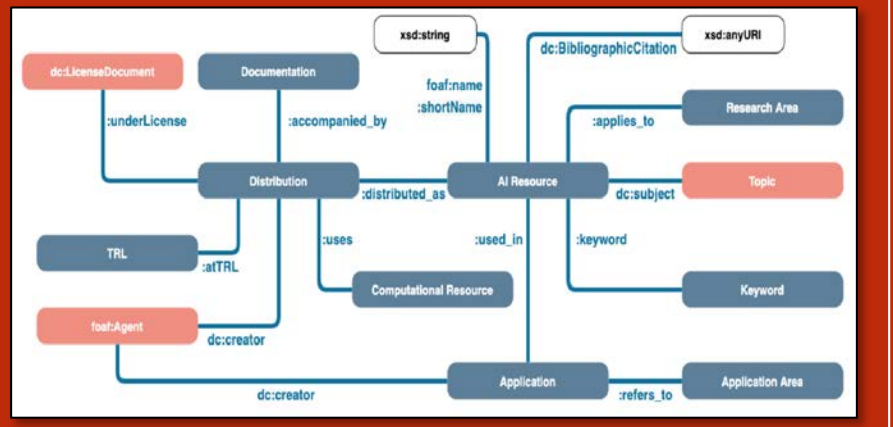


AI Ontology WG

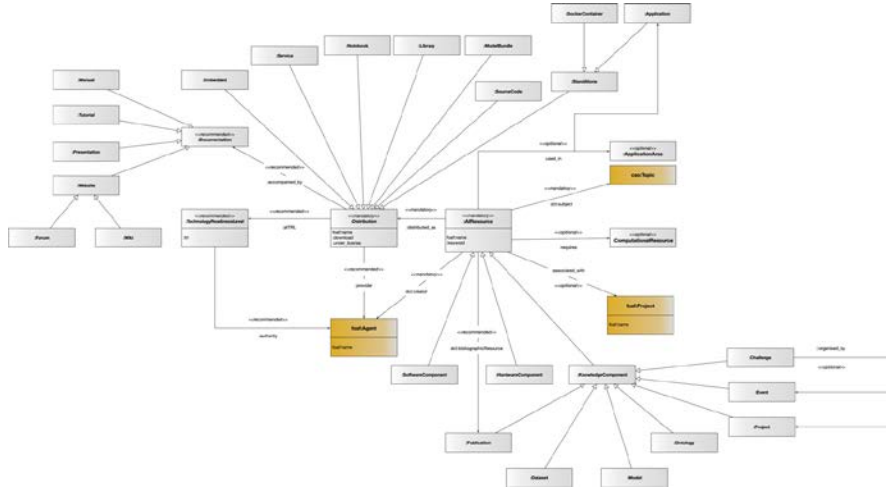
Objectives, Results and Next Steps

Costas D. Spyropoulos, Antonis Koukourikos
Javier Vázquez-Salceda, Miquel Buxons
Gabriel Gonzalez-Castañé

