

Study of Equivalence in Systems Engineering within the Frame of Verification and Systems Theory

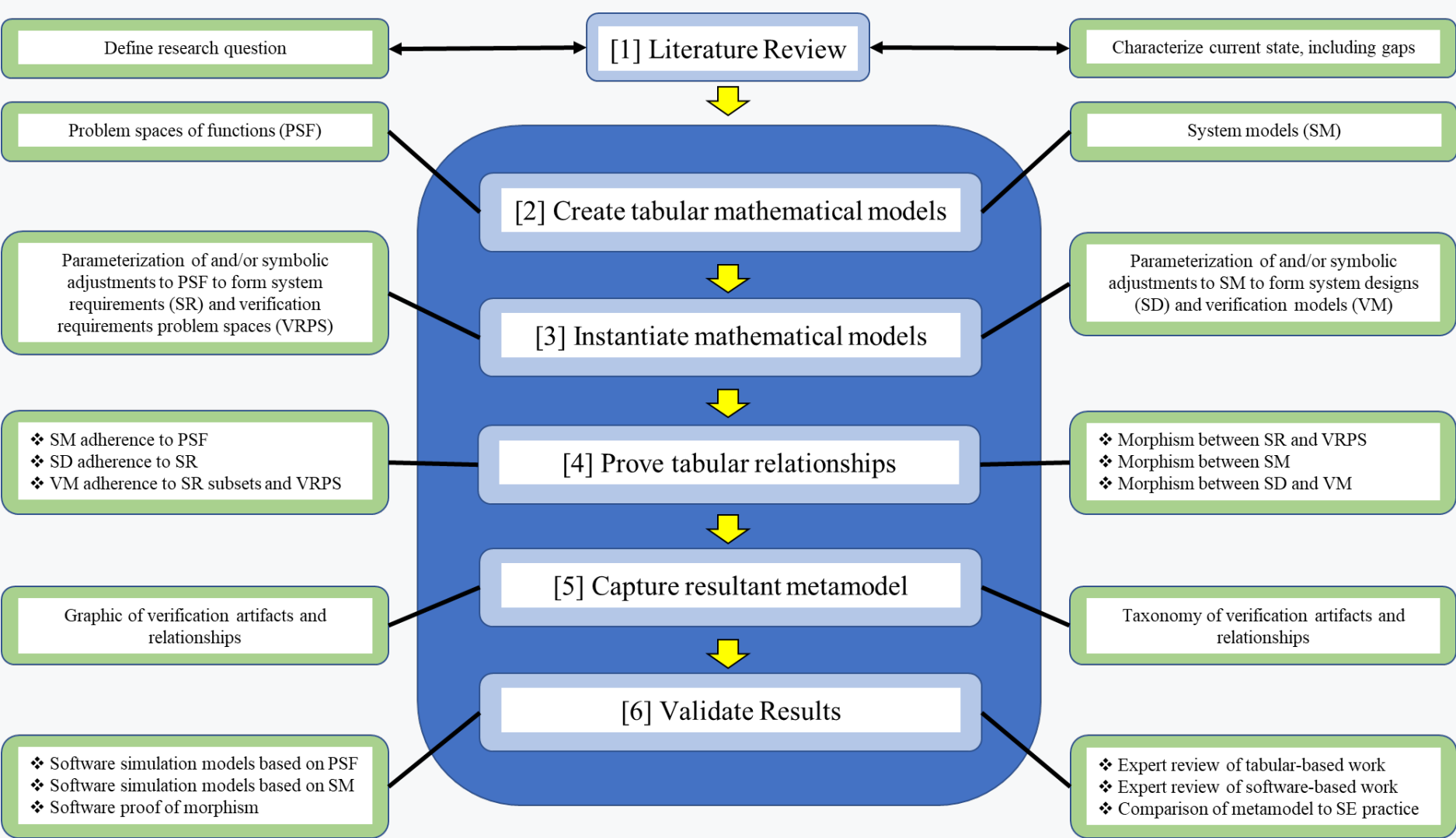
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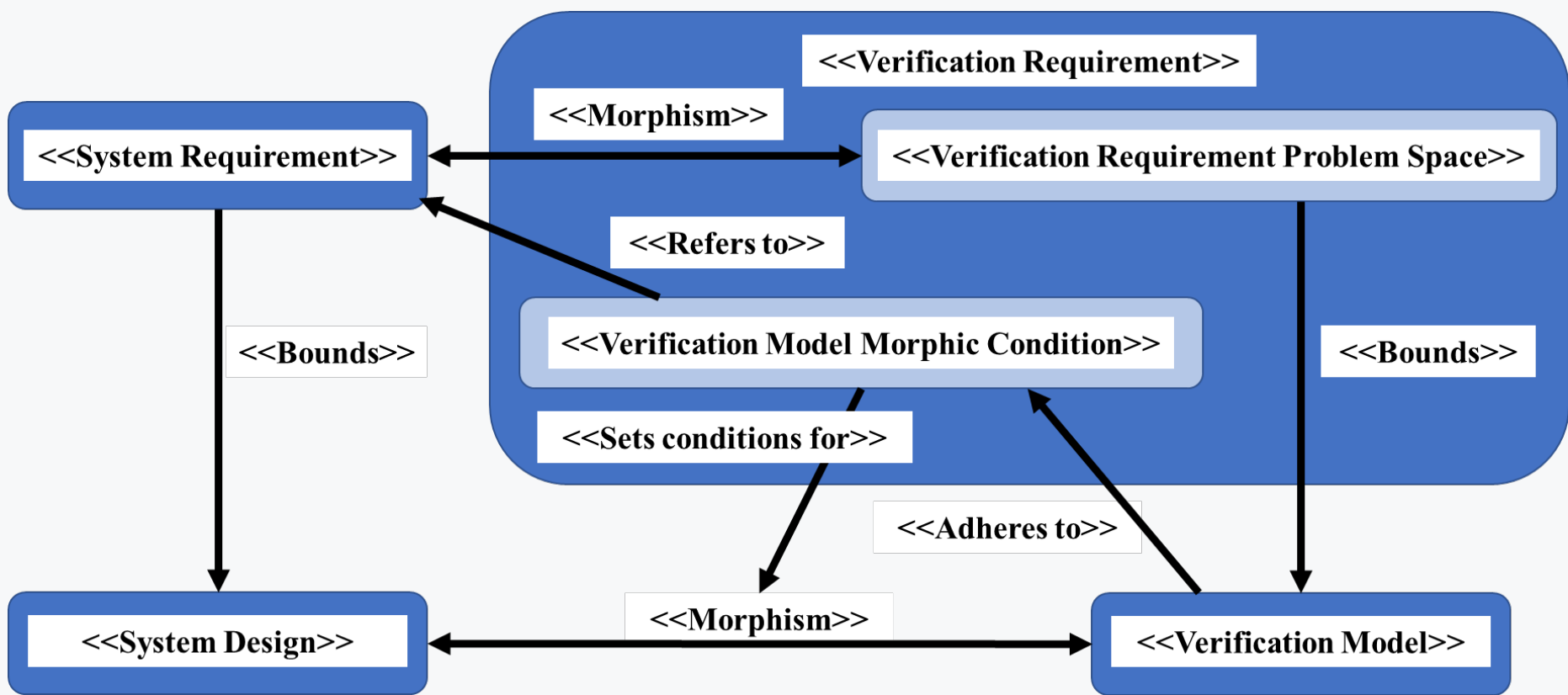


