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L'OPTIMISATION ET LA PRODUCTION

The AMaK project
Additive Manufacturing Knowledge

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BACKGROUND

Additive Manufacturing (AM) is changing the engineering design and manufacturing practices since a couple of decades1. This technology enables indeed to build parts with complex shapes and geometrical features by adding where it is required successive layers of material, whether in liquid, solid, or powder form. Beyond this opportunity, AM technologies also come with their own limitations, and taking the best of it rely on the skills and knowledge of a few number of people. AM experts use various strategies to design or manufacture parts properly but their knowledge is neither well formalized nor shared. There is here an opportunity to capture and formalize their knowledge, and to propose methods to structure information about this activity.

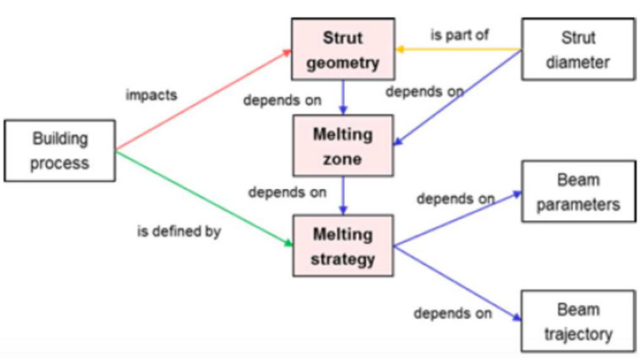
OBJECTIVES

The aim of AMaK project is to propose and test methods and tools to support the elicitation and the structuration of AM knowledge. It is part of our ongoing research work aiming at integrating AM knowledge to CAD/CAM system.

METHOD

Many knowledge elicitation techniques are proposed in the literature. Milton[2] proposes a useful synthesis of the most important ones. The idea of the project was to test the most promising ones for capturing AM expert knowledge, then, to adapt most interesting one to our context, and finally, to use the new method for capturing some additive manufacturing knowledge content. The global research methodology is based on the dialogical model[3]. Practioners (the AM experts) are involved in the research process through the elicitation process and by legitimizing the results. These latter are formalised by the researchers.

RESULTS OF THE AMaK PROJECT



Some limitations in the existing elicitation techniques: Three techniques have been chosen among Milton's list, namely: Unstructured Interview (UI); Semi-Structured Interview (SSI): Limited Information Task (LIT). These techniques Were ested individually with three AM experts. any important concepts for the AM domain were identified from these sessions, resulting in some useful concept maps (example on the left).

1 Mary Kathryn Thompson and others, 'Design for Additive Manufacturing: Trends, Opportunities, Considerations, and Constraints', CIRP Annals - Manufacturing Technology, 65.2 (2016), 737–60.
2 N.R. Milton, Knowledge Acquisition in Practice: A Step-by-Step Guide (London: Springer, 2007).
3 M-J. Avenier and A. Parmentier Cajaiba, 'The Dialogical Model: Developing Academic Knowledge for and from Practice', European Management Review, 9.4 (2012).

G-SCOP
SOME STATISTICS

Staff :

- **62 permanent researchers**
- **16 administrative and technical personel**
- **15 to 20 temporary employees**
- **65 doctoral students**
- **50 trainees per year**

Publications per year :

- **60 articles**
- **70 conferences**

Theses and Accreditations for Research :

- **15 to 20 theses defended per year**

Annual Consolidated Budget:

- **7.2 million euros**
- **An average of 1.8 million euros of contracts per year**

Internal Projects at G-SCOP (2015-2017)

- Budget de 50 000 Euros

Funded Projects :

- An approach for eliciting and capturing Knowledge content related to the practice of additive manufacturing experts (**AMaK**)
- Rigidité de Métriques : isométrie, dimension et le voyageur (**RIME**)
- Optimisation des performances dans la prise en charge à domicile (**OptimADom**)

Publications of the project

- Grandvallet,C., Vignat,F.,Pourroy,F.,Prudhomme,G.,& Béraud,N.(2018). An Approach to Model Additive Manufacturing Process Rules.Int.Journal of Mechanical Engineering and Robotics Research, 7(1), 9–15.
- Grandvallet,C.,Pourroy,F.,Prudhomme,G., & Vignat, F.(2017).From elicitation to structuring of additive anufacturing knowledge In Proceedings of the International Conference on Engineering Design, ICED (Vol. 6).
- Grandvallet,C.,Pourroy, F.,Prudhomme, G., & Vignat,F.(2017).Testing three techniques to elicit additivemanufacturing knowledge.Lecture Notes in Mechanical Engineering. In: Eynard B.et al. (eds) Advances on Mechanics,Design Engineering and Manufacturing. Springer.
- Movahedian,F.,Front,A., Rieu,D.,Farastier,A.,Grandvallet,C., Pourroy,F.,& Prudhomme,G.(2017). A participative method for knowledge elicitation in collaborative innovation projects.IEEE RCICS,Brighton,UK.

RESULTS OF THE AMaK PROJECT

But the main result was the existence of differences and contradictions between experts' statements, leading to a lack of confidence or trust with regard to this elicited knowledge. This observation can be explained by the relatively immature stage of the AM knowledge that makes it difficult for the experts to provide comprehensive or straight answers. This result led us to propose a new collective elicitation approach. A promising collective elicitation approach: Inspired from a previous work[4], our main idea is to rely on a collective debate between several AM experts in order to elicit some pieces of their knowledge. The argumentative nature of a debate is suitable for knowledge elicitation since opinions, propositions and arguments are a direct manifestation of this knowledge.

			Support parameters	
			Position	
			Positioning in relation with the part	Distribution
Product criteria	Part quality (post process)	Surface quality	++ 5	eg: under the part or outside; under a surface to be machined or not
		Geometrical quality	++ 4	
		Dimensional quality	++ 4	+ 3
		Physico-chemical quality	+ 2	+ 1
		Mechanical behaviour	+ 2	+ 1

The debate is initiated with an inluence matrix (see an excerpt below). The matrix crosses the part quality criteria (rows) with AM design or process parameters (columns). The latter are previously identified with any of the individual elicitation techniques. Before the collective session, AM xperts are asked to individually populate each cell f the matrix by answering the following question: "in your opinion, what is the influence of this design/process parameter on this quality criteria?" Four levels of influence are allowed: strong (++), weak (+), no influence (0), and "I don't know" (?). They also have to indicate their degree of conviction, anging from 0 (It's just a feeling) to 5 (I can prove it).

The debate takes place by confronting the individual matrices cell by cell. A facilitator assists parties to have a constructive discussion, focussing the debate on specific issues, and fostering convergence towards shared points of view among the experts. Those discussions are recorded and transcribed for further analysis and exploitation of the debate.

The first analysis that we made on some case studies proved the relevance of the approach for AM knowledge elicitation. Moreover, the participants increased their own knowledge through the confrontation with other experts, and the elicited knowledge is more than a collection of each individual one. In terms of structuration, the elicited knowledge was classified in four categories: definitions, influences, examples, and rules. The latter category includes rules that explain of how things are (namely, state rules), and rules that provide information on how things should be done (namely, action rules). The categories will be useful for urther exploitation of the elicited knowledge.

[4] I. Stenzel and F. Pourroy, 'Integration of Experimental and Computational Analysis in the Product Development and Proposals for the Sharing of Technical Knowledge', International Journal on Interactive Design and Manufacturing, 2.1 (2008), 1–8.