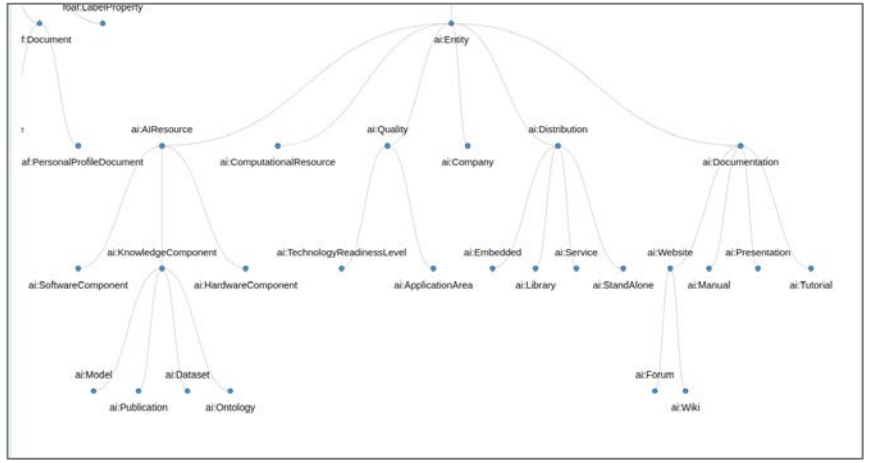
TGB Meeting
March 4 2022

Start Point: the AI4EU Conceptual Model

- **AI4EU Conceptual Model**
  (https://github.com/ai4eu/ai-resources-ontology)
  Ontology expressed using OWL W3C Standard
  Vocabularies expressed in SKOS W3C Recommendation
  Third-party ontologies used: DC-Terms, FOAF, CSO



- **AI4EU Knowledge Graph**
  (http://corese.inria.fr/srv/service/ai4eu)
  Corese Semantic Web Server
  web interface and SPARQL endpoint



- Problems:
  - Original AI4EU CMS not fully connected with the Conceptual Model
  - **Current AI4EU CMS is even more disconnected from the AI4EU Conceptual Model**

Why Ontologies?
Relevance of Ontologies in the AI on demand Ecosystem

- **Ontologies** are a computational, structured way to organize a dictionary of terms.
- If done properly they allow not only **semantic annotation**, but also **semantic reasoning**
- In the context of the AI on demand Ecosystem they may be useful for

    1. **Semantic annotation of resources**
    2. **Semantic Search**
    3. **Semantic Interoperability between different platforms**

Why Ontologies?
Relevance of Ontologies in the AI on demand Ecosystem

1. Semantic annotation of resources

Precisely tag AI resources in the platform beyond the current AI Technical Categories

- Allow users to better describe the resources they share (sub-techiques, appropriateness to problems's properties)
- This process doesn't need to be tedious, it could be an IA analysing the asset's text description and proposing tags to the user

2. Semantic Search

Improve searches on the AI on demand platform

- Better tagged resources → easier to find what you are looking for
- Use the ontology to do query extension (sinonyms, supra-concepts, sub-concepts)

Why Ontologies?
Relevance of Ontologies in the AI on demand Ecosystem

3. Semantic Interoperability between different platforms

- Option 1: (bilateral) to create 1-to-1 semantic mappings between AI4EU and other platform Schemas (AIPlan4EU, Bonsapps, Open ML....)

- Option 2: (intermediate model) to create an intermediate schema that can be used by any platform to exchange information with the other plaftorms (e.g., by using Model Transformations)

The AI Ontology WG
Origins

- Nov 2020
  Starts as an **intra-Project initiative**, as the Ontology Task Force within AI4EU's WP7

- March 2021 onwards
  Evolves into an **inter-Project initiative**, inviting all ICT-48 and ICT-49 projects arround AI4EU

- Initial **objectives**:
  - To avoid replication of work across projects on ontologies
  - To seek for a "common ontology" (if possible) to support the future AI-on-demand platform + other related projects (ICT48, ICT-49 and beyond)
  - To make knowledge discoverable across platforms
  - To incorporate trustworthy AI topics related to Knowledge Classification

- Initial members: **AI4EU, AIPlan4EU, AI4Copernicus, I-NERGY, StairwAI** + **ELG**
- New members: **DIH4EU, TAILOR, AI4Media**

The AI Ontology WG: some results

March – May 2021: Initial **compatibility analysis** between the **CSO taxonomy** (imported in AI4EU ontology) and **JRC's AI Watch "Taxonomy"**

