MODEL-BASED SYSTEMS ENGINEERING DESIGN AND TRADE-OFF ANALYSIS WITH RDF GRAPHS

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INTRODUCTION

Project Motivation

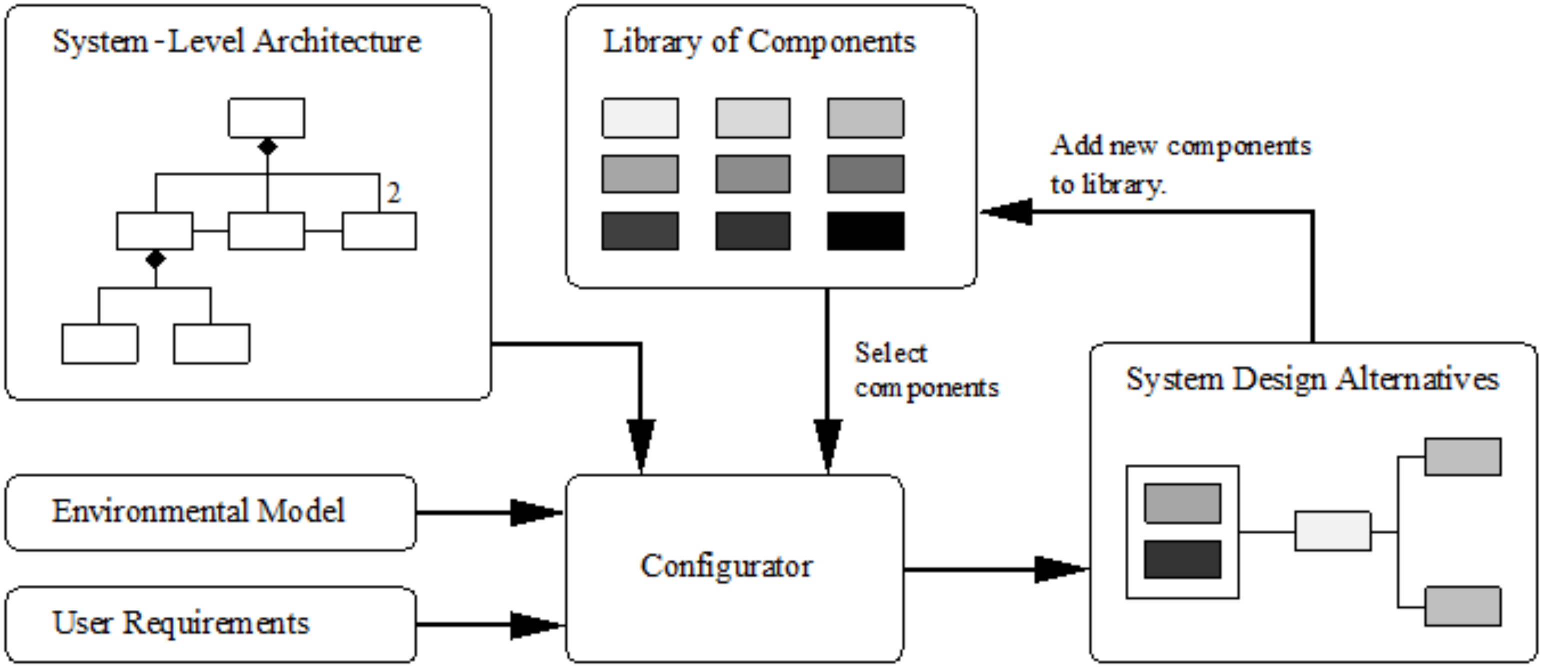
- Complexity of engineering systems is on the rise.
- Strategic approaches to design will employ semantic descriptions of application domains and use ontologies and rule-based reasoning to enable validation of requirements, automated synthesis of potentially good design solutions, and communication among multiple disciplines.

Tenet of our Work

- Semantic Web concepts and technologies can provide assistance in the model-based system engineering and design of modern-day systems. But how?

MOTIVATING DESIGN PROBLEM

Prototype implementation: Satisfaction of requirements & components selection for a Home Theater Design Problem



Outcomes:

1st Search procedure will find combinations of components that satisfy requirements

2nd Design requirements stated in such a way that no feasible designs exist

OUTLINE

Questions

- What is the Semantic Web?
- What technologies are provided by the Semantic Web?
- Which technologies in the Semantic Web will be useful for design?
- Can Semantic Web Technologies be used to create a chain of transformations for the synthesis of design alternatives?
- What parts of the design process can be handled by Semantic Web?
- What parts of the design process cannot be handled by Semantic Web?
- Can the limitations of Semantic Web be overcome through the use of Java/ Python software?
- To what extent is it possible to simplify the design process?

