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Enhancing the Academic Portfolio – SE Research and Teaching for Academia



Contents

- Are there still engineering focused universities **without SE**?
- **Why should they include SE** in their portfolio?
- Some **key challenges** to including SE
- What is **ontology** and how can it help address these challenges?
- A generic SE domain ontology for universities:
'SERaT4Ac' (SE Research and Teaching for Academia)
 - High-level, iterative **approach** to build an SE domain ontology
 - Building the class hierarchy
 - Defining object and datatype properties
 - Creating instances of classes
 - Establishing traceability by linking instances of classes
 - Typical **examples** of information managed in an SE domain ontology
 - SE courses
 - Need to ensure employability of students
 - Academic staff members (generic roles and employees)
 - Professional SE certifications
- **Conclusions**

Are there still engineering focused universities without SE?



- Many universities across the globe offer well established Systems Engineering (SE) courses and academic degrees (undergraduate and postgraduate, including research degrees at master and doctorate levels), as well as continuous professional development programs (for both industry and public sectors).
- Some universities even have world-class reputation for the excellence they demonstrate in SE research & teaching.
- However, there are **still many universities worldwide** that offer courses in traditional fields of Engineering but **not yet in SE**, let alone specific SE degrees or qualifications.
- Given that SE is essential for the development and in-life support of systems, even more so with the increasing levels of complexity of today's and tomorrow's systems and Systems of Systems (SoS), it seems **urgent and important** for such universities **to consider an extension of their academic portfolio**.



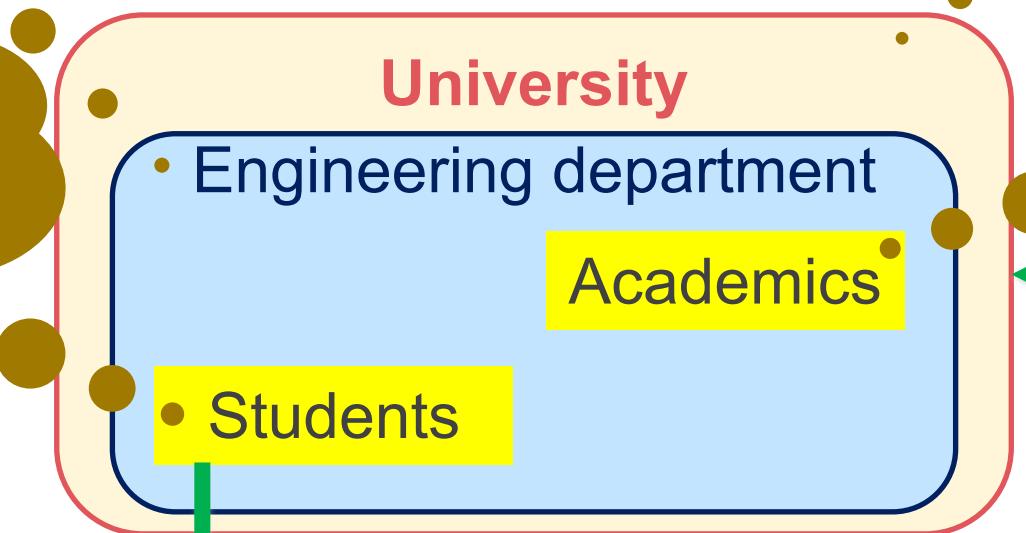
Why should they include SE in their portfolio?

Attract good academics and students – enhanced by comprehensive research and teaching portfolio including SE, professional certifications and course accreditations

Good career choices and high employability – enhanced by good range of engineering subjects including SE and professional certification

Successful bidding process and systems – enabled by sound SE and SE certified resources

Employers
(industry, public sector and academia)



High ranking (research and teaching) and funding – only possible with good academics & students

Research funding and opportunities – enhanced by being part of a leading university that offers a comprehensive range of courses including SE

Soundness of proposals and academic strength of the participating universities – SE aspects must be appropriately addressed

Funding bodies
(industrial, governmental and international)



Some key challenges to including SE

- **Lack of strategic SE vision => unwillingness to invest**
- Lack of suitable SE academics and interested students (short term)
- Therefore no immediate research funding and study fees (short term)
- **Culture of little cooperation among different disciplines and faculties**
- **Lack of visibility of the intended SE domain portfolio**
- **Employability of students for SE jobs (knowledge alone not sufficient)**
- Quickly evolving **body of knowledge and state of the art**

What is ontology and how can it help address these challenges?