1	Concept degree AI_Watch	concept	In CSO?	Comment	Preferred path in CSO
2	AI domain	Reasoning			reasoning ← ontologies ← semantics
3	AI domain	Planning			
4	AI domain	Learning			
5	AI domain	Communication			communication (main field)
6	AI domain	Perception			
7	AI domain	Integration and interaction			
8	AI domain	Services			
9	AI domain	AI Ethics and Philosophy			
10					
11	AI subdomain	Machine Learning			machine learning ← artificial intelligence ← computer science
12	AI subdomain	Natural Language processing			natural language processing ← artificial intelligence ← computer science
13	AI subdomain	Computer vision		No satisfactory CSO match	computer vision ← computer imaging and vision ← computer science
14	AI subdomain	Audio processing			
15	AI subdomain	Multi-agent systems			multi-agent systems ← artificial intelligence ← computer science
16	AI subdomain	Robotics and Automation		Unspecific idea behind the concept	
17	AI subdomain	Connected and Automated vehicles			
18	AI subdomain	AI Services			
19	AI subdomain	AI ethics			
20	AI subdomain	philosophy of AI			
21					
22	Outlier – keyword	mathematical programming			
23	Outlier – keyword	automated planning			
24					
25	Keyword	case-based reasoning			case-based reasoning ← knowledge based systems ← artificial intelligence ← computer science
26	Keyword	causal inference			
27	Keyword	causal models			
28	Keyword	common-sense reasoning			common-sense reasoning ← artificial intelligence ← computer science
29	Keyword	expert systems			expert systems ← artificial intelligence ← computer science
30	Keyword	fuzzy logic		No satisfactory CSO match	fuzzy logic systems ← adaptive control systems ← process control ← automation ← engineering
31	Keyword	graphical models			graphical models ← bayesian networks ← artificial intelligence ← computer science
32	Keyword	inductive programming			inductive logic programming ← machine learning ← artificial intelligence ← computer science
33	Keyword	information theory		No satisfactory CSO match	information theory ← communication
34	Keyword	knowledge representation & reasoning			knowledge representation and reasoning ← logic programming ← formal logic ← artificial intelligence ← cc

The AI Ontology WG: some results

March – May 2021: Initial **compatibility analysis** between the **CSO taxonomy** (imported in AI4EU ontology) and **JRC's AI Watch "Taxonomy"**

- This compatibility analysis influenced the first re-organization of the CMS Taxonomy

Current AI4EU business categories	Current AI4EU technical categories	HLEG categories	IJCAI categories	JRC categories
AI for agriculture	Algorithm Selection	Machine Learning	Multi-Agent Systems	Knowledge representation
AI for air traffic management	Computational logic	Machine Reasoning	Computer vision	Automated reasoning
AI for fashion	Computer vision	Robotics	Constraints and Satisfiability	Common sense reasoning
AI for space	Constraints and SAT	Data sets	Heuristic Search and Game playing	Planning and Scheduling
AI in autonomous driving and mobility	Decision support systems		Humans and AI	Searching
AI for law	Deep Learning		Knowledge Representation and Reasoning	Optimisation
AI in retail and ecommerce	Dialogue processing		Machine Learning	Machine learning
AI in Human Resources	Heuristic search		Multidisciplinary Topics and Applications	Natural language processing
AI in health	Knowledge representation		Natural Language Processing	Computer vision
AI for telecommunication	Machine Learning		Planning and Scheduling	Audio processing
AI for robotics	Multi-agent systems		Robotics	Multi-agent systems
AI for media	Natural language processing		Uncertainty in AI	Robotics and Automation
AI for IoT	Planning			Connected and Automated vehicles
AI for ambient intelligence	Probabilistic models			AI Services
AI for industry and manufacturing	Reasoning			AI Ethics
AI for finance & insurance	Robotics			Philosophy of AI
AI for environment and sustainability	Semantic Web			
AI for cybersecurity	Speech/Audio processing			
AI for citizen services & education	Other			
AI for art and music	Collaborative AI			
AI in software engineering	Explainable AI			
Trusted and Privacy preserving AI	Integrative AI			
Other	Physical AI			
	Verifiable AI			

