Dongsu JEONG, Dohyun Kim, Yoonho SEO, 2021. Method for process-based modeling of combat scenarios using interaction analysis weapon systems. *Frontiers of Information Technology & Electronic Engineering*, 22(3):415-436. https://doi.org/10.1631/FITEE.1900649

Method for process-based modeling of combat scenarios using interaction analysis weapon systems

Key words: Weapon systems; Process -based modeling (PBM); Combat scenario; Interaction analysis; Metamodel; Petri net

Dongsu JEONG
E-mail: jdsvs2979@korea.ac.kr
ORCID: https://orcid.org/0000-0002-8210-9389

Motivation

- Weapon system development has increasingly become complex and costly. Using modeling and simulation (M&S) technology in the conceptual design stage is effective in reducing the development time and cost of weapons.
- The development of the simulation models for new weapons spends trial-and-error time. It is very complicated to design the weapons and the weapon functions consisting of many other entities. A comprehensive analysis of weapons used in combat is difficult because the interoperability between heterogeneous simulation models is limited.
- To support review of weapon functions including these characteristics, in this research we develop a process-based modeling (PBM) method that models the interactions between weapons in the combat scenario.

Method

- Resource modeling designs weapons in physical and behavioral components using CBD and FBS.
- Functional module modeling generates the functional modules that describe weapon functions using common functional elements derived using ontology technology.
- Process modeling generates combat scenarios of allies and enemies from standard norms and generates combat processes for reviewing weapon functions according to the sequence of weapon utilization.

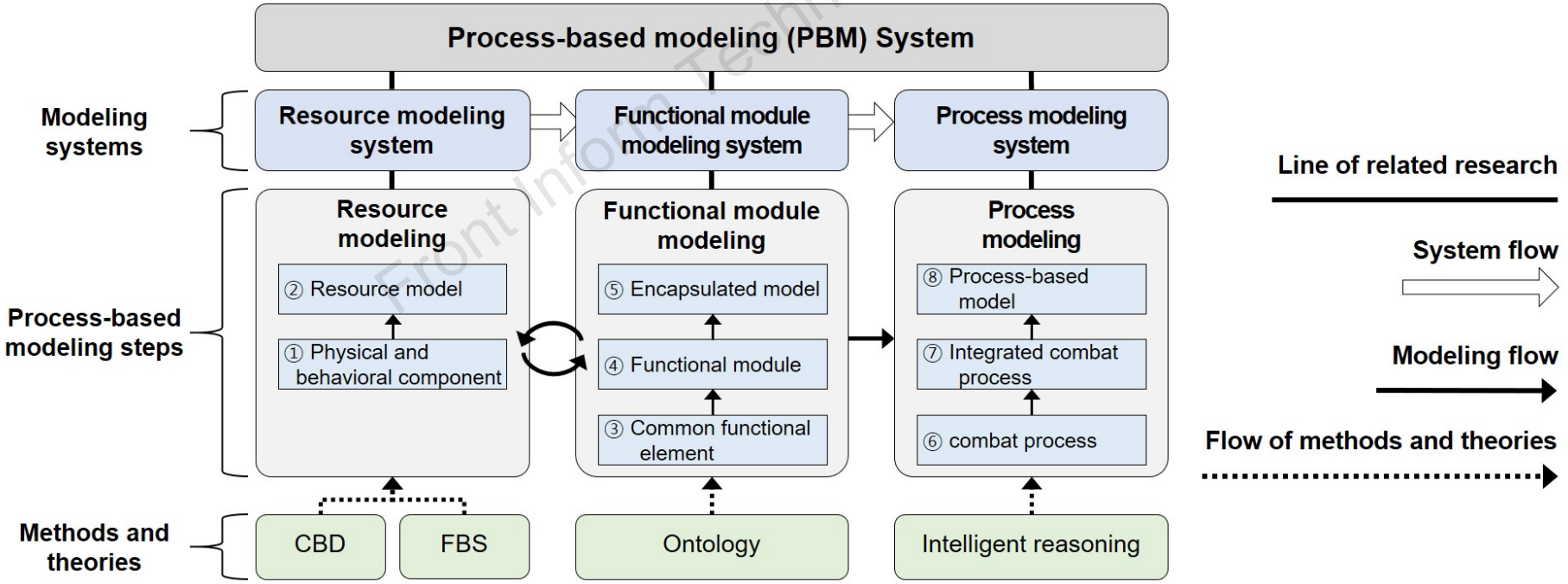

Fig. 1 Overall flow of the process-based modeling method

Method

- Resource modeling is the step in which a combat entity is created, and takes into account the physical and behavioral elements of the weapon information that constitutes the weapon systems.