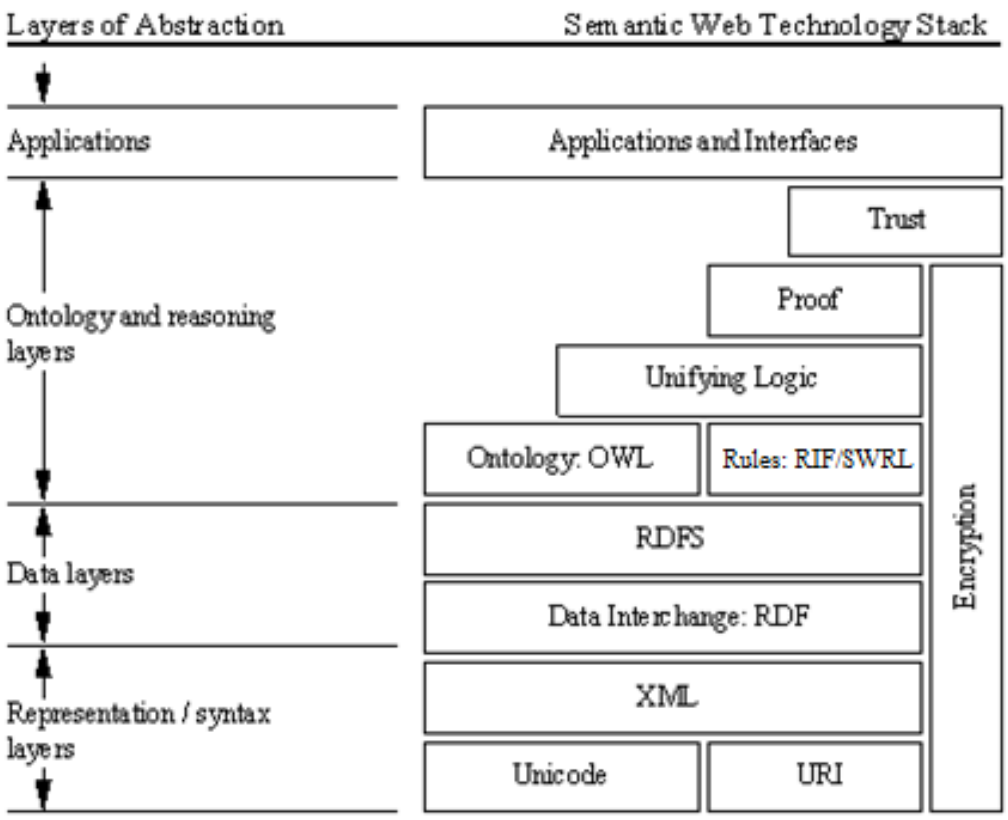
WHAT IS THE SEMANTIC WEB?

Goals of the Semantic Web

- Facilitate communication of knowledge
- Automated discovery of new knowledge

How can Semantic Web help design?

- Validation of requirements
- Automated synthesis of design solutions
- Formal design representations

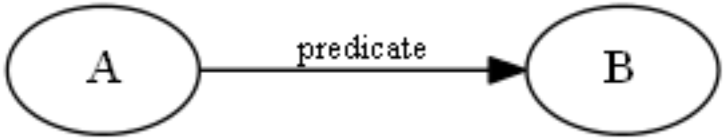


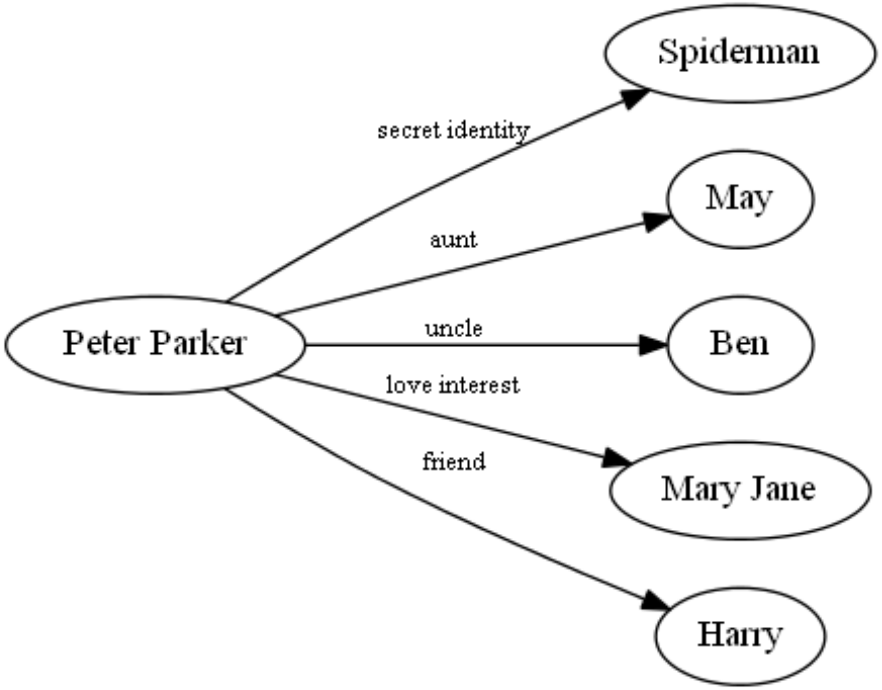
WHAT IS THE SEMANTIC WEB?

Resource Description Framework

- Graph-based data model for describing relationships between objects and class in simple, but general, way.

