Formulating preliminary design optimization problem of an agrifood process using expert knowledge: Application to milk microfiltration

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FORMULATING PRELIMINARY DESIGN OPTIMIZATION PROBLEM OF AN AGRIFOOD PROCESS USING EXPERT KNOWLEDGE:

Application to milk microfiltration

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CONTEXT

- Skim milk crossflow microfiltration pore diameter 0.1 µm (MF 0.1 µm) is used in dairy industry to separate casein micelles (retentate) from serum proteins (permeate). This fractionation method allows the preservation of « native » properties of dairy proteins and offers many ways of valorization for the two products.
- In the literature, optimization of MF 0.1 µm is only partial and empirical.
- Many links between the process operating variables, product state variables and optimization objectives are not formalized. Knowledge elicitation can be coupled with optimization in order to solve the problem.

Optimisation

- Complexity of the food product itself
- **Lack of knowledge** concerning mechanisms limiting process performances
- Heterogeneity of involved variables (ordinal, cardinal, discrete or continuous variables)

Product

Milk
(Product state variables)

Membrane
(polymeric, ceramic…)

Processing designs
(UTP or without, diafiltration…)

Operating conditions
(Transmembrane pressure, temperature…)

Multiple designs but no existing rules to guide the design of this process.

Characteristics of obtained products (permeate & retentate)
(composition, purity…)

Costs
(Investment, operating cost)

Env. impacts
(water, energy…)

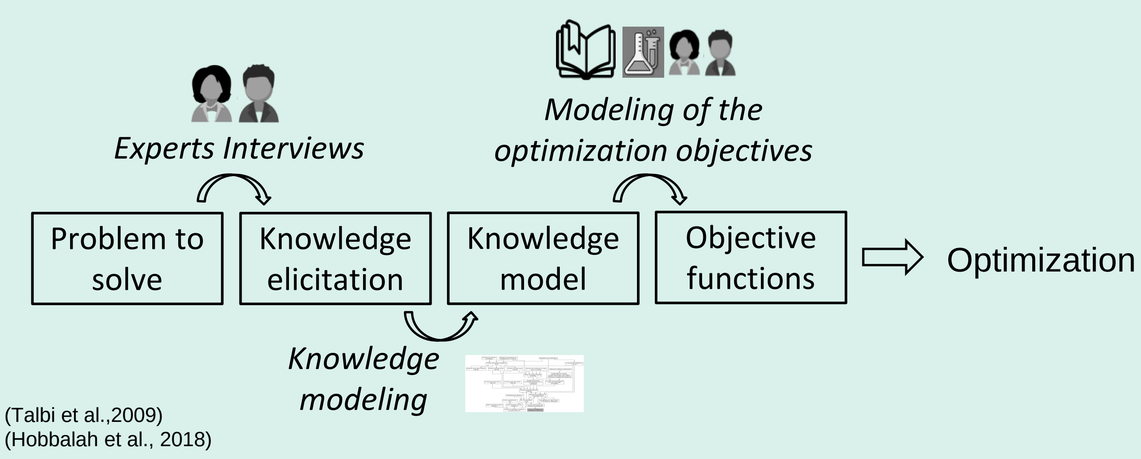
Conflicting objectives

- Mainly based on know-how of operators and available expert knowledge
- Does not take into account links between product, multiple designs and conflicting objectives

METHOD

HOW TO FORMULATE A DESIGN OPTIMIZATION PROBLEM USING EXPERT KNOWLEDGE ELICITATION ?

Example of an agrifood process : skim milk 0.1 µm crossflow microfiltration



(Talbi et al.,2009)
(Hobbalah et al., 2018)

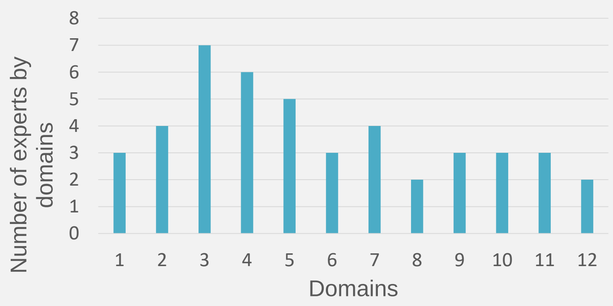
- The problem domain was divided into domains of knowledge : easier way to identify experts and collect knowledge.
- Influence relations between variables and objectives were represented as causal maps.
- After validations by experts, maps of the same knowledge domain were merged, discussed and validated by the group of the domain experts.
- The final map represent the knowledge model to use for formulating the optimization objectives as functions.

RESULTS

Domains of knowledge : MF 0,1 µm

Costs	Permeate fraction	Performance of the filtration
Environmental impacts	Process design	Membrane properties
Diafiltration	Operating variables	Retentate fraction

Experts and domains



Different types of experts :
Industrialists, scientists, equipment manufacturers

Important to setup :

- shared glossary
- generic process scheme

Semi-structure interviews

- 11 experts
- 36 interviews
- 14h30 of audio recording

Intermediate maps (exemple)

Expert 1 Expert 2 Expert 3

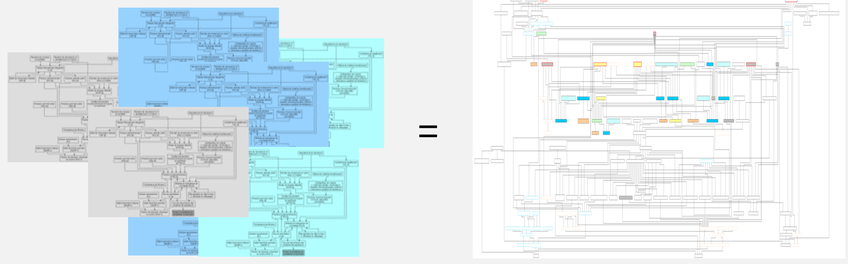
Merged by domain

Individual validations by expert on their maps

Domain 1 Domain 2 Domain 3

Validation of domain map by the domain expert group

Final map 123 variables - 218 influence relations



Discussion and Validation of the whole map by the whole group of experts

CONCLUSION

- The optimization problem studied is complex with conflicting objectives and heterogeneous variables.
- The integration of expert knowledge allows the identification of relevant objectives regarding to industrial issues. The MF process is considered from conception to performances with the identification of lack of knowledge in order to plan new experiments.
- Causal maps allow an easy to understand representation of the influences between the variables and make it possible to establish which variables influence which objectives. Based on these maps, the objective functions will be formalized allowing to perform the optimization.

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