Color codes

AI4EU category not present in other taxonomies

AI4EU category that is a sub-category in other taxonomies

The AI Ontology WG: some results

March – May 2021: Initial **compatibility analysis** between the **CSO taxonomy** (imported in AI4EU ontology) and **JRC's AI Watch "Taxonomy"**

- This compatibility analysis influenced the first re-organization of the CMS Taxonomy

Business categories	Research areas (AI4EU)	Technical categories (JRC)
AI for agriculture	Collaborative AI	Knowledge representation
AI for air traffic management	Explainable AI	Automated reasoning
AI for fashion	Integrative AI	Common sense reasoning
AI for space	Physical AI	Planning and Scheduling
AI in autonomous driving and mobility	Verifiable AI	Searching
AI for law		Optimisation
AI in retail and ecommerce		Machine learning
AI in Human Resources		Natural language processing
AI in health		Computer vision
AI for telecommunication		Audio processing
AI for robotics		Multi-agent systems
AI for media		Robotics and Automation
AI for IoT		Connected and Automated vehicles
AI for ambient intelligence		AI Services
AI for industry and manufacturing		AI Ethics
AI for finance & insurance		Philosophy of AI
AI for environment and sustainability		
AI for cybersecurity		
AI for citizen services & education		
AI for art and music		
AI in software engineering		
Trusted and Privacy preserving AI		
Other		

The AI Ontology WG: some results

May – July 2021: **AI Platforms vs Representation needs map** to identify
1) commonalities and shared needs, 2) gaps in the existing AI4EU conceptual model

main concept ->	AI (Software) Artifacts	Problems	Datasets	Benchmarks	HW infrastructure	Academic and Educational Resour	Courses and Certifications	People (and Skills)	Orgs, Services, Areas	*Ethics*
sub-concepts ->	AI Models, AI Algorithms, AI Tools, AI Libraries,	[AIPlan4EU: please propose examples of concepts] Problem			HW resource, HW properties, HW provider, Container	Academic Resources (Papers,Books,)Edu	Bachelor/Master Degrees,Short Courses,(	Experts,Consultants,Develop	Company, Organization Application Areas, Services	Fairness, Explainibility, etc...
some suggested properties to be modelled ->	*AI areas and sub-areas, AI techniques, licenses*	*[AIPlan4EU: please propose examples of properties and relations]*	*data format*	*measurement*	*power, latency, ...*	*title, author, publisher, language*	*open/close date, fees, required certifications, required qualifications*	*expertise, competences*	*business sector, services provided, business need*	
Project-Specific Ontologies and Data Models										
AI4EU – European Artificial Intelligence On-Demand Platform https://www.ai4europe.eu/ *Data Model or Ontology?*: both *urls to current description/model*: <to be added> prefix: ai	[Imports CSO, DCIM] AI Resource form: defines Technical Categories ai:AIResource ai:Application ai:Distribution ai:Embedded ai:Library ai:Model ai:ModelBundle ai:Notebook ai:Service ai:SoftwareComponent ai:SourceCode ai:StandAlone Research Areas Vocabulary: Explicable AI, Verifiable AI, Physical AI, Integrative AI, Collaborative AI, Algorithm selection, Computational logic, Computer Vision, Constraints and SAT, Decision support systems, Heuristic search and game playing, Knowledge representation and reasoning, Machine learning, Multi-agent systems, Planning, Speech and signal processing, Natural language and dialogue processing, Probabilistic models	<to be checked>	ai:Dataset ai:Distribution ai:Ontology	[To add a specialization of ai:Dataset for benchmarks]	ai:HardwareComponent ai:ComputationalResource ai:DockerContainer	ai:Publication ai:Presentation ai:Documentation ai:EducationalResource ai:Forum ai:KnowledgeComponent ai:Manual ai:Tutorial ai:Website ai:Wiki	ai:Challenge ai:Event ai:Forum ai:KnowledgeComponent ai:SuccessStory ~~ai:Tutorial~~	[Imports FOAF]	ai:AIOrganization ai:Company ai:ApplicationArea ai:Project ai:Service	ai:Quality [To examine adding specialization classes for explainability, trust]
Bonseyes/BonsAPPs https://www.bonseyes.eu/ https://www.bonseyes.com/ *Data Model or Ontology?*: Data Model *urls to current description/model*: <to be added>	AIArtifact (Model, Algorithm, Tool, AI Application), ToolChain, Inference Engine, licenses	Challenge	Data (subclass of AIArtifact - undefined)	Benchmark, AI Benchmark, Measurement Metric	Machine, Platform, DockerImage			Profile (user)	Company, Laboratory, LaboratoryArtifact	
StairwAI https://stairwai.nws.cs.unibo.it/ *Data Model or Ontology?*: both *urls to current description/model*: <to be added> prefix: sw ai	sw ai:Model (= ai:Model), sw ai:Algorithm, sw ai:Tool, sw ai:Library (= ai:Library) sw ai:AIArtifact (similar but not equivalent to ai.AIResource), sw ai:Distribution doap:Version, sw ai:AITechnique (= cso:Artificial	sw ai:Need sw ai:ProblemStatement	sw ai:Dataset (= dcat:Dataset)	sw ai:Benchmark, sw ai:Measurement sw ai:Metric (based on Bonseyes' Data Model)	ai:hardwareComponent, sw ai:AIHardwareComponent, sw ai:hardwarePlatform, cso:HardwarePlatform	ai:KnowledgeComponentsw ai:AcademicP	sw ai:Certification (= esco:Qualification),sw	sw ai:Person(= foaf:Person) sw ai:Agent (= foaf:Agent) esco:Skill	sw aiOrganization (= foaf:Organization & org:Organization), sw ai:BusinessArea (= saro:Sector), org:Post, sw ai:JobPosting (= saro:JobPosting) sw ai:OpenCall	not implemented in the current version of the model