An ontology defines a ‘common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them’ (Noy & McGuinness, 2000).

In order to build the SE domain ontology presented in this paper, the open source ontology editor **Protégé** and the **OWL** (Ontology Web Language) notation were selected. Protégé was developed by the Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine, and has since become the world’s leading open source ontology editor with over 300,000 registered users from a large variety of industrial and academic domains worldwide (Stanford University, 2014).

What is ontology and how can it help address these challenges?



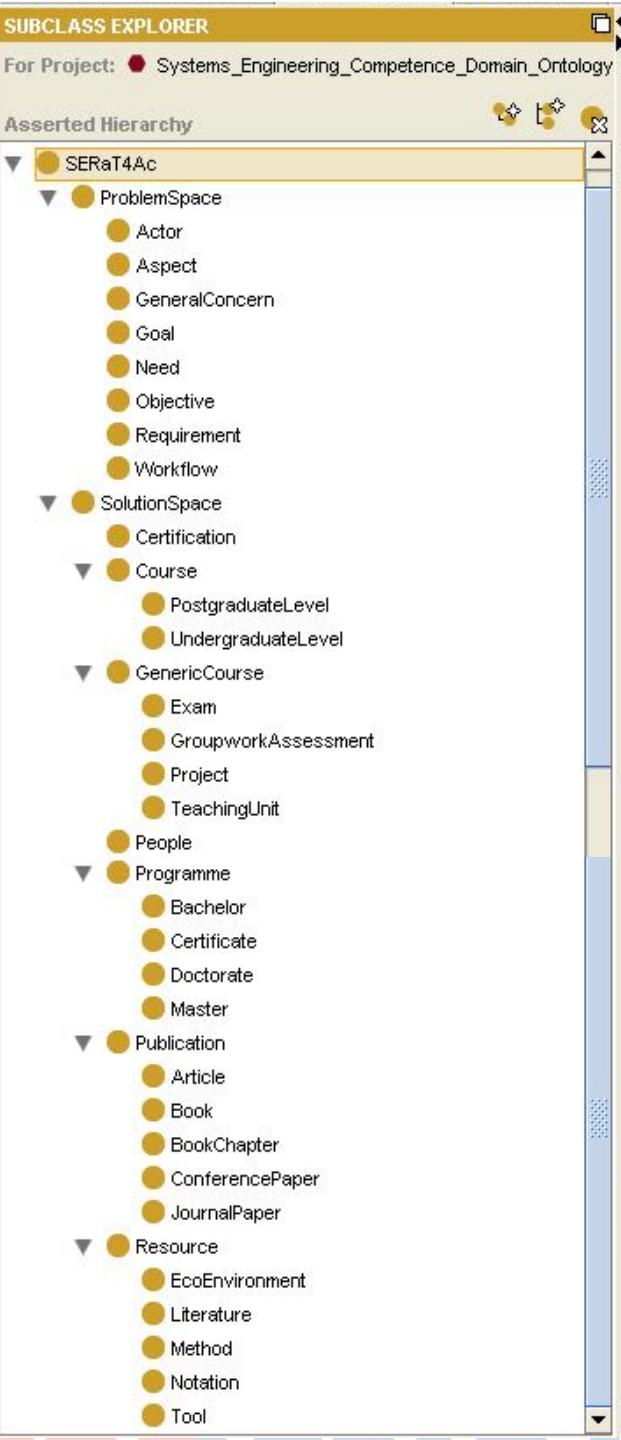
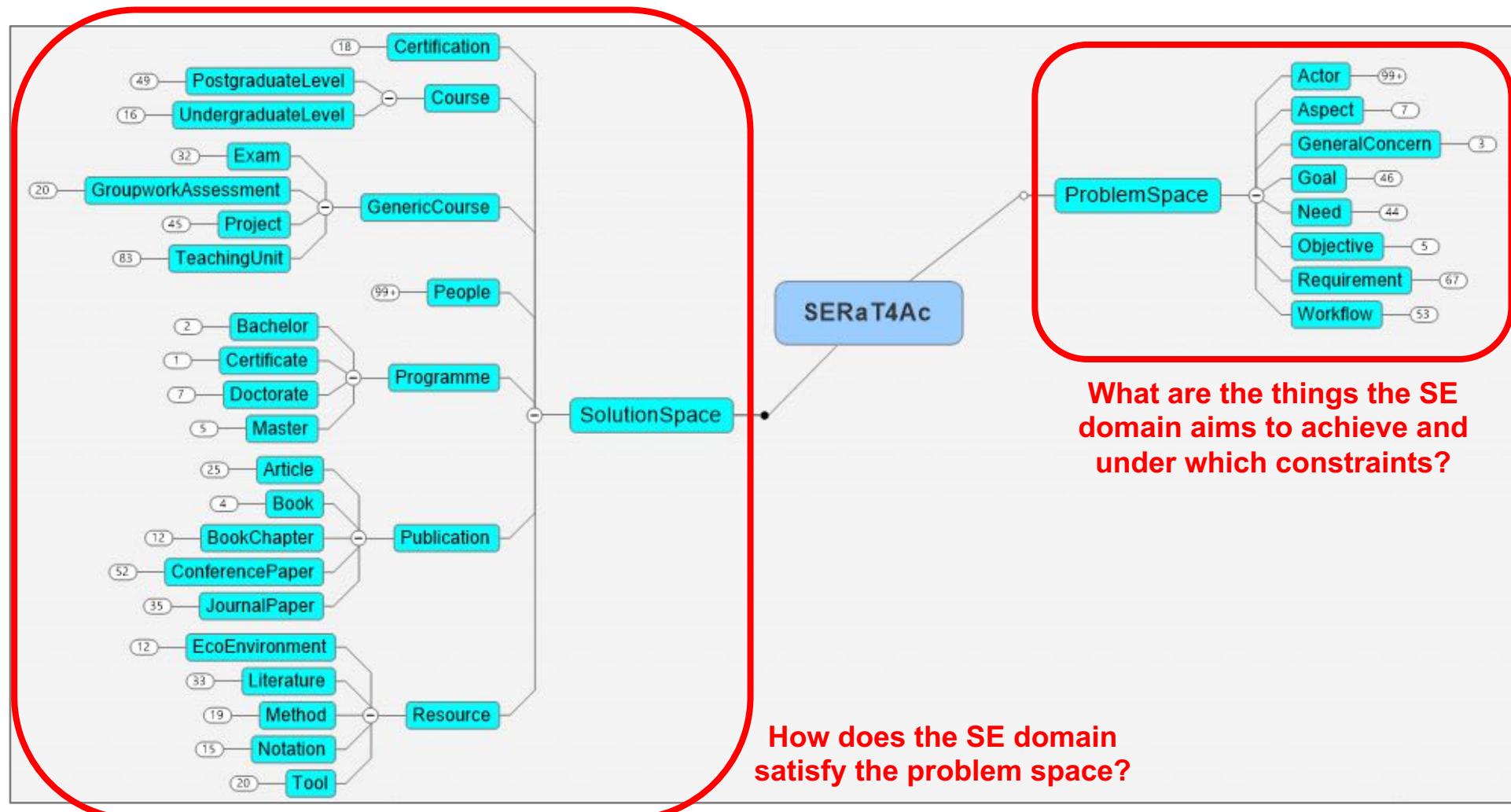
The **SE domain** of a university as the System of Interest (SoI) can be specified in terms of its problem and solution spaces, not to:

