A Systematic Literature Review on Knowledge Representation Approaches for Systems-of-Systems

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Agenda

1. Systems-of-Systems (SoS)

2. Knowledge Representation

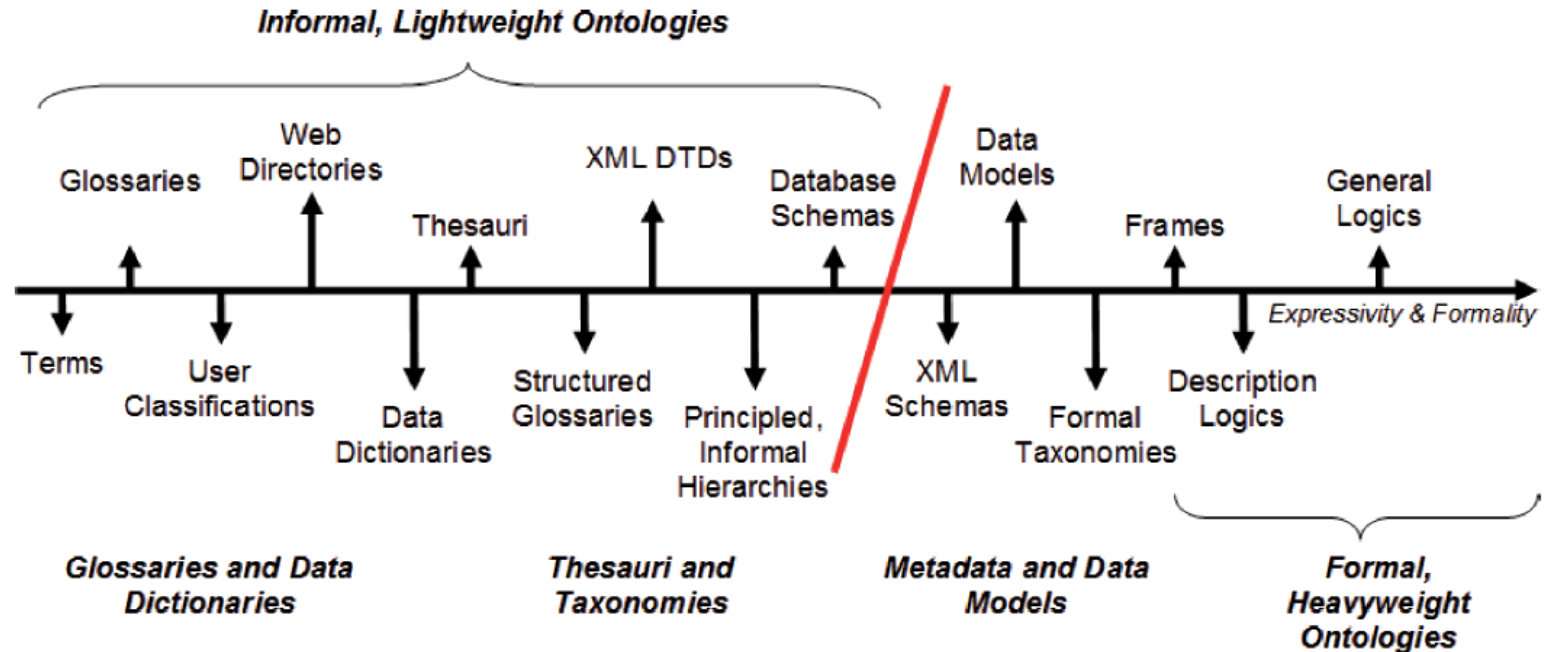3. Systematic Literature Review (SLR)

4. Conclusion

Systems-of-Systems

- A class of systems composed of independent constituent systems
- Operational and managerial independence
- Evolutionary development
- Emergent Behavior
- Distribution

Knowledge Representation

- Understand, design, and implement ways of representing information
- Ontologies, taxonomies, thesauri, vocabularies
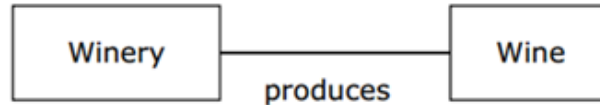
Knowledge Representation

Informal, Lightweight Ontologies

Glossaries · Web Directories · Thesauri · XML DTDs · Database Schemas · Data Models · Frames · General Logics

Terms · User Classifications · Data Dictionaries · Structured Glossaries · Principled, Informal Hierarchies · XML Schemas · Formal Taxonomies · Description Logics

Expressivity & Formality

Glossaries and Data Dictionaries · **Thesauri and Taxonomies** · **Metadata and Data Models** · **Formal, Heavyweight Ontologies**

Degree of Formality

Informal

Wine is a product of a winery.

Semi-formal

Winery —produces— Wine

Formal

```
<a:owl_objectproperty rdf:about="produces" rdfs:label="produces">
   <rdfs:range rdf:resource="Winery"/>
   <rdfs:domain rdf:resource="Wine"/>
</a:owl_objectproperty>
```

SLR - Planning

- **RQ 1**: Which Knowledge Representation approaches have been applied to SoS?
  - RQ 1.1: What is the degree of formality of the approach (informal, semi-formal, formal

- **RQ 2**: What is the main motivation for using Knowledge Representation in SoS?

