situation is said to be available for that humans. When humans perceive these states, the situation is called a perceived situation. A perceived situation is named desired if it is from goal-driven behavior nature or it is named expected if it is from an event-driven behavior nature. Situation awareness (Endsley 2016) is the capability of a human to perceive objects in his environment, to understand the situation and to project future status of these objects before to make any decision that occurs, according to (Boyd 1995), in a cycle of observe-orient-decide-act (OODA) loop. However, designating situations of interest may early impact the specification of stakeholder's requirements to which manufacturing systems will have to respond. For example, let's consider a Human-Artifact parts (I_{AP}^{HP}) interaction (Figure 1). Thus, telling "a field operator requests the service of a logic controller to perform his tasks every day in a workshop" is a working situation that commits in its totality a human part interacting with an artifact part and that reflects a user intention for acting. Telling "The controller logic should be automatically synthesized from a plant model" is a control situation underlying a designer intention to improve the service. Right coupling both makes the targeted situation operational.

2.3. Defining a situation

Among many others definitions, that of (Zask 2008) contains relevant knowledge elements for responsiveness issues *A situation is defined as being all moments during which an interaction between a living being and an environment takes place in the form of a reciprocal action :*

- Humans are constitutive of situations as they construct them by intention for serving some goals (Berthoz et Petit 2006).
- Situations are designated as timely moment during which interactions between at minimum a human (e.g. a control operator) and at minimum an object (natural or artefactual) will be in the form of a reciprocal action.
- A situation presents a dynamical character. It implies to consider constitutive objects of a situation but also the set of interactions between these objects. Interactions are the popular systemic word for expressing that phenomena interact between objects source and objects sink according to a logic of effects (Ducrocq 1996). Typically, phenomenon designates events that result from reciprocal actions and that are perceptible by a sentient being (Ken Wilber in (Mella 2009)), meaning that phenomena are implicitly required by Humans as setting of the dynamics of the situation.
- According to (Hall et Rapanotti 2005), a phenomenon belongs to two different domains. In the causal domain, phenomena are perceived as deterministic and predictive, and can be controlled in an ordered manner by humans. For control purposes, these phenomena must be "visible" by all constitutive elements of the situation of interest. In the biddable domain, phenomena are perceived as unpredictable, pointing out the relationships between a situation and its environment. Here, phenomena are totally hidden or eventually perceived but not understood, but, in any case, having an influence on a situation. For responsiveness purposes, these external phenomena to the situation are those linked to change and uncertainties.
- A situation is said to be operational as long as it meets the expectations of its stakeholders such as those who are constitutive of it, those who exploit its results, those who maintain it, those who diagnose it. When a situation no longer meets their expectations, it is considered as problematic in general (Schutz et Luckmann 1973), incidental - when the causes of the degradation are identified thanks to specific procedures that aim to restore it - or disrupted - because associated to unexpected events not identified - (Journé et Raulet-Croset 2008). In any case of problem or opportunity for improving the normal functioning of a situation, a situation gets its stakeholders involved to define and to interpret what has happened and to envisage the actions to be taken to restore its normal functioning.

For illustration, defining the above-told working situation consists in (Figure 1, left):

- Making visible the constitutive parts of a situation of interest such as a field operator (HP), a logic controller (AP) and a controlled equipment as the physical part (PP) processing a flowing valuable object for which is required a situation of interest that commits in its totality HP, AP and PP ,
- Making appearance of the phenomena of interest resulting from cause-effect relationships between the related parts such as a sound sending by the flowing object and sensing by a field operator for physical-physiological phenomena ($PheE_{\Phi}, PheE_{\Psi}$)

related dynamics of a situation. A special attention must be paid on the modeling holistic completeness, which can be systematically guided by the architectural “conceptagon” framework ordering twenty-one system thinking concepts into seven triads (Boardman et Sauser 2013). Even if currently used for a system-of-interest definition, this pragmatic framework may be of-interest to check the system completeness of a situation. For example, the triad {Interior, Boundary, Exterior} enables to frame the boundaries surrounding a situation system. For illustration, applying this heuristic to the previous manufacturing working situation enables to frame the workshop as a situation system surrounded by a plant ... which can be part of a wider system of systems requiring to pay attention on triad {emergence, holarchy (instead of hierarchy), openness}. For responsiveness issues, the triad {Inputs, Transformations, Outputs} exhibits the role of the flowing object as holon-product giving being to the situation system as addressed by (Morel et al. 2007)(McFarlane 2003).