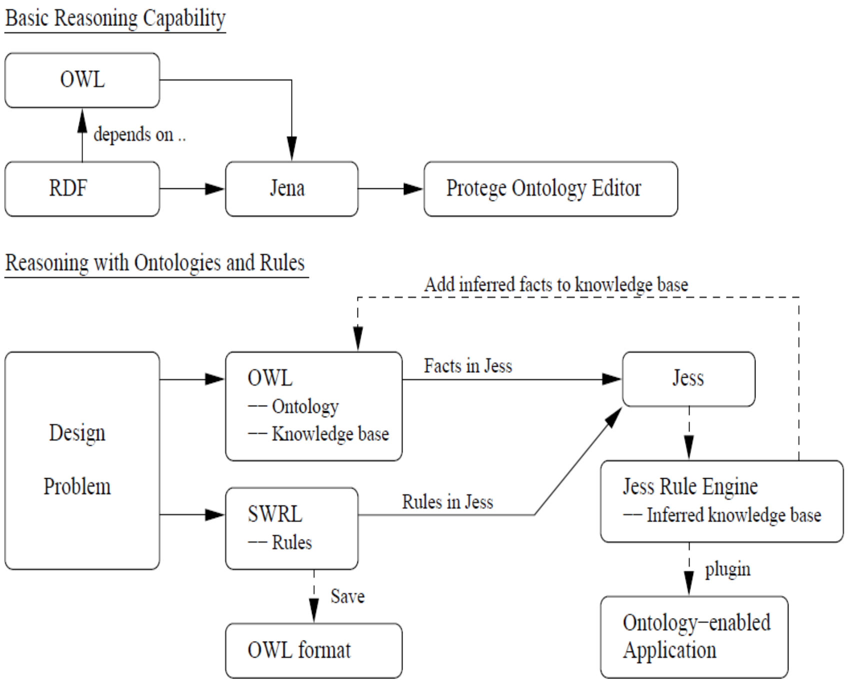
RDF Triples and Graphs



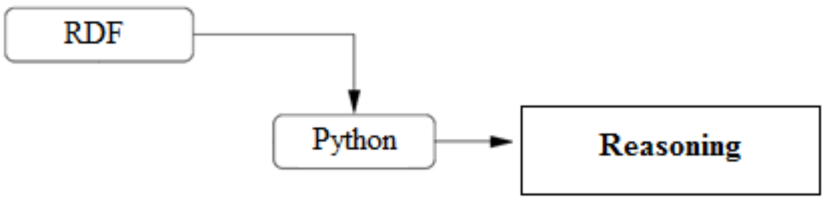


SIMPLIFIED DESIGN WITH RDF AND PYTHON

USING SEMANTIC WEB …



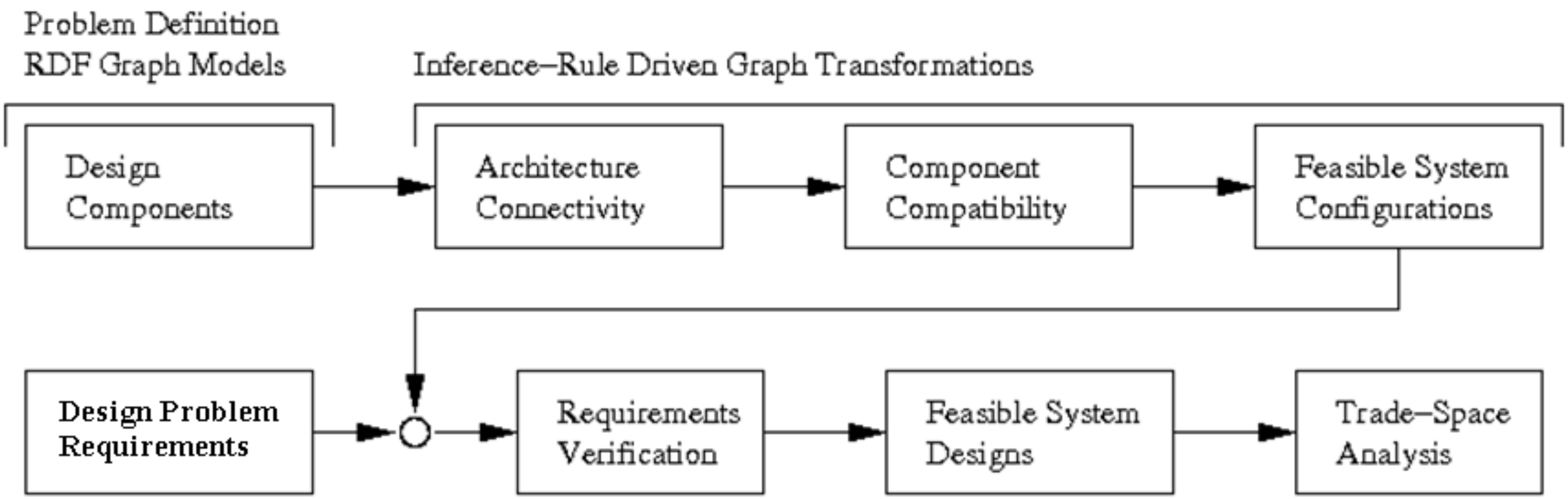
NO ONTOLOGIES …



- Straightforward and uncomplicated
- Smaller graph size
- Practical design solutions can be obtained

