Stairway to AI: Ease the Engagement of Low-Tech users to the AI-on-Demand platform through AI, H2020

Design of the knowledge representation in the StairwAI AI Asset Management System - 2nd version

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Document Control Sheet

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0.2	17/05/2022	Minor corrections into sections 2,3,4 and 6 that were previously presented in D3.1	Javier Vázquez-Salceda
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0.6	02/06/2022	Introduce some further modifications to the conceptual models after the model discussion made during the StairwAI Plenary Meeting (Bolognia, from May 31 to June 1 2022).	Miquel Buxons, Javier Farreres, Javier Vázquez-Salceda
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1.0	30/06/2022	Final version including feedback from partners	

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Acronyms

Acronym	Explanation
ADMS	Asset Description Metadata Schema
AI	Artificial Intelligence
AMS	Asset Management System
API	Application Programming Interface
CSO	Computer Science Ontology
DCAT	Data Catalogue vocabulary
DOAP	Description Of a Project ontology
EBG	EU Business Graph
ESCO	European Skills, Competences, qualifications and Occupations ontology
EOSC	European Open Science Cloud
FaBiO	the FRBR_aligned bibliographic ontology
FOAF	Friends Of a Friend ontology
FRBR	Functional Requirements for Bibliographic Records model
HW	Hardware
ISO	International Organization for Standardization
ML	Machine Learning
NMT	Neural Machine Translation
NLP	Natural Language Processing
NLU	Natural Language Understanding
ORG	The Organization ontology
OWL	Web Ontology Language W3C Specification Simple Knowledge Organization System
PURL	Permanent Uniform Resource Locator
ROV	Registered Organisation Vocabulary
SARO	Skills and Recruitment Ontology

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SIOC	Semantically-Interlinked Online Communities
SKOS	Simple Knowledge Organization System ontology
SME	Small and Mid-size Enterprise
StairwAI AMS	StairwAI Asset Management System
SW	Software
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
VOID	Vocabulary of Interlinked Datasets
W3C	World Wide Web Consortium
WP	Work Package

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1. Executive Summary

Deliverable D3.2 is produced within WP3 (Task 3.1) and it reports the work towards the definition of the *AI Assets Conceptual Semantic Model*, the knowledge representation to be instantiated in StairwAI's AI Asset Management System (StairwAI AMS for short, also produced within WP3). This StairwAI AMS should support the operation of the Horizontal Matchmaking in WP5, the Vertical Matchmaking in WP6, and the Multi-lingual interaction components in WP4, and therefore the chosen knowledge representation will affect how these WP4-WP5-WP6 modules will exchange information among them. The requirements, captured from different project deliverables and technical Work Packages as main components of the StairwAI Architecture, are followed by the analysis of existing initiatives (the AI4EU Knowledge model, other ICT48 and ICT49 projects, other initiatives) that can be used as basis for the knowledge representation, and, finally, the proposed knowledge model is described in the form of a top ontology connected with other ontologies.

A first version of the knowledge representation was presented in D3.1. "Design of the knowledge representation in the StairwAI AI Asset Management System - 1st version", which was delivered in M9. This deliverable reports a second version of the *AI Assets Conceptual Semantic Model*, after the initial data gathering made by WP3 in Task 3.3, Task 3.4, Task 3.6 and to the updated requirements gathered by WP2 in D3.2. It also incorporates some changes coming from the interactions with related EU initiatives within the AI Ontology Working Group.

The continuation of the work presented here will be described in D3.4 "StairwAI AI Asset Management System - 2nd version" in M24 describing the prototype that implements the version of the *AI Assets Conceptual Semantic Model* described in this document.

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2. Introduction

StairwAI's main aim is to enhance the AI-on-demand platform services through a service layer that provides *horizontal matchmaking* (namely an automatic mapping between user requirements into assets of the AI-on-demand platform to meet users' business needs) and *vertical matchmaking* (automatic mechanisms for hardware resource dimensioning and hardware resource provider discovery to satisfy end user needs). The use of both services by users will be eased through natural multi-language interaction (a chatbot based on Natural Language Processing techniques that will ease the interaction with the system in the native language of the user). Figure 2.1 shows the planned interactions between the StairwAI services and the AI-on-demand platform.

The three core modules in the StairwAI system (the Multi-Lingual Virtual Assistant, the Horizontal Matchmaking module and the Vertical Matchmaking module) require the support of a semantically-enhanced information system to model all the different assets (libraries, tools, algorithms, professionals, academic resources, hardware and cloud services, job positions, experts, etc) that are exchanged among them. This information system is the *StairwAI Asset Management System* (StairwAI AMS for short). This system will structure all information about assets in the form of a knowledge graph, that is, a Semantic Web graph where entities are defined as class hierarchies that may be interconnected by extra domain-specific properties.