- Replace the Human Resource Management tools of the university;
- Manage content of books, papers or other documents;

But rather to:

- ✓ Enhance the **decision-making** by the leadership of the university and the new SE domain;
- ✓ Enhance both **strategic planning and operational management** of the SE domain;
- ✓ Make the relevant **meta-knowledge explicit and re-usable**;
- ✓ **Avoid misunderstandings**;
- ✓ **Increase resilience** by reducing dependency on key individual staff members;
- ✓ **Enable continuous improvement, change management and training** of new staff members.

Building the class hierarchy





Defining object and datatype properties

PROPERTY BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

Object Datatype Annotation All

Object properties

- achieves ↔ isAchievedBy
- actsAs ↔ isEnactedBy
- arisesDuring ↔ givesRiseTo
- conducts ↔ isConductedBy
- conflictsWith ↔ conflictsWith** (highlighted with a red box)
- contributesToAchievementOf ↔ contributesToAchievement
- follows ↔ precedes
- givesRiseTo ↔ arisesDuring
- hasBeenCompletedWith ↔ hasCompleted
- hasBeenDerivedFrom ↔ isUsedToDerive
- hasCompleted ↔ hasBeenCompletedWith
- hasDomainExpert ↔ isDomainExpertOf
- hasNeed ↔ isNeedOf
- hasObjective ↔ isObjectiveOf
- hasOwner ↔ owns
- hasRelevantStakeholder ↔ isRelevantStakeholderOf
- hasRootGoal ↔ isRootGoalOf
- hasSubGoal ↔ isSubGoalOf
- hindersAchievementOf ↔ hindersAchievementOf
- includesPerformanceOf ↔ isPerformedDuring
- isAchievedBy ↔ achieves
- isApplicableFor ↔ isOfRelevanceFor
- isConductedBy ↔ conducts
- isConsideredDuring ↔ isConsideredFromThePerspectiveOf
- isConsideredFromThePerspectiveOf ↔ isConsideredDuring

PROPERTY EDITOR for conflictsWith (instance of owl:ObjectProperty, owl:SymmetricProperty)
For Property: http://www.owl-ontologies.com/OntoREM.owl#conflictsWith

Annotations

| Property | Value |
|--------------|--|
| rdfs:comment | One need or goal or requirement of the problem space is in conflict with one or several other needs or goals or requirements of the problem space. |

Domain **Range**
Need
Requirement
Goal

Range **Domain**
Need
Requirement
Goal

Functional
 InverseFunctional
 Symmetric
 Transitive

Inverse
 conflictsWith



Defining object and datatype properties

PROPERTY BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

Object Datatype Annotation All

Datatype Properties

- hasActor
- hasAdditionalInformation
- hasConditionForAction
- hasConstraintOnAction
- hasDestinationOfAction
- hasHistory
- hasMeansOfRequirementsValidation
- hasObjectOfAction
- hasOldID
- hasPriority
- hasRationale
- hasRequirementScope
- hasRequirementStatus
- hasShallAction
- hasSource
- hasUniqueId
- hasUrgency
- hasValueOf
- isAttended**
- isBasedOnAssumption
- isOfRequirementType
- wasEntered
- wasLastUpdated

PROPERTY EDITOR for isAttended (instance of owl:DatatypeProperty)
For Property: <http://www.owl-ontologies.com/OntoREM.owl#isAttended>

Annotations

| Property | Value | Lang |
|--------------|---|------|
| rdfs:comment | To show how a specific course is attended by a student. | |