Nevertheless, the problem-oriented and solution-oriented specifying nature of the coupling relationship must be more formally addressed to completely align the interdisciplinary knowledge reflecting the situation system under designation with disciplinary knowledge, such as control.

3.2. Problem frames approach

In (Jackson 1997), the author evoked the notion of situation within the problem frames approach relating to systemic issues in software engineering and in a large extent to cooperative control and systems engineering. In this approach, a situation is related to our reality, our world of interest (W_{ol}), as the source of requirements (R) to express conditions over phenomena that must be controlled by a related artifact (AP) under specification. These requirements of interest (equation 1) contain optative properties to express what the artifact must do under the assertion that other indicative properties are controlled in some extend by the situation itself or which must be contained in case of biddable effects (Hall et Rapanotti 2005). Proof has been given (Gunter et al. 2000) that the requirements specification result (S) can be formally validated only when the resulting artifact is testing with relevant knowledge (K) on real conditions with respect to shared measurable properties (equation 2).

$$W_{ol}, S \vdash R \text{ (Equation 1)}; K, S \vdash R \text{ (Equation 2)}$$

It should be note that these works point out that the requirements contain an informal designation part for capturing fuzzy and/or unpredicted phenomena of (W_{ol}) before to be formally grounded for a specification.

Later, (Jin 2006) underlines the interest of system thinking paradigm in order to well state problems to be solved in (W_{ol}) by well understanding (K) to elicit (R) for problem-oriented descriptive specification (S_D) according to:

$$K, R \rightarrow S_D \text{ (Equation 3)}$$

Here, (R) stipulate how a required artifact (AP) must stand in (W_{ol}) by designating phenomena ($PheE_T$) it must exhibit

for establishing interactions (I_{source}^{sink}) with source and sink objects (O_{Source}, O_{Sink}) of its environment in order to enact a given situation within (W_{ol}). Thus, (R) specifies interactions requirements according to (Equation 3’):

$$I_{source}^{sink} \subseteq (AP \times PheE_T \rightarrow O_{Sink}) \cup (O_{Source} \times PheE_T \rightarrow A)$$

Thus, (S_D) in an open-ended change situation is dependent of relevant knowledge on both what can close the situation for control issues and on what can contain the situation for responsiveness (among other) issues. By extent (Morel et al. 2014), for systems engineering domain, a solution-oriented prescriptive specification (S_P) is dependent in response of relevant interdisciplinary engineering knowledge (K_E) according to:

$$S_P \leftarrow R, K_E \text{ (Equation 5)}$$

It must be noted that, in (Hall et Rapanotti 2005), the authors assert that the prescription in (W_{ol}) must express indicative properties related to human- (AP) interactions specification (UI) and the knowledge and the behavior specification (I) of an human as a constitutive element of the given situation, together with (S_D) according to:

$$W_{ol}, S_D, I, UI \vdash R \text{ (Equation 5’)}$$

The related specification processes (Figure 1) results from refinement iterations (Bouffaron 2016) all along a system project life cycle between interdisciplinary knowledge that are respectively source of problem-oriented verified specification (Equations 3 and 3’) and sink of solution-oriented verified specification (Equations 5 and 5’) until a contractual validation (Equation 2).