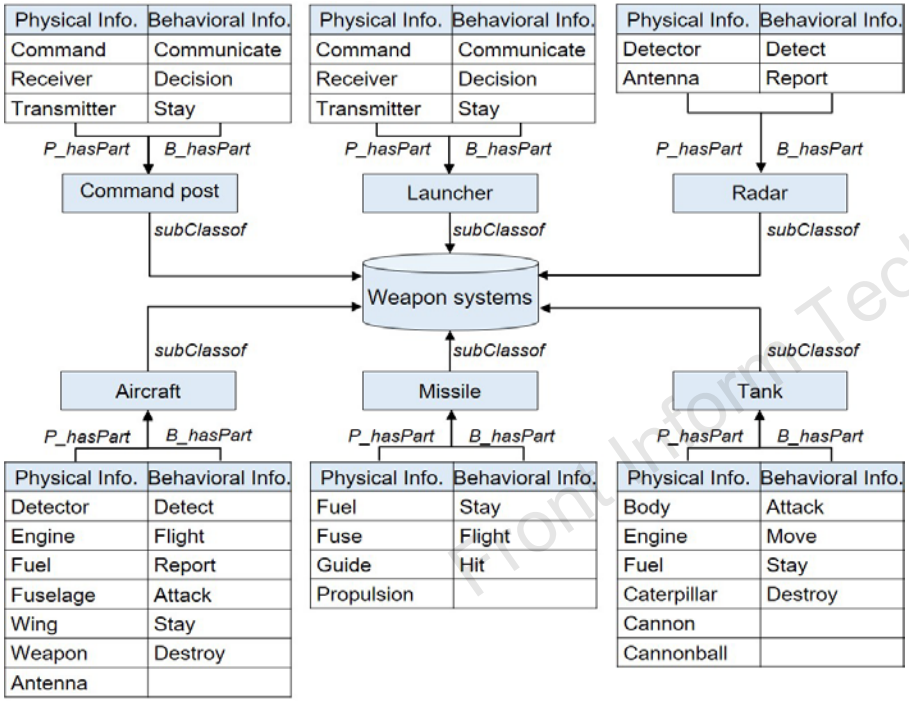

Fig. 2 Physical and behavioral components

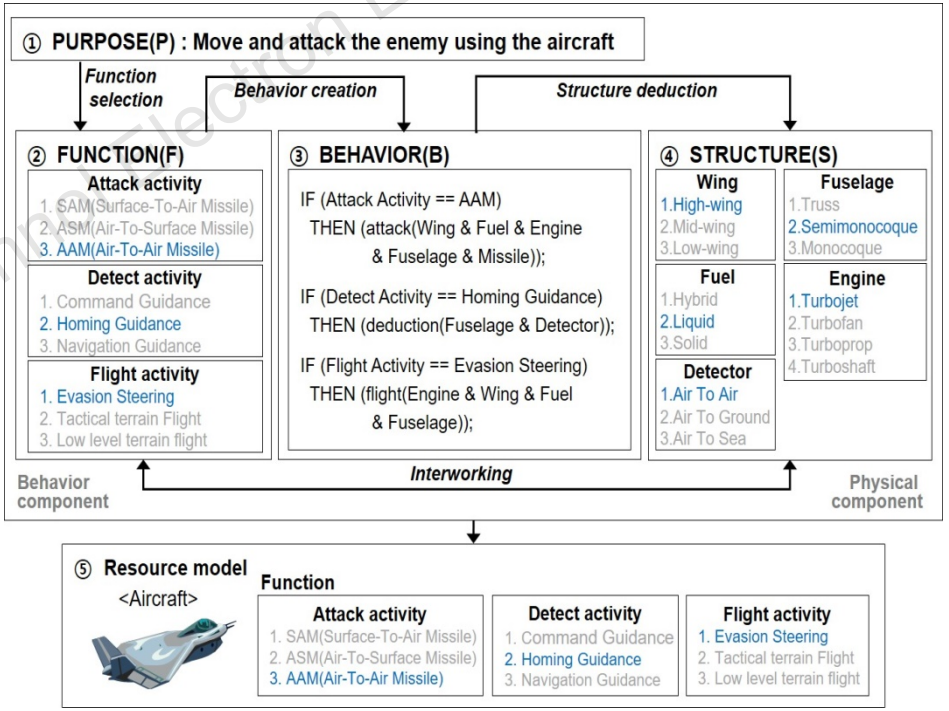

Fig. 3 An aircraft creation example based on FBS

Method

- Functional module modeling is a step in combining the behavioral functions to express the missions of a weapon.
- The behavioral functions represented in this step are elements that various weapons can use in common and that can be structured as one module using ontology technology.