Domain: Course

Range: string

Functional

Allowed values

- On-site full time
- On-site part time
- On-line



Creating instances of classes

CLASS BROWSER

For Project: Systems_Engineering_Competence_Domain_Ontology

Class Hierarchy

- ProblemSpace
 - Actor (15)
 - Aspect (5)
 - GeneralConcern (3)
 - Goal (26)
 - Need (3)
 - Objective (5)
 - Requirement (39)
 - SystemLifecycleProcess
 - Workflow (7)
- SolutionSpace
 - Certification (6)
 - Course
 - PostgraduateLevel (9)
 - UndergraduateLevel (2)
 - GenericCourse
 - Exam (32)
 - GroupworkAssessment (20)
 - Project (45)
 - TeachingUnit (83)
 - People (117)
- Programme
 - Bachelor (3)
 - Certificate (2)
 - Doctorate (3)
 - Master (5)
- Publication

INSTANCE BROWSER

For Class: PostgraduateLevel

Asserted Inferred

Asserted Instances

- MasterDissertationProjectSE
- OperationsEngineering
- QualityAndConfigurationManagement
- RequirementsEngineering
- SoftwareEngineering
- SystemsEngineeringAdvanced
- SystemsModeling
- VerificationAndValidationManagement
- PostgraduateLevel_3

Create instance

INDIVIDUAL EDITOR for PostgraduateLevel_3 (instance of PostgraduateLevel)

For Individual: http://www.owl-ontologies.com/OntoREM.owl#PostgraduateLevel_3

Annotations

| Property | Value | Lang |
|--------------|-------|------|
| rdfs:comment | | |

isAttended

| Value | Type |
|-------|------|
| | |

isConductedBy

| Value | Type |
|-------|------|
| | |

withTheParticipationOf

| Value | Type |
|-------|------|
| | |

hasDomainExpert

| Value | Type |
|-------|------|
| | |

makesUseOf

| Value | Type |
|-------|------|
| | |

Asserted Types

- PostgraduateLevel

Annotations

Annotations



Establishing traceability by linking instances

CLASS BROWSER

For Project: Systems_Engineering_Competence_Domain_Ontology

Class Hierarchy

- ProblemSpace
 - Actor (15)
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INSTANCE BROWSER

For Class: PostgraduateLevel

Asserted Inferred

Asserted Instances

- MasterDissertationProjectSE
- OperationsEngineering
- QualityAndConfigurationManagement
- RequirementsEngineering
- SoftwareEngineering
- SystemsEngineeringAdvanced
- SystemsModeling
- VerificationAndValidationManagement
- PostgraduateLevel_3

INDIVIDUAL EDITOR for PostgraduateLevel_3 (instance of PostgraduateLevel)

For Individual: http://www.owl-ontologies.com/OntoREM.owl#PostgraduateLevel_3

Annotations

| Property | Value | Lang |
|--------------|-------|------|
| rdfs:comment | | |

isAttended

| Value | Type |
|-------|------|
| | |

isConductedBy

| Value | Type |
|-------|------|
| | |

withTheParticipationOf

| Value | Type |
|-------|------|
| | |

makesUseOf

| Value | Type |
|-------|------|
| | |

Select Resources..

Allowed Classes

- CaseStudy (3)
- EcoEnvironment (9)
- Literature (13)
- Method (16)
- Notation (5)
- Tool (27)

Direct Asserted Instances

- BPMN
- OWL
- RAD
- SysML
- UML

OK Cancel

The screenshot shows the Protégé ontology editor interface. The left panel is the Class Browser, displaying the class hierarchy for 'Systems_Engineering_Competence_Domain_Ontology'. The middle panel is the Instance Browser for the 'PostgraduateLevel' class, showing asserted instances like 'MasterDissertationProjectSE' and 'PostgraduateLevel_3'. The right panel is the Individual Editor for the instance 'PostgraduateLevel_3'. A 'Select Resources..' dialog is open in the foreground, showing a list of allowed classes: CaseStudy (3), EcoEnvironment (9), Literature (13), Method (16), Notation (5), and Tool (27). A list of direct asserted instances is also shown: BPMN, OWL, RAD, SysML, and UML. The 'Notation' class is highlighted with a red box, and the 'OWL' instance is also highlighted with a red box, indicating they are being selected for linking.