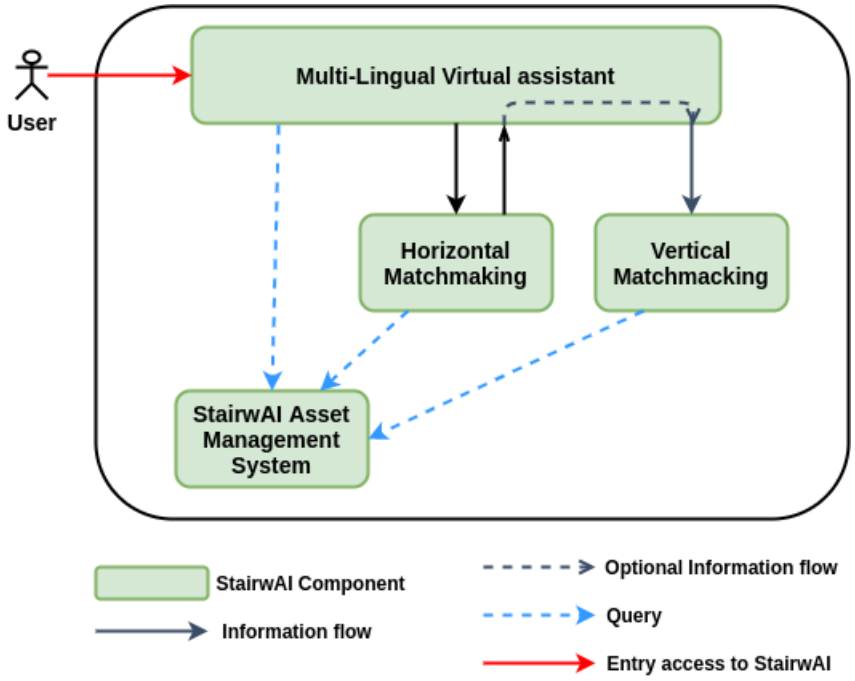

Figure 2.1 - Interactions between StairwAI's main components

In order to ensure the semantic coherence of the knowledge graph database used by the StairwAI AMS at all times and the semantic alignment with other initiatives within the AI4EU ecosystem, an *AI Assets Conceptual Semantic Model* should be defined. This model is specified using the Web Ontology Language (OWL) W3C Specification [1] as it not only provides a proper way for the semantic definition and interrelations of entities

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but also eases the import and usage of external entities and constructs from widely used ontologies (such as ORG, DCAT or FOAF).[1]

2.1. Purpose and Scope of the document

The purpose of this deliverable is to report the work made in Task 3.6 towards the definition of the second version of the *AI Assets Conceptual Semantic Model.* It is the semantic knowledge representation within the StairwAI AMS that encompasses the main elements used by the three main StairwAI modules: the Horizontal Matchmaking (built in WP5), the Vertical Matchmaking (built in WP6) and also the Multi-lingual interaction components (built in WP4). The deliverable describes the model's requirements, identifies existing initiatives that may be used as basis for the conceptual model, and describes the proposed *AI Assets Conceptual Semantic Model* as a top ontology interlinking other ontologies.

This *AI Assets Conceptual Semantic Model* (proposed in Section 5) has been implemented as a knowledge graph within the StairwAI AMS working prototype. It is worth noting that the instantiation of the Conceptual Semantic Model into the knowledge graph is not reported in this deliverable, as it will be reported as part of D3.5 "StairwAI AI Asset Management System - 2nd version" to be published in Month 24.

The first version of the *AI Assets Conceptual Semantic Model* was based on the collection of requirements within Phase 1 of the StairwAI project (months M1 to M6). Requirements have been collected by direct interaction with Task participants within the Work Package 3. Furthermore, the following documents (from other Work packages) have been used as support for capturing requirements:

- Deliverable D1.1 "Data management plan" (published on June 30, 2021). The document describes the data envisioned to be produced by all work packages, including the work package where this document is placed - WP3 Data sets – and needed by WP4-WP5-WP6 components to support the multi-lingual virtual assistant, horizontal and vertical matchmaking, respectively. The analysis of this information is used and supports the requirements in Section 3.
- Deliverable D2.1 "Requirements for the AI-on-demand platform" (published on June 30, 2021). The document provides the requirements for the Horizontal and Vertical Matchmaking - WP5 and WP6 accordingly. Since there are no direct requirements for neither the *StairwAI Asset Management System* nor the *AI Assets Conceptual Semantic Model*, we have analysed potential indirect requirements (requirements in WP5 and WP6 components that may imply a requirement to the knowledge representation they use) that we have included in Section 3.