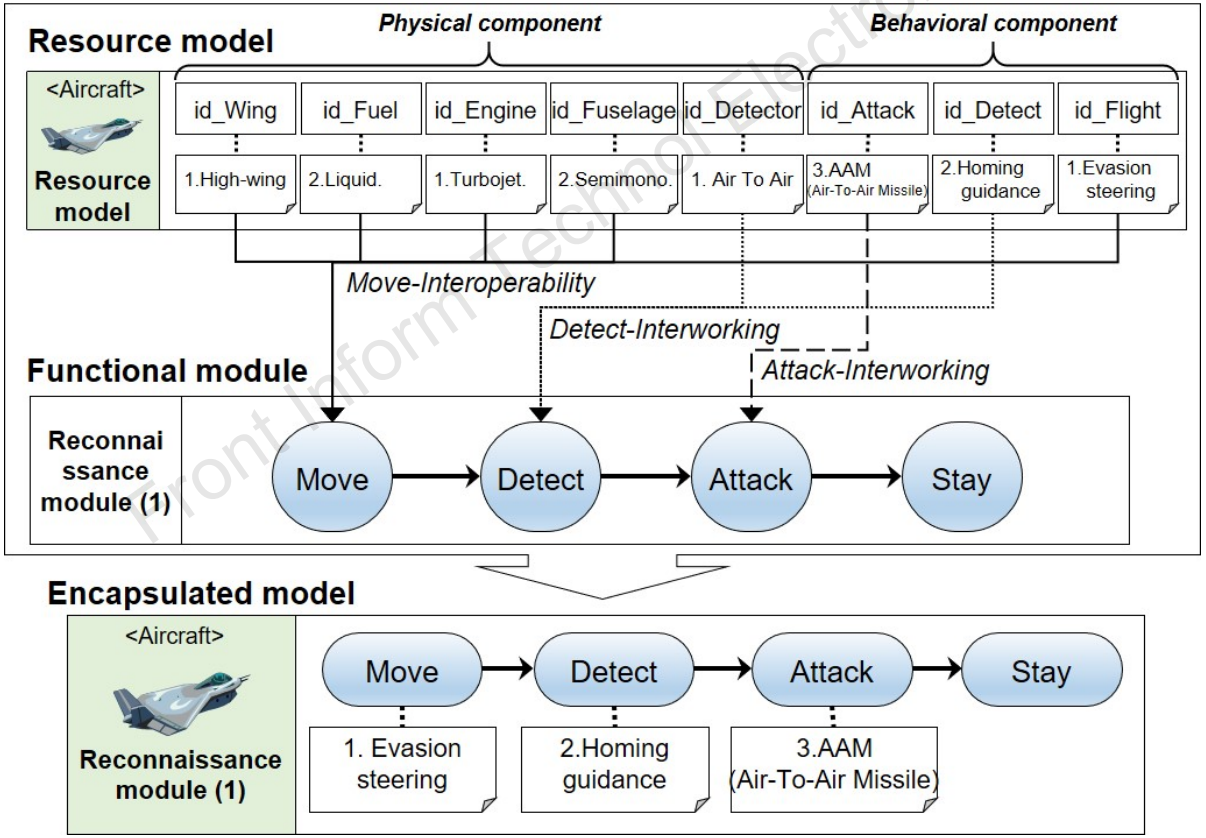

Fig. 6 An example of an encapsulated model combining a resource model with a functional module

Method

- Process modeling is a step in creating a combat scenario model that reviews the interrelationships between the functions of the weapons used in the combat.
- The combat scenario should express the intimate relationships of weapons corresponding to the friendly and enemy combat scenarios as logical procedures.