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OVERVIEW OF RESEARCH TASKS



RESULTS & CONCLUSIONS



Initial results:

1. PSF were proven to be (or not) equivalent to other PSF
2. SM were proven to adhere (or not) to PSF
3. VRPS were proven to be (or not) equivalent to SR
4. SD were proven to adhere to SR
5. VM were proven (or not) to adhere to SR subsets
6. VM were proven to be (or not) equivalent to SD
7. VMMC combination (intersection) with the above defined the space of acceptable VM

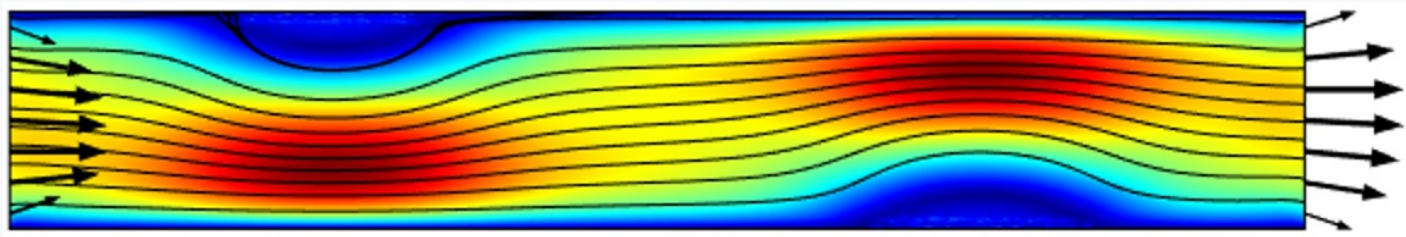
Validation:

1. Software confirmed results
2. Expert review confirmed results

Final results:

1. **Metamodel of verification artifacts (shown below)** characterized the entities and relationships used to theoretically define VM
2. **Comparison to current state of SE practice** suggests novelty in that VM are currently, largely limited to definition based on descriptive/qualitative relationships

MOTIVATION, QUESTION, & HYPOTHESIS



Motivation: Above is an image of a micro-/nanofluidic channel modeled through science-based finite meshing and computational fluid dynamics. While such **theoretical underpinning** is common in other engineering domains; such is **not** currently **inherent in** the practice of systems engineering (SE) and **defining verification models (VM)**. For example, we **currently use** the term fidelity with a **qualitative assumption of** high-, medium-, or low-**representativeness** to a final product.