The AI Ontology WG: some results

May – July 2021: **AI Platforms vs Representation needs map** to identify
1) commonalities and shared needs, 2) gaps in the existing AI4EU conceptual model

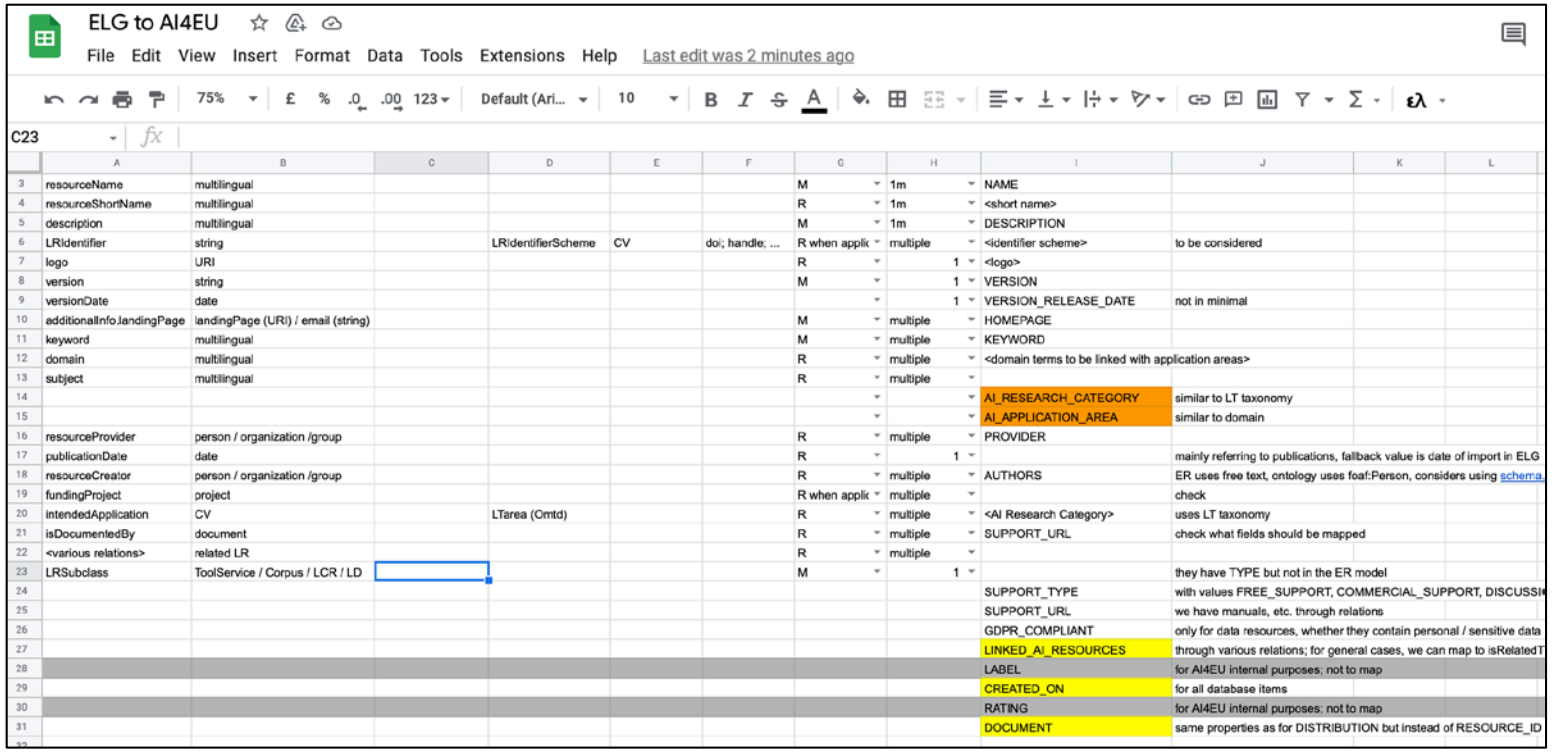
main concept ->	AI (Software) Artifacts	Problems	Datasets	Benchmarks	HW infrastructure	Academic and Educational Resour	Courses and Certifications	People (and Skills)	Orgs, Services, Areas	*Ethics*
sub-concepts ->	AI Models, AI Algorithms, AI Tools, AI Libraries,	[AIPlan4EU: please propose examples of concepts] Problem			HW resource, HW properties, HW provider, Container	Academic Resources (Papers,Books,)Edu	Bachelor/Master Degrees,Short Courses,(	Experts,Consultants,Develop	Company, Organization Application Areas, Services	Fairness, Explainibility, etc...
some suggested properties to be modelled ->	*AI areas and sub-areas, AI techniques, licenses*	*[AIPlan4EU: please propose examples of properties and relations]*	*data format*	*measurement*	*power, latency, ...*	*title, author, publisher, language*	*open/close data, fees, required certifications, required qualifications*	*expertise, competences*	*business sector, services provided, business need*	
AIPlan4EU Bringing AI Planning to the European AI On-Demand Platform *Data Model or Ontology?*: Data Model *url/s to current description/model:* https://github.com/aiplan4eu/upf/wiki/Planning-Taxonomy	AI Planning algoritms taxonomy(Heurisic search, Reduction to Satisfiability, MCTS, Local search, Symbolic search, Reinforcement Learning, Plan-space planning, Analytical, Case-based planning, Reductions, Width-based planning)	problem taxonomy(Pure scheduling, Presence of Time, Presence of numerical quantities, Hierarchical structure, Motion planning, Simulated entities, Agents, Discrete non-determinism, Observability, Optimization objectives, Optimization Kind)							Use-cases(Underwater Vehicles, Planning agricultural operations, Planning for consumer-goods experiments, Planning for Space, Autonomous Vehicles Fleet Management, Indoor Robotics, Flexible Manufacturing)	