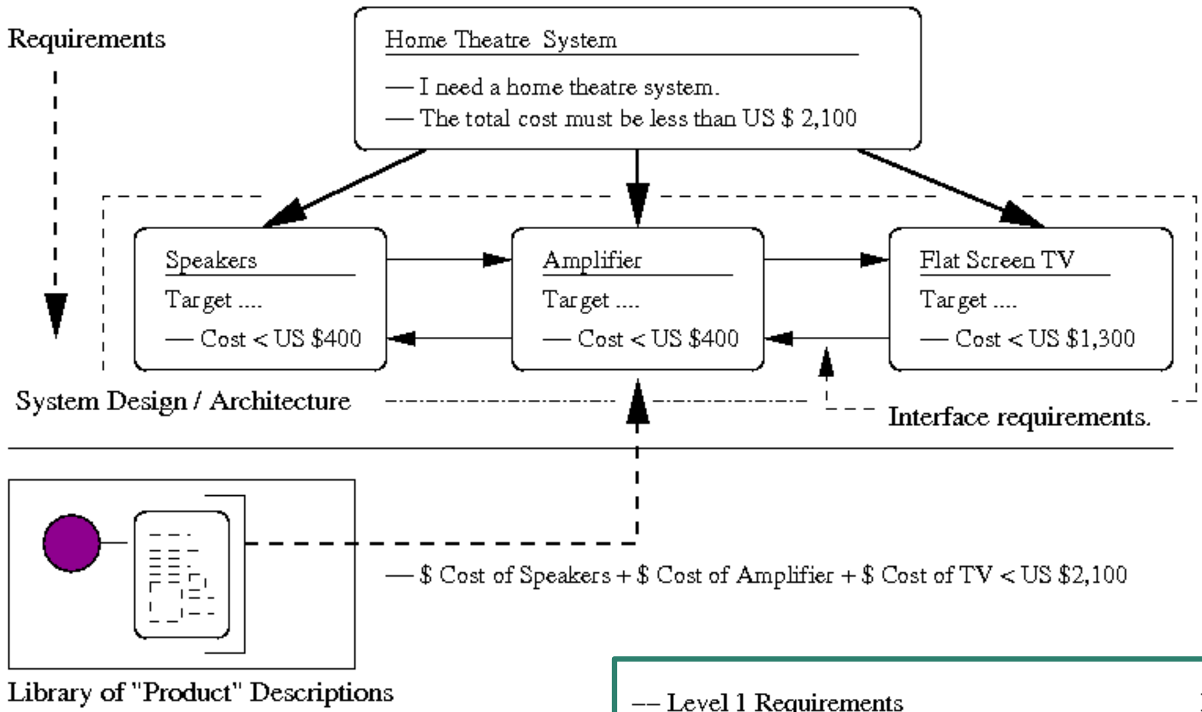
DESIGN METHODOLOGY

Synthesis of design solutions from RDF graph representations of requirements and design components



Explore: **RDF graphs** for representation of requirements and design component properties. **Python** for implementation and sequencing logical reasoning and inference mechanisms.