- **RQ 3**: What application domains have the Knowledge Representation approaches of SoS been applied to?
  - **RQ 3.1**: Is the approach applied to a real case study / system?
  - **RQ 3.2**: For what purposes were the identified studies conducted? (eg., communication, interoperability, Systems-of-Systems Engineering (SoSE), or other uses)?

- **RQ 4**: What are the terms covered by Knowledge Representation approaches in SoS?

SLR - Planning

Search String

("system-of-systems")

AND

("glossary" OR "classification" OR "dictionary" "thesaurus" OR "taxonomy"

OR "ontology" OR "vocabulary" OR "schema" OR "frame" OR "hierarchy"

OR "knowledge representation" OR "body of knowledge")
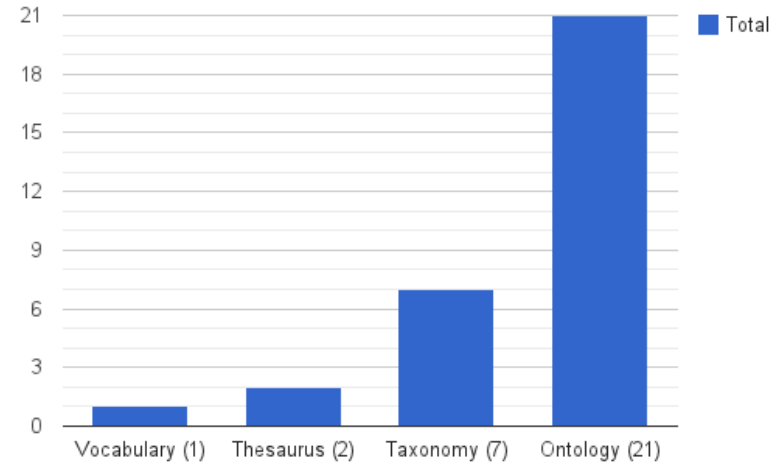
SLR - Conduction

- October 17, 2014
- 124 papers
- Reading Process
  - Introduction > Conclusion > Full paper
- Final set: **31 papers**

SLR - Reporting

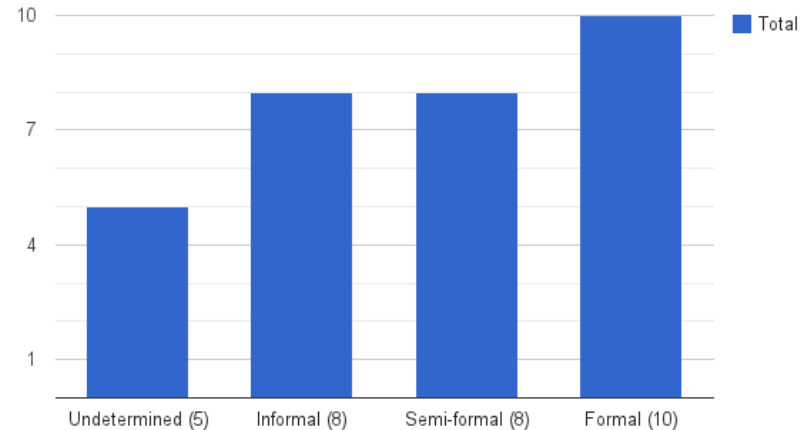## Knowledge Representation Approaches applied to SoS

- No studies addressing glossary, hierarchy, dictionary, or frame
- The majority of included studies in this review is related to ontologies

SLR - Reporting

Degree of Formality

- The amount of studies discussing each degree of formality considered in this study is approximately equal
  - Informal
  - Semi-formal
  - Formal
  - Undetermined (not possible to classify the degree of formality)


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SLR - Reporting

Main motivation for using Knowledge Representation approaches in SoS

- **Terminology standardization and knowledge sharing**: information and expertise sharing (communication)
- **SoS integration**: formal specification of systems integration (interoperability between systems)
- **SoSE activities**: guide SoSE activities, such as SoS evaluation and requirements (support to systems engineering)
- **SoS management**: management activities related to SoS, such as failure mitigation and crisis management.