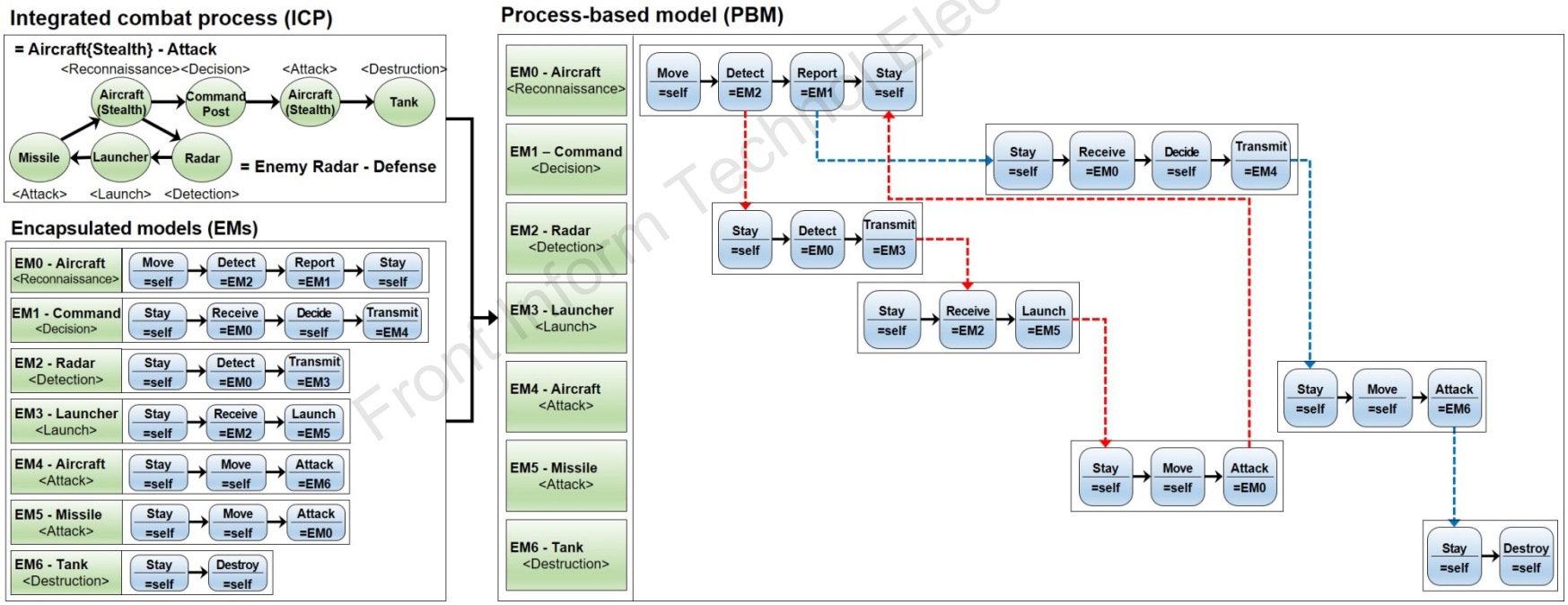

Fig. 8 An example of a process-based model combined with an integrated combat process with encapsulated models

Major results

- We used the Levels of Conceptual Interoperability Model (LCIM) to evaluate how well different interoperability approaches satisfy the various levels of the developed model, referring to Wang et al. (2009) and Tok (2012). The results are shown in Table 4.
- The PBM method allows transparency to ensure conceptual alignment while protecting the intellectual property of the detailed implementation. This enhances the practical usability of the method.

Table 4 Interoperability analysis of the process-based model proposed in this paper and the models proposed in related papers

Level	Interoperability at this level	Lee B and Seo (2014)	Luo et al. (2016)	This paper
L6 (conceptual)	Grasp processes, contexts, information, and modeling assumptions for a conceptual model	X	X	Δ
L5 (dynamic)	Realign information protection and consumption to understand the context and meaning according to the state changes of the context and meaning	X	Δ	O
L4 (pragmatic)	Be aware of the context and meaning of the information being exchanged	Δ	O	O
L3 (semantic)	Understand and exchange semantic phrases	Δ	O	O
L2 (syntactic)	Exchange an agreed protocol and the right forms of data	O	O	O
L1 (technical)	Detect technical connection and data change between systems	Δ	O	O

X: least interoperability; Δ: medium interoperability; O: best interoperability

Conclusions

- The main contribution of this paper is to present a process-based model of the combat scenario that considers the interactions between combat entities with behavioral functions. This means that the variant forms of the combat scenario model can be easily generated through a combination of process modules. The PBM method additionally provides the following contributions:
  1. reconfigurable combat scenario generation,
  2. visual representation of combat entities and combat scenarios used at the engagement level,
  3. integrated design of methods used to model combat entities and combat scenarios, and
  4. transparency of conceptual alignment while protecting the intellectual property contained in combat scenario model information.

- These contributions address the complexity of weapon development in advance and can reduce the cost and time associated with the trial and error of development by reviewing the weapon functions through the process-based model.