The second version of the *AI Assets Conceptual Semantic Model* is an update of the first version, and it incorporates changes to the Conceptual Semantic Model that were identified as necessary during Phase 2 of the project (Months M7 to M18). It takes into account new representational needs coming from both the initial data gathering made by WP3 in Task 3.3, Task 3.4, and Task 3.6 and the build of the first prototypes of the StairwAI Chatbot (in WP4) and the Horizontal Matchmaking module (in WP5). It also incorporates some changes coming from the interactions with related EU initiatives within the AI Ontology Working Group (Task 3.2). Furthermore, the following document has been used as support for capturing new or updated requirements:

- Deliverable D2.2 "Requirements for the AI-on-demand platform" (published on June 30, 2022). The document updates the requirements for the Horizontal and Vertical Matchmaking - WP5 and WP6

[1] These ontologies and many others are described in Section 4.

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accordingly. Since there are almost no direct requirements for neither the *StairwAI Asset Management System* nor the *AI Assets Conceptual Semantic Model*, we analysed potential indirect requirements (requirements in WP5 and WP6 components that may imply a requirement to the knowledge representation they use), and those have been included in Section 3.

2.2. Context

The main project that is connected with StairwAI is AI4EU, devoted to the development of the European AI-on-demand platform. StairwAI's main objective is to ease the access of low-tech users to the AI4EU repository.

In its original conception, i.e., at the time of the proposal, StairwAI's AI Asset Conceptual Semantic Model was envisioned as an extension of the AI4EU Conceptual Semantic Model, providing a deeper structure and an extension to a wider range of assets. Furthermore, at that time, the details of the other ICT 49 projects that succeed in the same call – AI4Copernicus, AIplan4EU, Bonsapps, Inergy, and DIH4AI – were unknown. Therefore, the description of activities in WP3 assumed that 1) StairwAI would have been the only project that would extend the AI4EU Conceptual Semantic Model, 2) the AI4EU Conceptual Semantic Model (released in deliverable D3.4, by the end of the AI4EU project, i.e., end of 2020) would have been immutable and as such it would be a clear starting point for the semantic model in StairwAI, and 3) StairwAI would have been the only project involved with AI4EU in the discussion about the future evolution of the AI4EU Conceptual Semantic Model.

At the time of the StairwAI project kick off, the context changed. It was identified by WP8 that there was a need for aligning StairwAI with the other ICT 49 projects as, at least 3 of them – AI4Copernicus, AIPlan4EU, and I-Nergy –, had plans to extend (in different directions) the AI4EU conceptual semantic model to support new knowledge representation for the AI-on-demand platform. In addition, there were other initiatives such as European Language Grid (ELG) or other ICT 48 projects such as Tailor and AI4Media that expressed their interest to align with or connect to the AI-on-demand platform. For all of these reasons, modifications to the AI4EU Conceptual Semantic Model could not be decided autonomously but required the consensus of the other projects.

To foster a seamless cooperation between all these projects, a workshop planned from StairwAI WP8 initiative (Task 8.3 "Synchronization with AIPPP, Big Data and joint efforts with ICT48 and ICT 49") together with AI4EU's Ecosystem Development Activities has been held. This workshop (within the umbrella of the AI4EU Technical Governance Board) evolved into the AI Assets Ontology Working Group, a working group with the aim of reaching a consensus on the definition of a common ontology that supports the AI-on-demand platform. The group is currently working and targets the following objectives:

- Avoid replication of work across projects on ontologies.
- Seek for a "common ontology" (if possible) to support the future AI-on-demand platform and other related projects (ICT48, ICT-49 and beyond).
- Make knowledge discoverable across platforms.
- Incorporate trustworthy AI topics related to Knowledge Classification.

At the time of writing this report, the working group is composed of representatives from AI4Copernicus, AI4Media, AIPlan4EU, DIH4EU, ELG, I-NERGY, TAILOR and StairwAI. The working group has already identified some gaps in the AI4EU Conceptual Semantic Model and has started the discussions on how to improve it. Some of the updates made in StairwAI's Semantic Model come from these discussions.

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2.3. Structure of the document

Section 3 outlines the set of requirements on the *AI Assets Conceptual Semantic Model*.