Example – SE courses



CLASS BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

INSTANCE BROWSER
For Class: PostgraduateLevel

INDIVIDUAL EDITOR for RequirementsEngineering (instance of PostgraduateLevel)
For Individual: http://www.owl-ontologies.com/OntoREM.owl#RequirementsEngineering

Annotations

Class Hierarchy

- Course (6)
 - PostgraduateLevel (7)
- GenericCourse
- People (117)
- Programme
- Publication
- Resource

Asserted Instances

- MasterDissertationProjectSE
- QualityAndConfigurationManagement
- RequirementsEngineering
- SoftwareEngineering
- SystemsEngineeringAdvanced
- SystemsModeling
- VerificationAndValidationManagement

Property

| Property | Value |
|--------------|---|
| rdfs:comment | This postgraduate course covers the current state-of-the-art in Requirements Engineering - including Research and Practice. |

isAttended

| Value | Type |
|-------------------|--------|
| On-site full time | string |
| On-site part time | string |
| On-line | string |

isConductedBy

- Prof_Clare_Clever
- Prof_John_Extremelybusy

hasDomainExpert

- Prof_John_Extremelybusy

withTheParticipationOf

- CourseLeader
- DomainExpert
- ExternalResearchPartner
- InternalResearchPartner

Asserted Types

- PostgraduateLevel

Example – Need to ensure employability



CLASS BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

Class Hierarchy

- owl:Thing
- SERaT4Ac
- ProblemSpace
 - Actor (15)
 - Aspect (5)
 - GeneralConcern (3)
 - Goal (26)
 - Need (3) **highlighted**
 - Objective (5)
 - Requirement (39)
 - Workflow (7)
- SolutionSpace
 - Certification (6)
 - Course
 - PostgraduateLevel (7)
 - UndergraduateLevel (2)
 - GenericCourse
 - Exam (32)
 - GroupworkAssessment (20)
 - Project (45)
 - TeachingUnit (83)
 - People (117)
 - Programme
 - Bachelor (2)
 - Certificate (1)
 - Doctorate (3)
 - Master (5)

INSTANCE BROWSER
For Class: Need

Asserted Instances

- NeedToAttractBestStudentsAndStaff
- NeedToEnsureEmployabilityForStudents **highlighted**
- NeedToPrepareStudentsForSECareer

INDIVIDUAL EDITOR for NeedToEnsureEmployabilityForStudents (instance of Need)

For Individual: http://www.owl-ontologies.com/OntoREM.owl#NeedToEnsureEmployabilityForStudents

Annotations

| Property | Value | Lang |
|--------------|---|------|
| rdfs:comment | The Systems Engineering domain of the university needs to ensure that students be attractive to industrial and academic employers, following their studies. | |

arisesDuring

- LeadAndManage

hasOwner

- Chairman
- CourseLeader
- ModuleLeader
- ProgramLeader

isNeedOf

- SystemsEngineering

conflictsWith

- Requirement_27
- Requirement_29

hasRelevantStakeholder

- Chairman

isSatisfiedBy

- Requirement_28
- Requirement_30
- Requirement_33
- Requirement_35
- Requirement_36
- Requirement_37
- Requirement_38
- Requirement_39
- Requirement_42
- Requirement_47
- Requirement_49
- Requirement_50