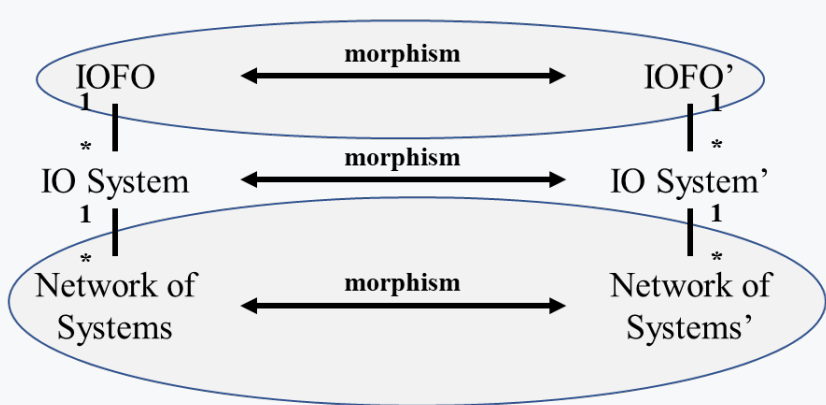
Question: On the basis of what relationships should VM be defined?

Hypothesis: VM should be defined on the basis of mathematical relationships to/from/between: system requirements (SR), **system design (SD)**, **verification requirements** consisting of **problem spaces of functions (VRPS)** and **conditions (VMMC)** that defined the desired pedigree of the VM relative to the SD

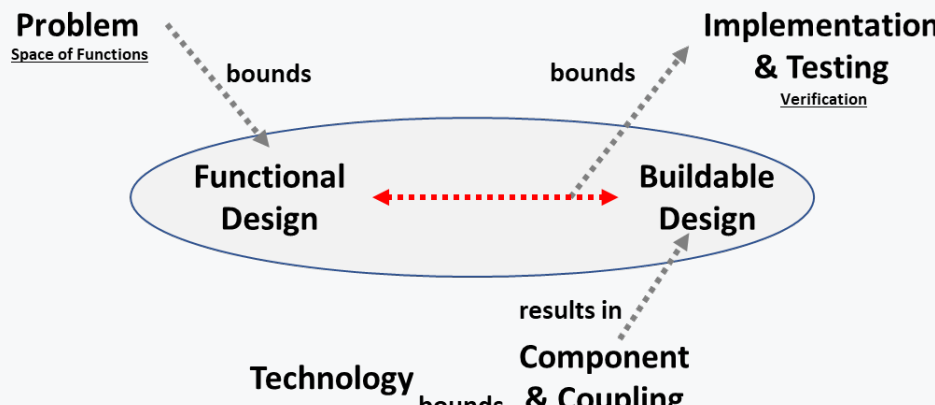
METHODOLOGY

- Leveraged rich theoretical foundations from Wymorian systems theory (e.g., [1]) : Theory problem spaces (of functions) to define system requirements (SR) and verification requirement problem space (VRPS); and T3SD/DEVS frameworks/formalisms to **mathematically define/characterize relationships** between **SR-VRPS**, **SR to system designs (SD)**, **SR-VM**, **VRPS-VM**, and **SD-VM**.
- Both T3SD and DEVS have the notion of mathematically characterized **equivalence between pairs of mathematical structures** referred to as a **morphism**.
- DEVS contains the notion of hierarchy of system specification, which serves as the basis for levels of equivalence based on increased definition of structure; where Level 0 (L0) is a problem space of functions (PSF) and level 1 (L1) and Level (2) is a system models (SM) with the number indicating increase in definition of internal structure (i.e., L1 does not define component and their coupling as L2 defined components and their coupling).

Theory of Modeling and Simulation (DEVS)



Tricotyledon Theory of System Design (T3SD)



FUTURE RESEARCH QUESTIONS OPENED

- To what extent does context matter to verification? The results suggest that context may matter; however, the equivalence of underlying mathematical structures defined on the basis of systems theory suggest existence of domain independence
- To what extent may the methods be extended to characterize validation? The research here was limited to verification of adherence to system requirement problem spaces of functions; however, there may exist extensions to characterize validation of adherence to stakeholder needs problem spaces of outcomes.

CONTACTS & REFERENCES

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[1] Wach P, Zeigler BP, Salado A. Conjoining of Wymore's Systems Theoretic Framework and the DEVS Formalism: Toward Scientific Foundations for MBSE. Applied Sciences, vol. 11, no. 11, p. 4936, 2021.