Section 4 then analyses existing ontologies, vocabularies, terminologies, taxonomies, and reference documents that could be either the base for this Semantic Model or the inspiration for some parts of it. Section 4 also analyses projects and initiatives (including but not limited to ICT-48 and ICT-49 projects) that are developing ontologies and data models that could be relevant for our knowledge representation.

Section 5 describes the proposed *AI Assets Conceptual Semantic Model* as a top ontology and its connection to other existing ontologies.

Section 6 summarizes the main results reported in this deliverable.

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3. Conceptual Model requirements

This section analyses the knowledge representation needs that the StairwAI AMS should cover, to then identify model requirements for the definition of the *AI Assets Conceptual Semantic Model*. As explained in Section 2.1, these requirements are based on information collected in StairwAI's Phase 1 *"Initial Requirements"* (months M1 to M6) and Phase 2 *"Development"* (months M7 to M18).

3.1. The StairwAI Asset Management System

One of the objectives of StairwAI is "*to act as a link between low-tech users to AI experts and consultants, training and education activities, assets/software/services/tools in the repository of AI4EU, and physical resources/technologies registered to the AI4EU platform*". Therefore, the StairwAI AMS should be able to refer to the AI Assets registered in the AI4EU platform, and this will be the first requirement to the AI Asset Conceptual Semantic Model:

R1.1 Alignment with the AI4EU Conceptual Semantic Model
The AI Assets Conceptual Semantic Model should be semantically aligned to the concepts related to AI Assets in the AI4EU Conceptual Semantic Model *essential*

It is important to note here that, as explained in Section 2.2, in its original conception StairwAI's AI Asset Conceptual Semantic Model was envisioned as directly extending the AI4EU Conceptual Semantic Model. However, in the current context, with several projects willing to expand the AI4EU conceptual semantic model in different directions, it is not clear that StairwAI's model will be an extension of the full AI4EU model.[2]

Furthermore, the role of the StairwAI AMS is to provide a neutral set of concepts that enable semantically enhanced information exchange among the StairwAI components, thus promoting interoperability. To better understand how the AI Assets Conceptual Semantic Model should support the data exchange between the *Multi-Lingual Virtual Assistant*, the *Horizontal Matchmaking* module and the *Vertical Matchmaking* module, we should first identify those exchanges (depicted in Figure 2.1):

- The process starts with the user accessing the StairwAI service layer. A personal assistant (a chatbot) will provide a multi-lingual natural language interaction with the user, with the purpose of capturing the user's needs. The underlying Natural Language Processing engine will connect the entities detected in the user dialogue with concepts in the StairwAI AMS to semantically enhance the information to provide as input of to the Horizontal Matchmaking block.

[2] In fact, as we will see in section 5.2, in its current version StairwAI's Asset Conceptual Semantic Model imports only some concepts from the AI4EU Conceptual Semantic Model, while redefining others.

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- The Horizontal Matchmaking receives as input the set of (semantically enhanced) user's needs and maps them into (semantically annotated) categories of AI assets and resources included in the StairwAI AMS.
- In the case of AI assets referring to AI algorithms, the end user may require to sandbox, test or deploy the proposed solution and, therefore, a hardware specification – in terms of physical resources and technology – can be required as additional information. In such a case, the Vertical Matchmaking module receives the (semantically annotated) algorithms chosen by the user plus some user constraints (e.g., time, cost) to select the best resources required to meet the user needs and constraints.

The StairwAI AMS plays the role of a structured Knowledge Graph that includes all the types of assets covered by StairwAI, and it is exploited by the three main modules to get references to semantic concepts and then pass them as input to the next block. It is worth pointing out that the Horizontal Matchmaking and the Vertical Matchmaking modules may also feed information into the StairwAI AMS, as discussed in detail in the next sections.

3.2. Requirements from the Horizontal Matchmaking

The objective of the horizontal matchmaking service is the automatic discovery of AI assets (tools, data sets, AI experts, consultants, papers, courses, etc.) meeting the user requirements.

Figure 3.1 shows the main inputs and outputs of the Horizontal Matchmaking block. It takes as input the result of the natural language component – namely a set of user's needs – and maps them into proper ontology categories (the AI assets and resources that are classified within the StairwAI AMS).