hasDomainExpert

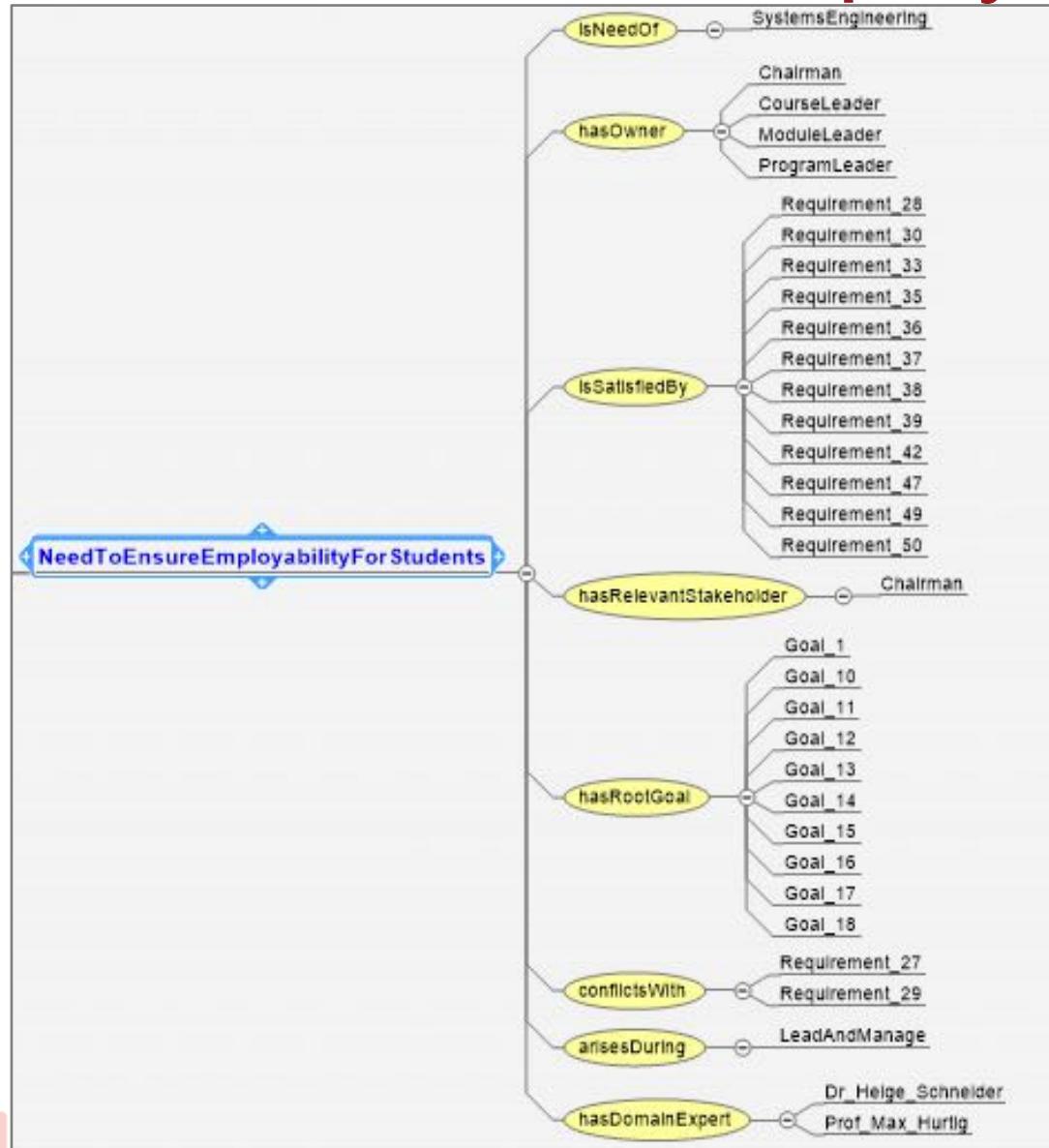
- Dr_Helge_Schneider
- Prof_Max_Hurtig

hasRootGoal

- Goal_1
- Goal_10
- Goal_11
- Goal_12
- Goal_13
- Goal_14



Example – Need to ensure employability



Alternative mind map view



Example – Academic staff member

CLASS BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

Class Hierarchy

- owl:Thing
- SERaT4Ac
- ProblemSpace
- Actor (15) **Selected**
- Aspect (5)
- GeneralConcern (3)
- Goal (26)
- Need (3)
- Objective (5)
- Requirement (39)
- Workflow (7)
- SolutionSpace
- Certification (6)
- Course
 - PostgraduateLevel (7)
 - UndergraduateLevel (2)
- GenericCourse
 - Exam (32)
 - GroupworkAssessment (20)
 - Project (45)
 - TeachingUnit (83)
- People (117)
- Programme
 - Bachelor (2)
 - Certificate (1)
 - Doctorate (3)
 - Master (5)