3.3. Synthesis

Elements of this framework of framing a situation system are constitutive of our generalized specification process orchestrating by detour into togetherness, interdisciplinary knowledge required by respondent systems to problems observed in the real. Thus, the knowledge (K_{Sit}) of what any stakeholder (HP) desires to be true revealed by interactions (I_{source}^{sink}) in a situation (Sit) in a related world-of-interest (W_{ol}) implies a descriptive specification (S_D^{Sol}) revealing optative properties of what (a system of interest S_{ol}) is required (1). In turn, the requested engineering domain knowledge (K_E) prescribes a prescriptive specification (S_P^{Sol}) enacting not only optative properties to be controlled but also some other indicative one which must at least be contained in the required situation system (2).

$$\begin{aligned} 1) & K_{Sit}, I_{source}^{sink} \rightarrow S_D^{Sol} \\ 3) & K_{Sit}, S_P^{Sol} \not\vdash S_D^{Sol} \\ 2) & S_P^{Sol} \leftarrow I_{source}^{sink}, K_{Sit} \end{aligned}$$

Note that a proof (3) of the related validation $\{\vdash\}$ and verification $\{\leftarrow\}$ requirements specification process (Fanmuy, Fraga, et Llorens 2012) must be performed, for

example by execution of the overall interdisciplinary models together relatively to TRL (Technology Readiness Level) levels. This initial requirement specification process is refined continuously between all involved knowledge assets.

4. SITUATION SYSTEM INTERDISCIPLINARY CO-SPECIFICATION

The cognitive role of a system architect to manage the overall actors involved to engineer a respondent system is all the more recurring to orchestration issues that new digital technologies are becoming available to conduct the interdisciplinary exchanges of documents as well of models.

4.1. Knowledge-based orchestration

This orchestration metaphor (Dillenbourg 2011) must not mask that a specification partition has not been composed a priori but has collectively to be so a posteriori all along a system project life cycle. Thus, the main difficulty is to translate any requesting human intention into a model of understanding for another required domain of knowledge. It must be noted that the responding knowledge for any specifications may be very different from the perceived one. To cope with possible interoperability concerns and depending of the steps of a project, natural binary language² or system-oriented language³ or domain-oriented language (Retho 2015) may be used. To contain another difficulty to make interoperable a variety of knowledge and know-how, the overall SE orchestration performs currently standardized engineering processes in a recursive, iterative and concurrent manner according to project templates, with the possible drawback to limit human capabilities (Nugent et Collar 2015) for creating solutions by detour as previously addressed for controlling a situation. Also, to cope with this possible technics interoperability concerns, we argue in (Bouffaron et al. 2014) that any engineering actors must be orchestrated with their own means around a common bus of executable co-specification enhanced by the available technologies to wholly digitalize model based systems engineering process.

4.2. Heuristics-based orchestration

We illustrate the heuristic nature of the overall specification situation system process by a particular partition relating to a cyber physical-like situation (Figure 1).

Differently from traditional automation system engineering, first coupling interactions may be between a requesting (K_{Sit}) and a possible responding knowledge domain in framing a situation (K_E^{Sit}) perceived as able to satisfy into wholeness the descriptive requirements specification (S_D^{Sol}) of some problems related to some facts (I_{Wol}^{Sit}) affording some lack of order in a given situation. It must be noted that the intermediate validation ($K_{Wol}, S_P^{Sol} \models S_D^{Sol}$) is not yet that formal addressed by the entailment relationships of the problem frame approach.

This early prescriptive requirement specification may be translated to a Systems centered Engineering Knowledge domain (K_E^{Sc}) in the form of SySML requirements and use case diagrams.

According to an acquired knowledge (McFarlane 2003) (Morel et al. 2003), the respondent (K_E^{Sc}) points out the interest of an architectural pattern making of the active flowing object the “controller” of the overall (S_P^{Sol}) by wearable technologies for IoT-based responsiveness issues.

(K_E^{Sc}) may orchestrate some intermediate requirements specifications with SySML activity and sequence diagrams for mission issues to Artefact centered Engineering Knowledge domain (K_E^{Cc}) for automatic control synthesis or SySML state chart diagrams in return, depending of verification or execution issues (Zaytoon et Riera 2017).

To reassess some possible uncertainties related to human to machine interactions beyond machine to machine digital interactions, (K_E^{Sc}) must pay a special attention on the contain of (I_{AP}^{HP}) in order to exhibit the interleaved phenomena as the junction of good/service/affordance for properties measurability purposes. (K_E^{Sc}) may orchestrate the requesting descriptive specification with the Human centered Engineering Knowledge domain (K_E^{Hc}) by instantiating (equation 3') in order to be aware of the phenomena to be checked in (I_{AP}^{HP}). We have previously addressed in (Bouffaron et al. 2014) that such physic-physiological interaction might be specified with SySML internal block diagrams before to be executed for whole Sol specification issues.