AI4Copernicus AI4EU Platform by Advancing Earth Observation Intelligence *Data Model or Ontology?*: Ontology *url/s to current description/model:* <to be added>	ai:Service co:AI Algorithm ai:AI Resource ai:Application ai:Distribution		co: EO Collection ai: Distribution dcat: Dataset		ai:HardwareComponentco: EO Ec	orkg-core:'Research Contribution' orkg-core:'Research Paper' ai:Publication ai:Presentation ai:Documentation ai:EducationalResource ai:Forum ai:KnowledgeComponent ai:Manual ai:Tutorial ai:Website ai:Wiki			foaf: Agent foaf: Organization ai:ThematicArea co: EO Data Access Platform	
I-NERGY Artificial Intelligence for Next Generation Energy *Data Model or Ontology?*: <both> *url/s to current description/model:* <to be added>	Machine Learning algorithms [Imports BIM]	<to be checked>	[Imports HAYSTACK] [Imports BRICK] [Imports BIM] data sources Buildings - Data sets from Electric Power & Energy Systems		[Imports BRICK] [Imports SAREF] Buildings - CIM					
DIH4AI platform for regional interoperable Digital Innovation Hubs Network *Data Model or Ontology?*: <to be added> *url/s to current description/model:* <to be added>									Taxonomy of services for SME's: technical services, business services	
TAILOR Foundations of Trustworthy AI *Data Model or Ontology?*: <to be added> *url to current description/model:* <to be added>										
ELG - European Language Grid https://www.european-language-grid.eu *Data Model or Ontology?*: - Data Model (XSD): https://gitlab.com/european-	ms:LanguageResource, with subclasses: ms:ToolService, ms:Corpus, ms:LexicalConceptualResource, ms:LanguageDescription		ms:Corpus ms:LexicalConceptualResource ms:LanguageDescription (includes models	ms:Evaluation ms:PerformanceIndicator (ms:metric, ms:measure, ms:unitofMeasureMe	ms:requiredHardware ms:additionalHWrequirements	ms:Document (used for publications, books, manuals, presentations, etc.)		ms:Person	ms:Organization ms:Group ms:Project omtd:Operation used as the "taxonomy of Language Technology areas" (LT	focus on GDPR issues for now (ms:personalDataIncluded, ms:sensitiveDataIncluded