INSTANCE BROWSER
For Class: Actor

Asserted Inferred

Asserted Instances

- AcademicSupervisor
- Chairman
- CourseLeader
- DirectorOfStudies
- DomainExpert
- ExternalExaminer
- ExternalResearchPartner
- IndustrialSupervisor
- InternalExaminer
- InternalResearchPartner
- Lecturer
- ModuleLeader
- ProgramLeader
- RelevantStakeholder
- Student

INDIVIDUAL EDITOR for AcademicSupervisor (instance of Actor)

For Individual: http://www.owl-ontologies.com/OntoREM.owl#AcademicSupervisor

Annotations

| Property | Value | Lang |
|--------------|---|------|
| rdfs:comment | The academic supervisor is part of the supervisory team for postgraduate research projects, i.e. master dissertation projects or Ph.D. or DPhil projects. | |

Properties and their asserted values:

- isEnactedBy
 - Dr_Elisabeth_Moreintelligent
 - Dr_Helge_Schneider
 - Dr_Kurt_Alreadythere
 - Prof_John_Exremelybusy
 - Prof_Max_Hurtig
- owns
 -
- performs
 - Publish
 - Research
 - Teach
- isRelevantStakeholderOf
 -
- participatesIn
 - DPhil
 - FinalYearProjectSE
 - MasterDissertationProjectSE
 - PhD



Example – Academic staff member

◆ Prof_Max_Hurtig (instance of People, internal name is http://www.owl...)

INDIVIDUAL EDITOR for Prof_Max_Hurtig (instance of People)

For Individual: http://www.owl-ontologies.com/OntoREM.owl#Prof_Max_Hurtig

Annotations

| Property | Value | Lang |
|--------------|-------|------|
| rdfs:comment | | |

actsAs

- ◆ AcademicSupervisor
- ◆ CourseLeader
- ◆ DirectorOfStudies
- ◆ DomainExpert
- ◆ InternalExaminer
- ◆ Lecture

isDomainExpertOf

- ◆ RequirementsEngineering
- ◆ SoftwareEngineering
- ◆ SystemsModeling

conducts

- ◆ MasterDissertationProjectSE
- ◆ RequirementsEngineering
- ◆ SoftwareEngineering
- ◆ SystemsModeling

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Example – Professional SE certifications

CLASS BROWSER
For Project: Systems_Engineering_Competence_Domain_Ontology

INSTANCE BROWSER
For Class: Certification

Asserted Instances

- ASEP
- CSEP
- OCSMP_MB_Advanced
- OCSMP_MB_Fundamental
- OCSMP_MB_Intermediate
- OCSMP_MU



Conclusions

- ✓ Given that SE is essential for the development and in-life support of increasingly complex systems and SoS, it seems **urgent and important** for engineering based universities to include SE in their academic portfolio.
- ✓ One possible **enabler** of the successful establishment of SE as part of the academic portfolio is to develop and maintain **an SE domain ontology** that helps to manage the complexity of the SE domain knowledge.
- ✓ The generic SE domain ontology '**SERaT4Ac**' (SE Research and Teaching for Academia) was developed using the leading open source ontology editor Protégé and the OWL notation; the applied, iterative ontology development process was presented, using typical examples.
- ✓ 'SERaT4Ac' is intended to serve as a **useful starting point** for universities who wish to follow the proposed approach, which of course would have to be adjusted to a specific university's existing infrastructure and ways of working; so that the new SE domain of the university would be fully **aligned with the university's context** in terms of its vision, strategy, policies, directives, and overall terminology.
- ✓ As part of **future research**, it would seem interesting to conduct one or several comprehensive case studies using the proposed, generic SE domain ontology to **critically evaluate the suggested use of ontology, including the re-use of existing ontologies.**

Thank you



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