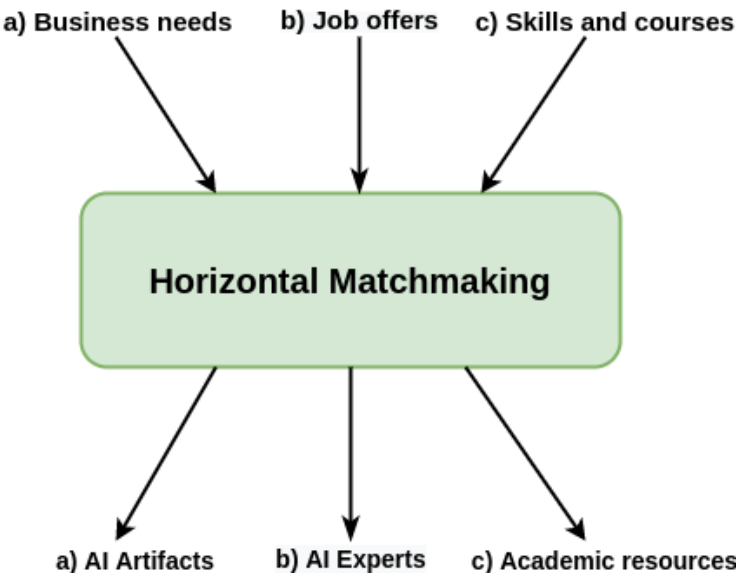

Figure 3.1 - Horizontal matchmaking

To enable Horizontal matchmaking, it is essential to construct a common language that, from the input that comes from the *Multi-Lingual Virtual Assistant*, produces a set of key components that are used to identify

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the AI Assets that are proposed to the user: algorithms, tools, libraries, data sets, benchmarks, courses, academic resources, people, job positions, etc. This introduces the first requirement for the AI Assets Conceptual Semantic Model:

R2.1 Coverage: Essential AI Assets
The AI Assets Conceptual Semantic Model should cover at least the following concepts: algorithms, tools, libraries, data sets, benchmarks, courses, academic resources, people, and job positions. *Essential*

The horizontal matchmaking service aims to support the following three cases each of which will add extra requirements to the AI Assets Conceptual Semantic Model:

> ***Case 1 – matching business needs to assets***: the Horizontal Matchmaking engine will receive as input the outcome of the *Multi-Lingual Virtual Assistant* providing user needs in the form of a business problem statement. The Horizontal Matchmaking service aims to find the combination of AI assets that satisfy the case study.
>
> ***Case 2 – matching Job offers with people's expertise***: the Horizontal Matchmaking engine will receive as input the outcome of the *Multi-Lingual Virtual Assistant* that, after parsing the job offer, will have identified the needs in the form of the position to be covered, the skills and the capacities required. The Horizontal Matchmaking service aims to find people with the required skills and competences.
>
> ***Case 3 – matching training requests with courses, papers, and experts***: the Horizontal Matchmaking engine will receive as input the outcome of the *Multi-Lingual Virtual Assistant* that provides user needs in the form of a parsed training request (knowledge, skills, and competences). The Horizontal Matchmaking service aims to find the relevant professors, academic material and on-line courses that match the request.

Fairness is an essential property of matchmaking and it should be guaranteed for every result. Therefore, StairwAI will provide a reputation mechanism that will rank resources available on the platform. This mechanism can be enforced and fuelled via a feedback loop from users toward the platform.

3.2.1. Requirements from the "business needs to assets" Horizontal Matchmaking

For the first matchmaking case (Case 1 – matching business needs to experts and assets), deliverable D2.1 provides further detail on the inputs and outputs of the Horizontal Matchmaking service, from which corresponding requirements to be reified in the ontology can be derived.

The system input can be characterized at two distinct stages:

- At an early stage, the system input consists of a natural language description of an industrial use case. The description will be a form in a semi-structured format that includes questions on A) the use case context; B) the use case motivation; C) data availability/provisioning; D) use case objective; E) additional requirements (e.g., fairness or explainability, when not part of the use case core).
- As a second stage, the system input will be the identified needs the Natural Language Processing block extracts from the direct interaction with the user. It is expected that the dialogue between the

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chatbot and the user will aim to get at least the information relating to the questions referred in the early-stage form.

This provides some insight into the kind of entities that may be required to represent the needs the *Multi-Lingual Virtual Assistant* sends to the *Horizontal Matchmaking* module for Case 1.