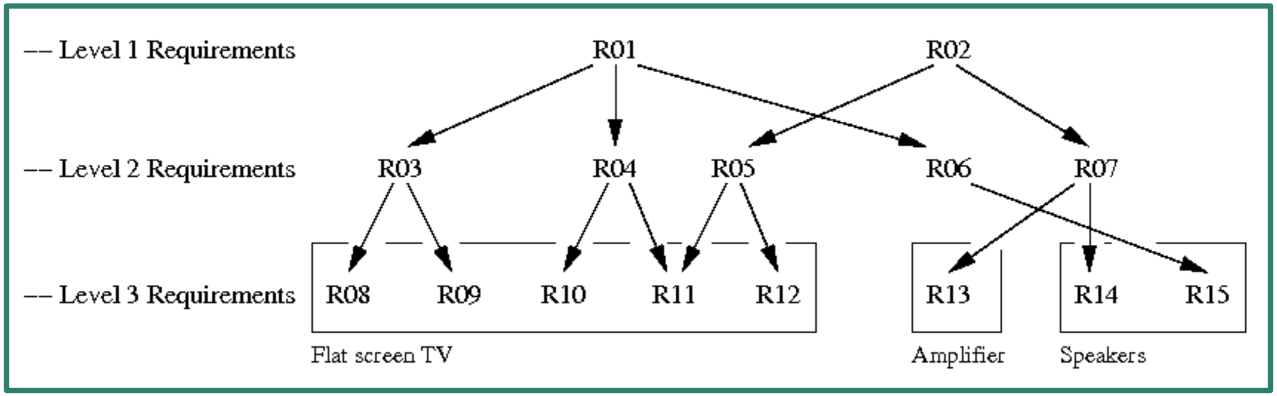
CASE STUDY: HOME THEATER DESIGN PROBLEM



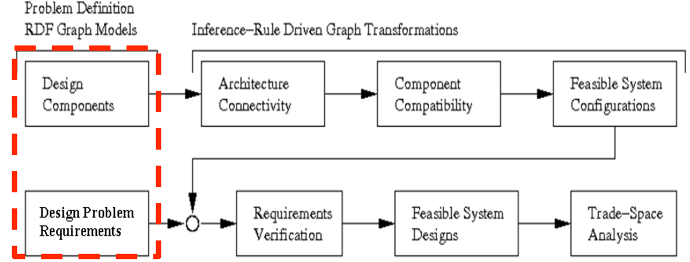
Design Space

TV	Amplifier	Speaker
3	3	3

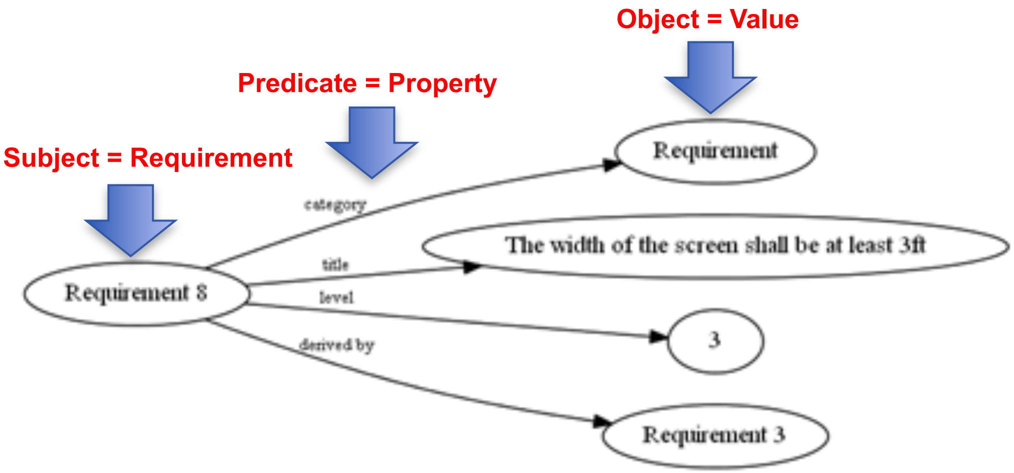
Potential System-Level Designs:	27

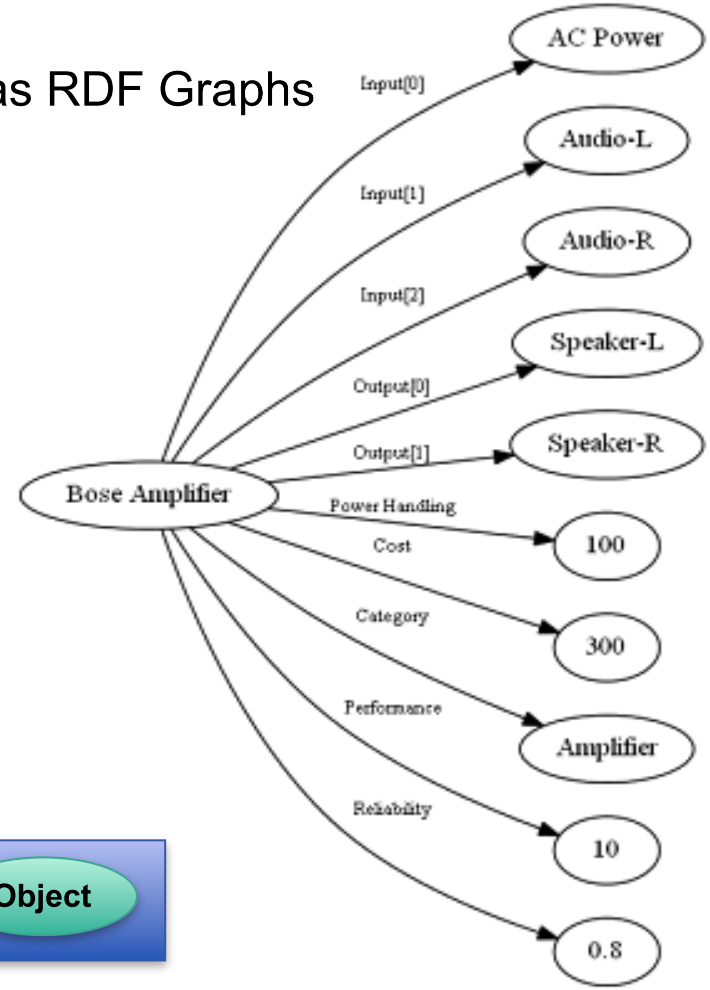


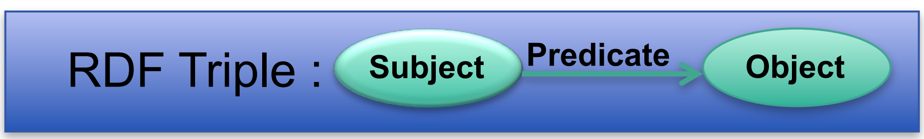
RDF GRAPH MODELS



Modeling Requirements & Design Components as RDF Graphs







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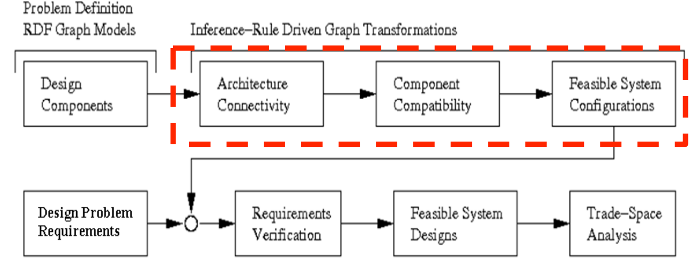
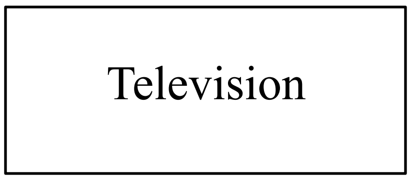
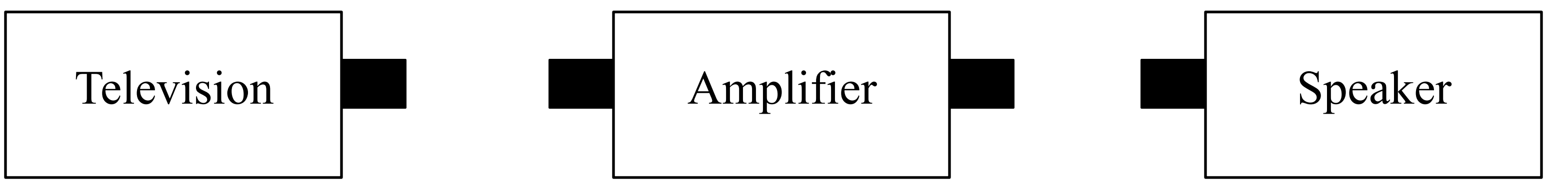
SYNTHESIS OF FEASIBLE SYSTEM CONFIGURATIONS