The AI Ontology WG: some results

Sept – Nov 2021: compilation of **research questions** for the Ontology WG

- Semantic Alignment between AI4EU Conceptual Data Model and other models

Q3.1 to explore the refinement of the semantic definitions given for the AI4EU classes, to better clarify alignments with existing classes in other ontologies (including, but not limited to ELG, OpenML, BonsApps)



ELG to AI4EU

File Edit View Insert Format Data Tools Extensions Help Last edit was 2 minutes ago

C23

	A	B	C	D	E	F	G	H	I	J	K	L
3	resourceName	multilingual					M	1m	NAME			
4	resourceShortName	multilingual					R	1m	<short name>			
5	description	multilingual					M	1m	DESCRIPTION			
6	LRIdentifier	string		LRIdentifierScheme	CV	doi; handle; ...	R when applic	multiple	<identifier scheme>	to be considered		
7	logo	URI					R	1	<logo>			
8	version	string					M	1	VERSION			
9	versionDate	date						1	VERSION_RELEASE_DATE	not in minimal		
10	additionalInfo.landingPage	landingPage (URI) / email (string)					M	multiple	HOMEPAGE			
11	keyword	multilingual					M	multiple	KEYWORD			
12	domain	multilingual					R	multiple	<domain terms to be linked with application areas>			
13	subject	multilingual					R	multiple				
14									AI_RESEARCH_CATEGORY	similar to LT taxonomy		
15									AI_APPLICATION_AREA	similar to domain		
16	resourceProvider	person / organization /group					R	multiple	PROVIDER			
17	publicationDate	date					R	1		mainly referring to publications, fallback value is date of import in ELG		
18	resourceCreator	person / organization /group					R	multiple	AUTHORS	ER uses free text, ontology uses foaf:Person, considers using schema.		
19	fundingProject	project					R when applic	multiple		check		
20	intendedApplication	CV		LTarea (Omtd)			R	multiple	<AI Research Category>	uses LT taxonomy		
21	isDocumentedBy	document					R	multiple	SUPPORT_URL	check what fields should be mapped		
22	<various relations>	related LR					R	multiple				
23	LRSubclass	ToolService / Corpus / LCR / LD					M	1		they have TYPE but not in the ER model		
24									SUPPORT_TYPE	with values FREE_SUPPORT, COMMERCIAL_SUPPORT, DISCUSSI		
25									SUPPORT_URL	we have manuals, etc. through relations		
26									GDPR_COMPLIANT	only for data resources, whether they contain personal / sensitive data		
27									LINKED_AI_RESOURCES	through various relations; for general cases, we can map to isRelatedT		
28									LABEL	for AI4EU internal purposes; not to map		
29									CREATED_ON	for all database items		
30									RATING	for AI4EU internal purposes; not to map		
31									DOCUMENT	same properties as for DISTRIBUTION but instead of RESOURCE_ID		