To reassess the Sol behavior under specification with regards to possible open-ended changes with the world of interest, (K_E^{Sc}) explores some unordered facts, which may occur beyond the system boundary by orchestrating specification relationships with the Situation centered Engineering Knowledge domain (K_E^{Sit}). In turn, (K_E^{Sit}) frames the related situation system in order to sketch the trend of reinforcing loops with regards to the balancing loops of the previous automata for resilient issues. And so on ... Note that any knowledge may directly orchestrate some intermediate requirements specifications with other ones in order to decrease the cognitive load of the system architect.

4.3. Technology-enhanced orchestration

The increased maturity of collaborative technologies enhances new model based systems engineering practices enabling the orchestration of the specification partition around a unique and extensible digital platform. For that purposes, for example, interdisciplinary knowledge and their related activities reflecting the set of logical relationships of the co-specification heuristics can be implemented by the mean of cognitive solutions available in the form of widgets (forum, blogs, files, libraries, ...) available in digital workplace⁴. In order to make better the “right job right” (Fanmuy, Fraga, et Llorens 2012), common environments of co-simulation are becoming available to wholly digitalize the

² ormfoundation.org

³ sysml.org

⁴ IBM connections, IBM.org

interdisciplinary systems engineering, from ideation to integration and validation through the architectural design of a solution and its components. The main advantage is to facilitate the exchange and the execution as a whole of the set of models built in their own domain of knowledge⁵.

Standardized openness interfaces⁶ are used for computer simulations to develop complex situation system models. Such executable co-specification environment has been put into practice in (Bouffaron et al. 2014) (Bouffaron 2016) with a set of execution models closed to the elements depicted in (figure 1, left).

4.4. Synthesis

A main advantage of this technology-enhanced orchestration is to cope with major knowledge interoperability issues by enhancing individual knowledge. The essential of the collective knowledge between the many involved actors can be shared in a common language, such as the de-facto standardized SysML. Openness of domain-oriented environments, such those related to systems dynamics modeling, is required for whole system executable situation-system modeling.

5. CONCLUSION

We argue in this paper that the current meaning of a requirement specification is not sufficient to investigate what may be “hidden” or may happen relating to phenomena as source-sink of interactions to be at least contained. The journey in the situation system landscape is orchestrated by detour between the tangible world of reality knowledge and the intangible world of interdisciplinary representations knowledge and know-how as addressed by the scenario in section 4.2. Note for illustration that the orchestration metaphor is more related to a “jazz band” because of the partition writing on the fly. Situation and system are conceptually associated in real life for technology-enhanced opportunity as well as for emerging systemic failures. The interleaving of the Human, digital and physical worlds envisioned by the IoT and CPS concepts required to reassess a priori some uncertainty of a targeted situation system. Despite that remains under debate in many scientific communities, the understanding of the notion of situation is not sufficiently a knowledge asset to be acquired for acting in the early steps of a project system. In view of that, a possible explanation is in the informal aspect of the design process to look outwards as well as in the lack of systemic attitudes. Thus, we have proposed a mental scheme based on a knowledge-based framework to be used individually as a cognitive heuristics in an interdisciplinary collaborative technology-enhanced environment. So, as engineers are first students, this overall vision is put into learning practices for some time now (Morel et al. 2014). For example, the targeted situation may be that of teaching responsiveness issues. Conversely, this vision is also put into practice with a research group working at distance on the essential artifacts of systemic and its relationship with cybernetics. For

example, the focus may be on the matter-energy related to flowing objects in order to maintain the togetherness between the interacting physical, artefactual and human parts of an existing large-scale situation-system having exhibited systemic failures. Even if others applications domains are explored, such IoT-based catering, we are still in an un-mature phase of this research and education project requiring to bridge informal and formal representations, included for situation-system specification validation by co-execution of models.