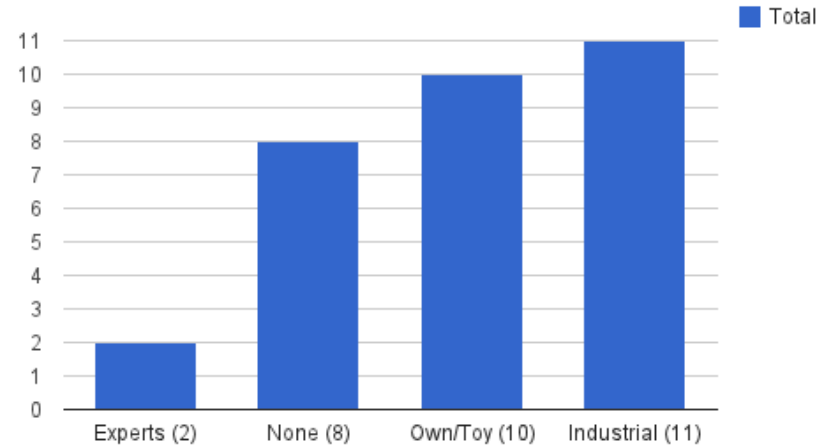# SLR - Reporting

Application Domains

- 10 studies on general domain

  - No specific domain

  - Can be applied to any domain

- 6 studies on military domain

- 4 studies on crisis management
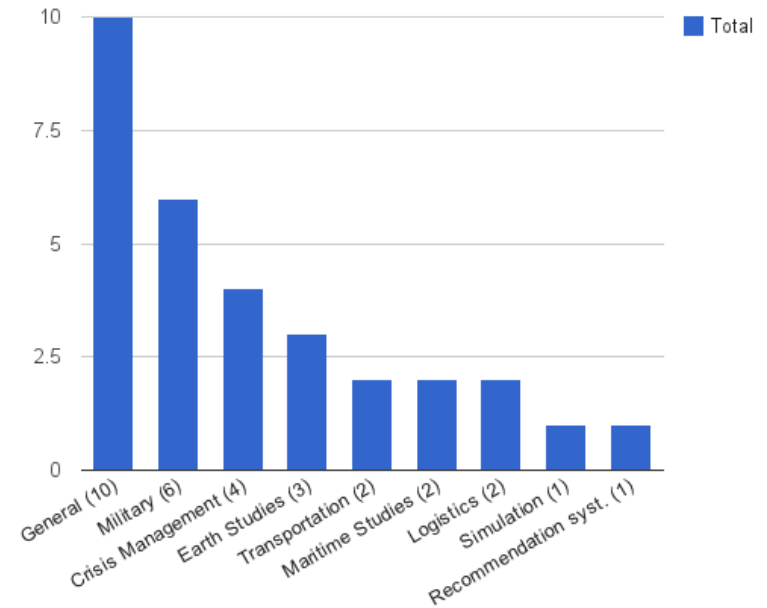
SLR - Reporting

## Subject of Study

- 8 studies not validated

- Formal studies were all validated
    - Own / Toy or Industrial scenario
    - Tendency to be validated

SLR - Reporting

Space of Use

- Interoperability of SoS (16 papers)
- Communication and SoSE (10 papers)
- Degree of formality x Space of use:
  Interoperability → formal approaches
  - 10 papers
  - Machine-readable (e.g. OWL)
- No studies on SoSE and formal approaches
  - Guide systems engineering
  - (e.g. diagrams, or natural language)
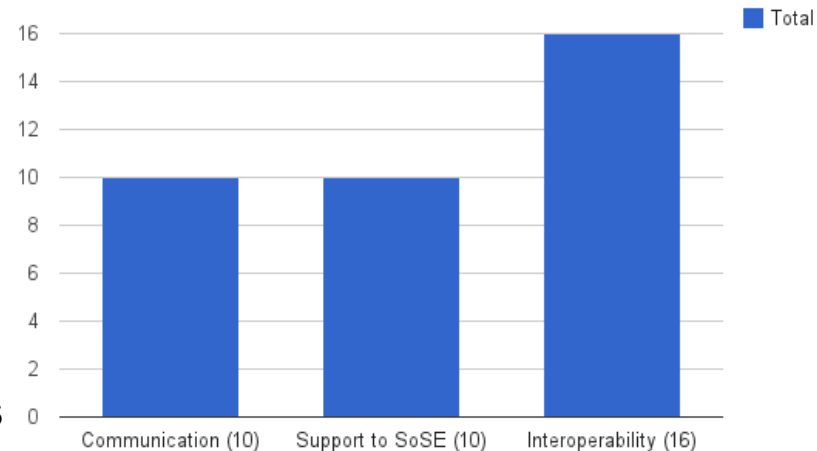
SLR - Reporting

Terms covered by Knowledge Representation approaches

- Many studies do not explicitly present terms
- Extraction limited to the information described in studies
- No direct relationship among the terms
- Few terms repeated across the studies (e.g. *stakeholder*)
  - Lack of consistency on the terminology
  - Address specific tasks
  - Do not concern with the SoS field as a whole
- Some terms can be related to the SoS field
  - *constituent system, interoperability, goal, domain...*
  - *virtual, collaborative, acknowledged, directed*

Conclusion

- Formal ontology is the most used
- Interoperability is the most addressed space of use
  - More likely to use formal approaches
- Approaches for SoSE → semi-formal or informal
- Formal approaches → validation
- Many studies are general regarding domain
- No consistency among extracted terms

Conclusion

- Common understanding cannot be established
  - Lack of consensus in SoS definitions
- Formally define and relate SoS concepts and terms
  - Establish a common understanding
  - Support communication among the community
  - Machine-readable
- Future work
  - Update the SLR and identify additional approaches

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