The AI Ontology WG: some results

Sept – Nov 2021: compilation of **research questions** for the Ontology WG

- Extending AI4EU Conceptual Data Model with reasoning/planning concepts

Q1.1 Can the AIPlan4EU plan taxonomy (or a subset of it) be useful to tag AI resources in the AI4EU catalog?

Q1.2 How to express (archetypical, domain-independent) problem types?

Q1.3 How to characterize kinds of solutions, and requirements on the solutions.

The AI Ontology WG: some results

Sept – Nov 2021: compilation of **research questions** for the Ontology WG

- Extending AI4EU Conceptual Data Model with Machine Learning concepts, and knowledge/data adquisition/processing/management concepts

Q2.1. How to express Knowledge Acquision Methods

Q2.2. How to express Data Catalogues and Collections. Relation to elg:Dataset and its subclasses

Q2.3. How to express Data Processing techniques (could be mapped in a kind of archetipical Problem class and subclasses, so this is related to Q1.2)

Q2.4. How to express Quality (on the original data and as requirement for the solution)

Q2.5. Can the AI4Copernicus data processing taxonomy (or a subset of it) be useful to tag AI resources in the AI4EU catalog?

Q4.1 Shall we extend in the Ontology the concepts related to Dataset, Model and ML Algorithm in order to better describe (a taxonomy of) Machine Learning Techniques, Machine Leaning models, more detail on data-driven Processes, Tool chains, maybe different aspects on Datasets, and include Benchmarks and metrics?

The AI Ontology WG: some results

Sept – Nov 2021: compilation of **research questions** for the Ontology WG

- Other extensions/refinements in the AI4EU Conceptual Data Model

Q5.1 Can we refine the taxonomy of AI techniques to a) allow resource publishers better characterize the resource they are publishing b) ease the search of AI resources, and c) support the horizontal matchmaking in StairwAI

Q5.2 Shall we add more properties and relations to the AI Resource classes/subclasses to include, the kind of archetypical problem (Optimization, Classification, Forecasting...) that may be tacked by the technique, and the requirements for its execution (can be parallelized, cannot be parallelized, requires GPU, ...

Q5.3 Shall we refine the hardware-related elements in the ontology to include concepts such as Machine, Platform, Container, execution Environment?

The AI Ontology WG
Next Steps

- Bring in other projects working on / interested in Ontologies about AI

- Not only focus on Ontologies, but also Data Models
    - to attract projects in the AI ecosystem that are not (yet) interested in ontologies

- Create a web page within the AI on demand platform on AI Ontologies
    - To list the existing ontologies in the field
    - To attract the ontology community to the platform → AI ontologies as another resource

Thank you for your attention!

AI Ontology WG

(if you are interested to join, send e-mail to jvazquez@cs.upc.edu)