R2.2 Coverage: Industrial Use Case Needs
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of a problem statement coming from an industrial use case. It should have some core entities that can be extended to represent the use case context (the company, the business sector), the use case motivation and objective (the problem to solve), the data required, and other requirements (such as time or cost) *essential*

It is important to note here that, at the time of writing this report, there is no clear definition of how the free text coming from the user inputs will be mapped into a set of categorized business needs. To better define requirement R2.2 information on the business data that will be used to train the Horizontal Matchmaking engine (DATASET 1) reported in Annex I of deliverable D1.1 "Data management plan" has been exploited. As work evolves in WP5 on how to map business needs to AI assets, we expect that a categorization of business needs will emerge, and it will be introduced in the updated AI Assets Conceptual Semantic Model.

The output of the Horizontal Matchmaking engine can be characterized at two distinct stages:

- At the first stage, the output will consist of a labelling of the input requests in terms of a reference ontology, representing the applicable classes of AI content. Both single-class (e.g., a single AI category) and multi-class mappings (multiple categories, with different weights or intensities) will be considered.
- As a second stage, the above mapping will be used to retrieve relevant resources and rank them, also characterized in terms of a mapping over the same ontology. The resources may include tools, similar use cases (possibly solved), datasets, papers, contact details for experts, and courses. The results show to the user are resources sorted by relevance, i.e., letting first those that have a greater proximity between a) the aspects of the AI to which the resource itself refers to, and b) the AI aspects identified in the query

In both cases, the Horizontal Matchmaking requires that the AI Assets Conceptual Semantic Model supports the semantic tagging of AI assets including tools, datasets, papers, people's details, or courses. This requirement is already covered by requirement R2.1. The only extra element introduced is the concept of solved used cases, which accordingly introduces a new requirement:

R2.3 Coverage: Industrial Use Case Solutions
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of solved industrial use cases. It should connect the problem statement with the proposed AI Assets to solve it. *essential*

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It is important to note here that, at the time of writing this report, there is no clear definition of all the information that will be associated with a Use Case Solution. In Chapter 5 we propose a class named Solution to cover this aspect. Once WP5 will specify how to connect the business needs to the proposed solution, our definition of a Case Solution will be updated, which we expect by the next version of the AI Assets Conceptual Semantic Model.

D2.2 in section 5.3.2 identifies non-functional requirements for the Horizontal Matchmaking service to support the matching of business use cases to AI Assets. As for these requirements, there is one that directly affects the Conceptual Semantic Model:

R7.25 Sufficiently General and Flexible: The ontology used for the characterization of both use case description and AI resource should be sufficiently general and flexible to ensure longevity and wide applicability for the matchmaking system. A preliminary analysis has identified the AI Watch taxonomy as a promising candidate.

This requirement in D2.2 can be translated into two direct requirements for the AI Asset Conceptual Semantic Model:

R2.4 Genericity and Flexibility
The Conceptual Model used for the characterization of both use case descriptions and AI resources should be sufficiently general and flexible to ensure longevity and wide applicability for the WP5 matchmaking system. *essential*

R2.5 AI Watch taxonomy alignment
The Conceptual Model used for the characterization of AI resources may be aligned with the taxonomy of AI techniques defined by JRC's AI Watch. *optional*

Requirement R2.5 is labelled as optional as there are several options that can be chosen to structure the AI Assets in the AI Asset Conceptual Semantic Model. Currently, The AI4EU Conceptual Semantic Model uses the taxonomy in the Computer Science Ontology (CSO)[3] to define the different kinds of AI Resources. Switching from the CSO taxonomy to the AI Watch taxonomy[4] is a key change in the AI4EU model, one that requires the consensus of the ICT 48 and ICT. Section 5.3 discusses its potential inclusion in the AI Asset Conceptual Semantic Model.

[3] Section 4.1.3 analyses the taxonomy within the Computer Science Ontology.
[4] Section 4.1.11 analyses the AI Watch taxonomy.

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3.2.2. Requirements from the "job offers" and "training requests" Horizontal Matchmaking

The other matching cases (job offers with curricula and training requests with courses, papers, and experts) are not covered in Deliverable D2.1. However, we try to extract some early version of the requirements for these cases to ensure the Conceptual Semantic Model is ready to meet them.