6. REFERENCES

- Allegro, B. D., et G. R. Smith. 2016. *Exploring the Branches of the Systems Landscape*. Les Éditions Allegro Brigitte D.
- Berthoz, Alain. 2009. *Simplexité (La)*. Odile Jacob.
- Berthoz, Alain, et Jean-Luc Petit. 2006. *Phénoménologie et physiologie de l'action*. Odile Jacob.
- BKCASE Editorial Board. 2017. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*. The Trustees of the Stevens Institute of Technology. Vol. 1.8. R.D. Adcock (EIC). Hoboken, NJ, USA. <http://www.sebokwiki.org>.
- Boardman, John, et Brian Sauser. 2013. *Systemic Thinking: Building Maps for Worlds of Systems*. Wiley. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Bouffaron, Fabien. 2016. « Co-spécification système exécutable basée sur des modèles-Application à la conduite interactive d'un procédé industriel critique ». Nancy, France: Université de Lorraine.
- Bouffaron, Fabien, Jean-Marc Dupont, Frédérique Mayer, et Gérard Morel. 2014. « Integrative construct for model-based human-system integration: a case study ». In *19th IFAC World Congress, IFAC'14*. Cape Town, South Africa.
- Boy, Guy André. 2005. « Human-centered design: The AUTOS pyramid ». *EURISCO International Newsletter*, 2005.
- Boy, Guy André. 2015. « On the complexity of situation awareness ». In *Proceedings 19th Triennial Congress of the IEA*, 9:14.
- Boyd, John. 1995. « OODA loop ». *Center for Defense Information, Tech. Rep.*
- Cool, Colleen. 2001. « The concept of situation in information science. » *Annual Review of Information Science and Technology (ARIST)* 35: 5- 42.
- Cormier, Olivier St-Martin, Andrew Phan, et Frank P. Ferrie. 2015. « Situational Awareness for Manufacturing Applications ». In *Computer and Robot Vision (CRV), 2015 12th Conference on*, 320- 27. IEEE.
- Dillenbourg, Pierre. 2011. « Trends in orchestration. Second research & technology scouting report ».
- Ducrocq, Albert. 1996. « concept de sémantiel et phénomène d'émergence ». In . France.
- Endsley, Mica R. 2016. *Designing for situation awareness: An approach to user-centered design*. CRC press.
- Fanmuy, Gauthier, Anabel Fraga, et Juan Llorens. 2012. « Requirements verification in industry ». In *Complex systems design and management conference*. Paris, France.