System Architecture Rules



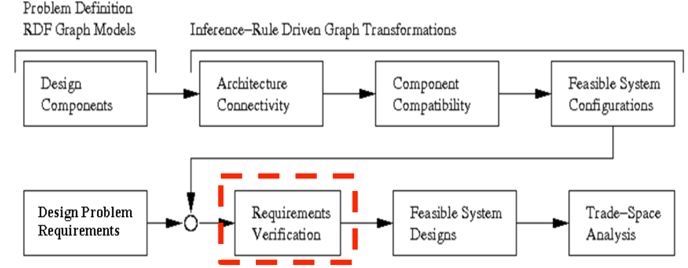
Component Compatibility Rules

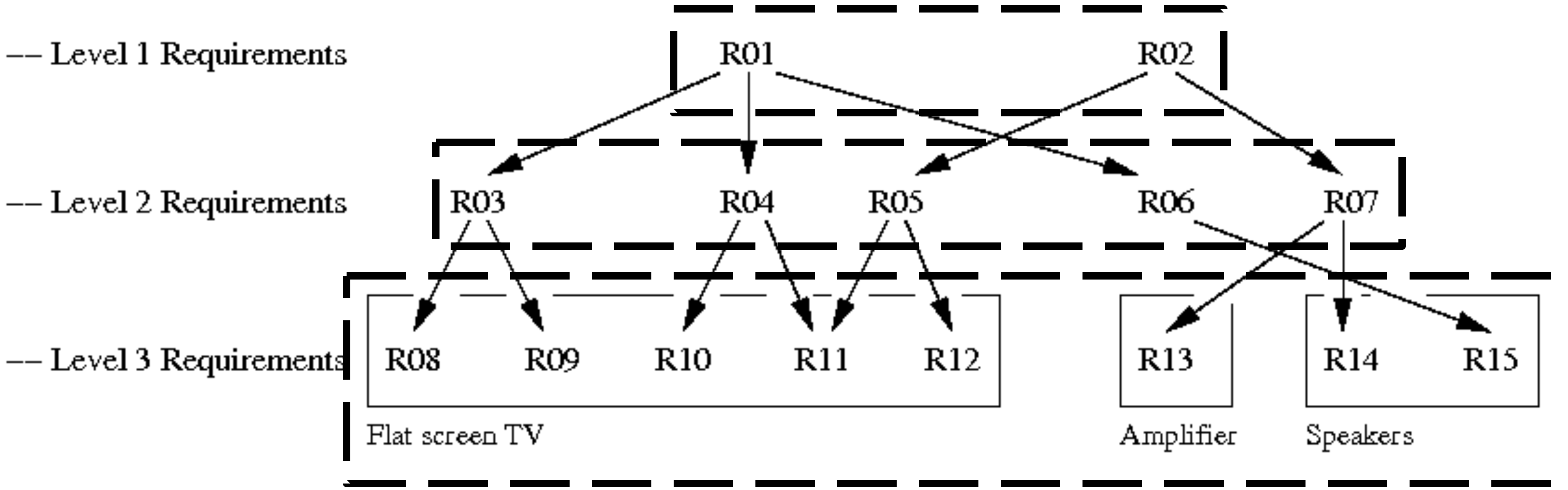


Design Space

Potential System-Level Designs:	~~27~~	**18**

QUANTITATIVE EVALUATION OF DESIGN REQUIREMENTS



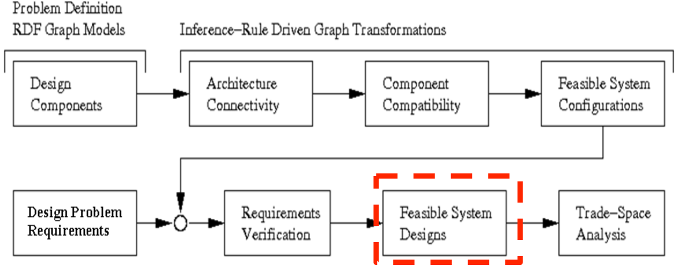


Component Specification: Inequality constraints

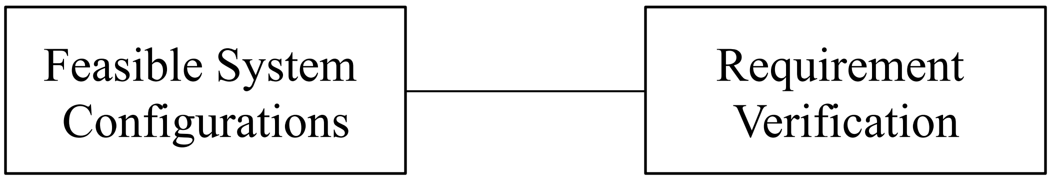
System-Level Design Requirements / Architecture-Level