In the case of matching job offers with people's expertise, the Horizontal Matchmaking engine will receive from the Multi-Lingual Virtual Assistant the needs in the form of the position to be covered, the skills and capacities required, or the expected years of experience in a similar job. The Horizontal Matchmaking service aims to find people with the required skills and competences. It can be translated into the following requirement:

R2.6 Coverage: Job positions and expertise
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of a job offers and the expertise of people. It should have some core entities that can be extended to represent, on one side, concepts related to a job offer (including, but not limited to the position to be covered, the skills and capacities required, the expected years of experience in a similar job) and to a person's expertise (skills and capacities, previous job positions) *essential*

It is important to note here that, at the time of writing this report, there is no clear definition of how the free text coming from the job offers will be mapped into a set of categorized job positions, skills, and competences. To better define requirement R2.6 we have used the information on the business data that will be used to train the Horizontal Matchmaking engine (DATASET 3) reported in Annex I of deliverable D1.1 "Data management plan". As explained in section 5.1, for the current version of the AI Assets Conceptual Semantic Model we will propose to use the European Skills, Competences, qualifications and Occupations (ESCO), that we analyse in section 4.1.7, and the Skills and Recruitment Ontology (SARO) that we analyse in section 4.1.8. As work evolves in WP5 we may revisit this proposal in version 2 of the AI Assets Conceptual Semantic Model.

In the case of matching training requests with courses, papers, and experts, the Horizontal Matchmaking engine will receive from the Multi-Lingual Virtual Assistant the needs in the form of a parsed training request. The Horizontal Matchmaking service aims to find the relevant professors, academic material, and on-line courses that match the request. We can translate this in the following requirement:

R2.7 Coverage: Training requests, professors, academic material, and on-line courses
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of training requests from users and different ways to provide such training. It should have some core entities that can be extended to represent, on one side, concepts related to a training request (including, but not limited to, the skills to

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be obtained) and the different AI assets that the Horizontal Matchmaker may suggest (including, but not limited to, academic resources, courses and people with experience in the field) *essential*

It is important to note here that, at the time of writing this report, there is no clear definition of how the free text coming from the training requests will be mapped into a set of categorized topics or skills. There is no dataset associated with this matchmaking service in deliverable D1.1 "Data management plan". As explained in section 5.1, for the current version of the AI Assets Conceptual Semantic Model we will propose to use the European Skills, Competences, qualifications and Occupations (ESCO)[5], that we analyse in Section 4.1.7), and the FRBR-aligned Bibliographic Ontology (FaBiO)[6] to cover these concepts. As work evolves in WP5 we may revise and refine this proposal in version 2 of the AI Assets Conceptual Semantic Model.

3.3. Requirements from the Vertical Matchmaking

StairwAI's vertical matchmaking has the objective to provide an automatic tool to dimension hardware resources given the algorithm to be used and the application to be solved, and also to find hardware resource providers.

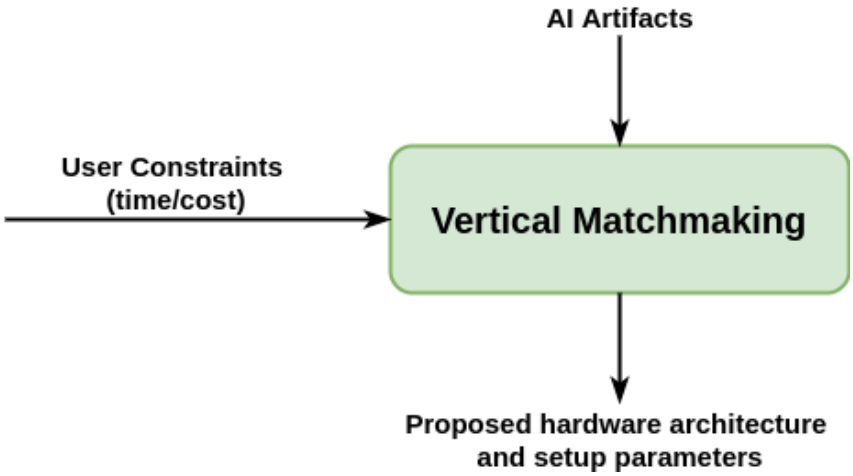

Figure 3.2 - Vertical Matchmaking

Figure 3.2 shows the main inputs and outputs of the Vertical Matchmaking service. It receives as input *i)* a set of selected algorithms or services that need to be deployed for the case study's successful realization and *ii)* the user constraints (e.g., time, cost). The combination of both input and the underlying technology – containerisation, virtualisation, baremetal – and the available implementation linked to the architecture will prune the multiple options and, by leveraging Machine Learning techniques, the best resources will be selected.

The system input is composed by:

[5] Section 4.1.7 provides an analysis of ESCO.
[6] Section 4.1.10 prvides an analysis of FaBiO

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- A set of selected algorithms or services. These algorithms come from the output of the Horizontal Matchmaking, and therefore these are already semantically annotated with the help of the StairwAI AMS, and covered by requirements R2.1 and R2.3.
- A set of user constraints. At this stage of the project, two main factors have been identified: time consumption and user costs. However, these can be extended to any other parameters that can be identified during the development of StairwAI (for instance, specifications on the hardware platforms currently available to the user or the expected solution quality). Since these user constraints are not covered by any previous requirement, let us define a new one.