⁵ 3DS.com© Dassault Systèmes

⁶ www.fmi-standards.org

- Forrester, Jay W. 1961. « Industry dynamics ». *Massachusetts, Cambridge*.
- Galara, Dominique. 2006. « Roadmap to master the complexity of process operation to help operators improve safety, productivity and reduce environmental impact ». *Annual Reviews in Control* 30 (2): 215- 22.
- Gunter, Carl A., Elsa L. Gunter, Michael Jackson, et Pamela Zave. 2000. « A reference model for requirements and specifications ». *IEEE Software* 17 (3): 37- 43.
- Hall, Jon G., et Lucia Rapanotti. 2005. « Problem frames for socio-technical systems ». In *Requirements Engineering for Socio-Technical Systems*, 318- 39.
- Jackson, Michael. 1997. « The meaning of requirements ». *Annals of Software Engineering* 3 (1): 5- 21.
- Jin, Zhi. 2006. « Revisiting the meaning of requirements ». *Journal of computer science and technology* 21 (1): 32- 40.
- Journé, Benoît, et Nathalie Raulet-Croset. 2008. « Le concept de situation : contribution à l'analyse de l'activité managériale en contextes d'ambiguïté et d'incertitude ». *M@n@gement* 11: 27- 55.
- Koestler, Arthur. 1978. *Janus: A Summing Up*. Calmann-Lévy.
- Kuras, M. L. 2006. « A Multi Scale Definition of a System ». TECHNICAL REPORT MTR 06B0000060. MITRE.
- Lawson, Harold W. 2010. *A journey through the systems landscape*. College Publications.
- Levalle, Rodrigo Reyes, et Shimon Y. Nof. 2017. « Resilience in supply networks: Definition, dimensions, and levels ». *Annual Reviews in Control*.
- McFarlane, Duncan. 2003. « Product identity and its impact on discrete event observability ». In *European Control Conference (ECC), 2003*, 121- 32. IEEE.
- Mella, Piero. 2009. « The Holonic Revolution ». *Holons, Holarchies and Holonic*.
- Millot, Patrick. 2015. « Situation Awareness: Is the glass half empty or half full? » *Cognition, Technology & Work* 17 (2): 169- 77.
- Monostori, László, Paul Valckenaers, Alexandre Dolgui, Hervé Panetto, Mietek Brdys, et Balázs Csanád Csáji. 2015. « Cooperative control in production and logistics ». *Annual Reviews in Control* 39: 12- 29.
- Morel, Gérard, Fabien Bouffaron, Olivier Nartz, Frédérique Mayer, Pascale Marangé, Eric Levrat, et Hervé Panetto. 2014. « Towards an iterative learning of systems engineering based on models. » In *10ème Conférence Francophone de Modélisation, Optimisation et Simulation, MOSIM'14*. Nancy, France.
- Morel, Gérard, Hervé Panetto, Marek Zaremba, et Frédérique Mayer. 2003. « Manufacturing Enterprise Control and Management System Engineering: paradigms and open issues ». *Annual Reviews in Control* 27 (2): 199- 209. <https://doi.org/10.1016/j.arcontrol.2003.09.003>.
- Morel, Gérard, Paul Valckenaers, Jean-Marc Faure, Carlos E. Pereira, et Christian Diedrich. 2007. « Manufacturing plant control challenges and issues ». *Control Engineering Practice* 15 (11): 1321- 31. <https://doi.org/10.1016/j.conengprac.2007.05.005>.
- Noran, Ovidiu, David Romero, et Milan Zdravkovic. 2014. « The Sensing Enterprise: Towards the Next Generation Dynamic Virtual Organisations ». In *Working Conference on Virtual Enterprises*, 209- 16. Springer.
- Nugent, Paul, et Emilio Collar. 2015. « The Hidden Perils of Addressing Complexity with Formal Process-A Philosophical and Empirical Analysis ». In *Complex systems design and management conference*, 119- 31.
- Ponto, C. F., et N. P. Linder. 2011. *Sustainable Tomorrow: A Teachers' Guidebook for Applying Systems Thinking to Environmental Education Curricula*. Association of Fish & Wildlife Agencies.
- Pouvreau, David. 2013. « Une histoire de la " systémologie générale" de Ludwig von Bertalanffy-Généalogie, genèse, actualisation et postérité d'un projet herméneutique ». Ecole des Hautes Etudes en Sciences Sociales (EHESS).
- Retho, Fabien. 2015. « Méthodologie collaborative d'aide à la construction de produits virtuels pour la conception d'aéronefs à propulsion électrique. » Supélec.
- Rolls, Edmund T. 2013. « What Are Emotional States, and Why Do We Have Them? » *Emotion review* 5 (3): 241 – 247.
- Schutz, Alfred, et Thomas Luckmann. 1973. *The structures of the life-world*. Vol. 1. Northwestern University Press.
- Valckenaers, Paul, et Hendrik Van Brussel. 2015. *Design for the Unexpected: From Holonic Manufacturing Systems Towards a Humane Mechatronics Society*. Butterworth-Heinemann.
- Váncza, József, László Monostori, Diederick Lutters, S. R. Kumara, M. Tseng, Paul Valckenaers, et Hendrik Van Brussel. 2011. « Cooperative and responsive manufacturing enterprises ». *CIRP Annals-Manufacturing Technology* 60 (2): 797- 820.
- Wiener, Norbert. 1948. « Cybernetics ». *Scientific American* 179 (5): 14- 19.
- Zask, Joëlle. 2008. « Situation ou contexte? » *Revue internationale de philosophie*, n° 3: 313- 28.
- Zaytoon, J., et B. Riera. 2017. « Synthesis and implementation of logic controllers—A review ». *Annual Reviews in Control*.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the valuable knowledge insights provided by Jean-Marc Dupont, Jean-Pierre Hennebicq and Gérard Morel for framing this conceptual scheme by acting as members of our collaborative working team on essential systems knowledge artifacts.