Satisfaction of Level 2 constraints through satisfaction of lower-level requirements

Evaluation of equality constraints and relationship dependency to components



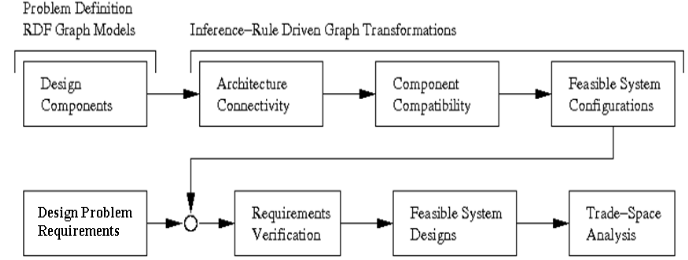
SYNTHESIS OF SYSTEM-LEVEL DESIGN ALTERNATIVES



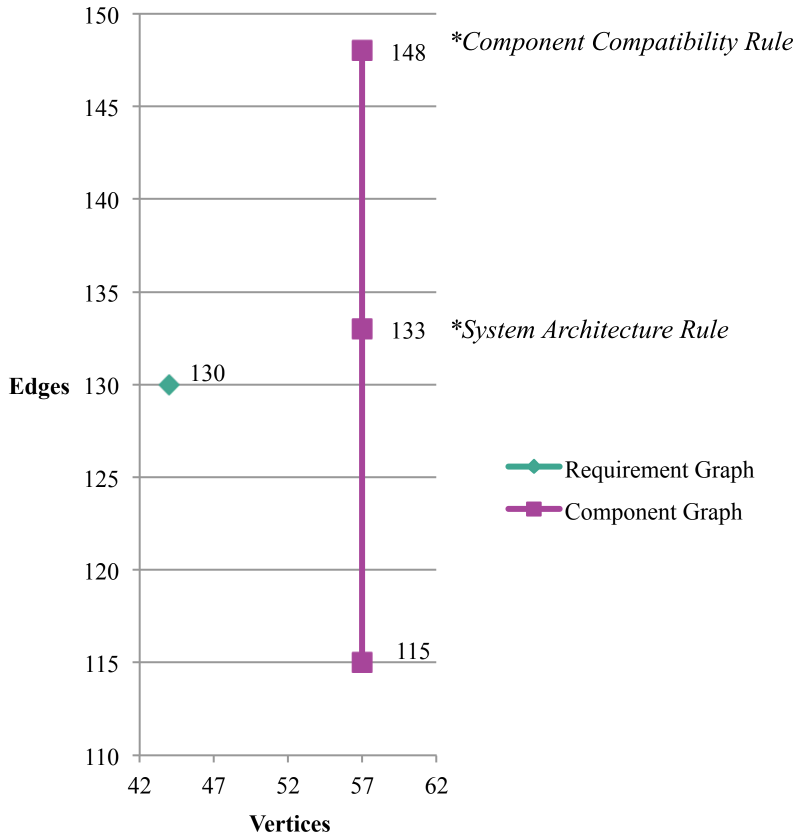
Design Space

System-Level Designs:	~~27~~	~~18~~	**9**

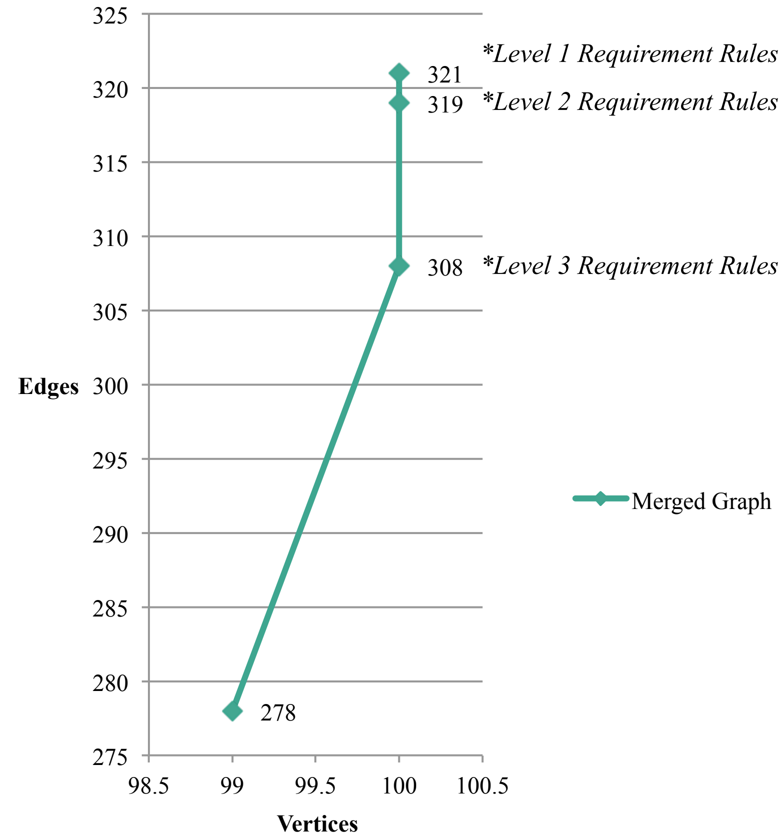
TRACKING RDF GRAPH SIZE



Requirement & Component Graph



Merged Graph



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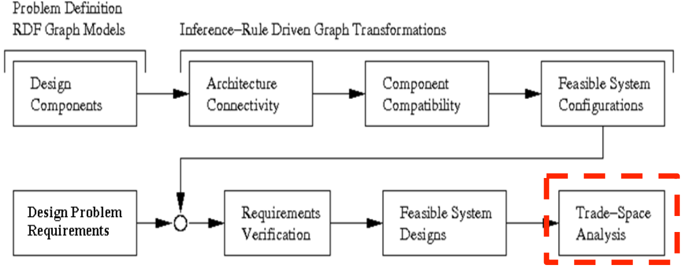
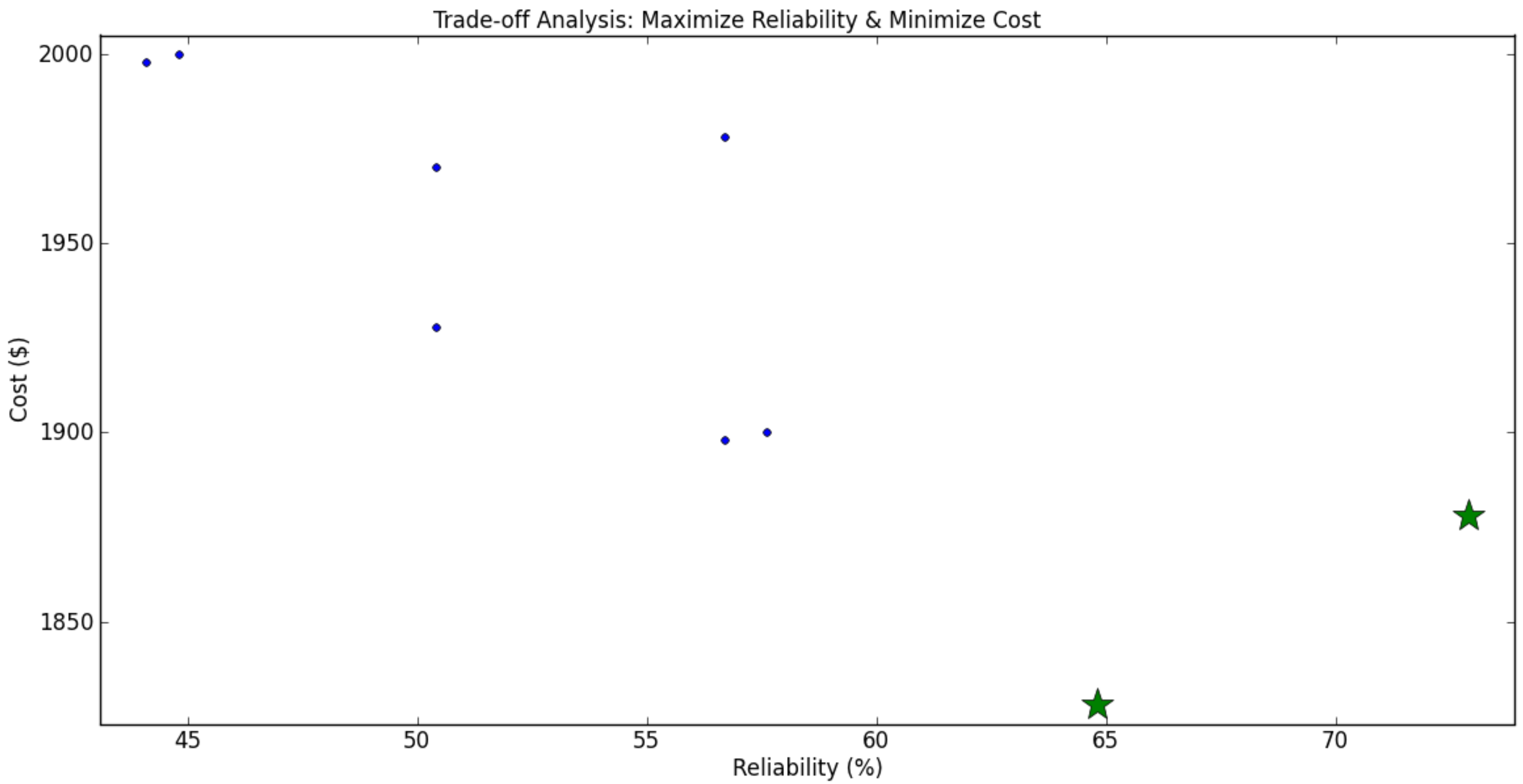
TRADE-SPACE ANALYSIS



Python: Systematic comparison of Feasible System Designs wrt cost, performance, and reliability



CONCLUSIONS AND FUTURE WORK

Benefits and Limitations

- Satisfy requirements and acquire good design solutions in a straightforward and uncomplicated manner.
- RDF graph representations provide desirable balance of expressiveness and flexibility.
- **Not scalable**: BUT during the early stages of development, design solutions for component selection are usually based upon smaller numbers of requirements and component options

So what about Jena, OWL and SWRL?

- RDF graphs are smaller – a lot smaller -- than OWL counterparts
- RDF graph storage can be simple – Strings. This works well with Python.
- Jena and OWL can represent and reason with physical quantities.

Questions?