R3.1 Coverage: user restrictions to the vertical matchmaking
The AI Assets Conceptual Semantic Model should represent the semantic tagging of the restrictions users may send through the multilingual interface to the Vertical Matchmaking service. It should have some core entities to represent restrictions (including, but not limited to, time consumption and hardware costs) *essential*

The optimization engine will match the selected algorithms/services with suitable hardware architectures under users' constraints. The optimization engine will exploit Machine Learning models to estimate the behaviour of an AI application on different hardware architectures. These Machine Learning models will be trained with an open-source cross-platform benchmarking framework for AI-based applications developed in WP6. Such a framework involves the creation of an artificially generated dataset of benchmarks for a range of AI applications (corresponding to the AI assets input of the Vertical Matchmaking service) executed on a variety of heterogeneous hardware architectures. This dataset corresponds to DATASET 5 in D1.1. At this stage in the project, it is not envisioned the need to represent and structure all these entities in the StairwAI AMS, and therefore no new requirements are introduced to the AI Asset Conceptual Semantic Model.

Finally, the output of the Vertical Matchmaking service will be the description of one or a set of the most suitable hardware architectures (and their configuration parameters) for the selected algorithms/services meeting the users' constraints. This result is returned to the user interface, where it needs to be translated to the original user language. In order to ease this translation, the AI Assets Conceptual Semantic Model should support the semantic tagging of parametrized Hardware Architectures. Accordingly, a new requirement needs to be introduced:

R3.2 Coverage: Parametrized Hardware Solutions
The AI Assets Conceptual Semantic Model should represent the semantic tagging of sets of hardware architectures (and their configuration parameters) *essential*

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It is important to note here that, at the time of writing this report, there is no clear definition on all the information that will be associated with a parametrised hardware architecture. In Chapter 5 we propose a set of classes (Solution, Hardware Platform, Environment and Container) that are inspired by the Bonseyes data model (discussed in section 4.2.2).

3.4. Requirements from the Multilingual interaction

As shown in Figure 2.1, the Multilingual interaction feature in StairwAI is provided by the *Multi-Lingual Virtual Assistant*. It provides a web interface that is the front end of the multilingual interaction with the user. It will include a user assistant (chatbots that have capabilities of communicating in foreign languages) in order to enable easy, cross-lingual access to AI resources. It includes also a Natural Language Processing (NLP) engine that supports the user interface and translates the structured information extracted from user utterances in the source language into queries to the StairwAI AMS, or into the target internal language used by the other blocks in StairwAI (the Horizontal Matchmaking service and the Vertical Matchmaking service) in their inputs and outputs.

The description of the exact methods that are used inside the NLP engine are reported in Deliverable D4.1 " StairwAI Chatbot MVP" (published May 31, 2022). Some of these methods may require the use of thesaurus, dictionaries, or ontologies covering one or several of the human natural languages that will be supported in the multilingual interaction. However, note that such knowledge representations are not to be confused with the (language-neutral) AI Asset Knowledge representation of the StairwAI AMS, and therefore they are out of the scope of the AI Asset Conceptual Semantic Model.

The StairwAI AMS should provide the Multilingual Interaction components with the internal language of concepts that are used by the Horizontal and Vertical Matchmaking components (either as inputs or as outputs). Therefore, the main requirement from the Multilingual Interaction components to the AI Asset Conceptual Semantic Model is covering all concepts present in those inputs and outputs, and this requirement is already represented by the union of R2.1, R2.2, R2.3, R2.6, R2.7, R3.1, and R3.2. No additional requirement is needed.

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4. Related Models and Initiatives

One of the objectives of Task 3.1 is "*[...] investigating and identifying AI-related vocabularies, ontologies and other potential knowledge representations towards the definition of a dynamic and interoperable AI Asset Management System that deals with different AI4EU assets (libraries, models, tools, datasets, hardware, experts, academic resources, etc)*". This section reports the result of this investigation. It analyses existing core ontologies, vocabularies, terminologies, taxonomies and reference documents that may be relevant to the modelling requirements identified in Section 3. It also analyses running projects and initiatives that are developing ontologies, data models or taxonomies that could be relevant for our knowledge representation, with a special focus on EU-funded projects in the ICT-48 and ICT-49 calls.

4.1. Analysis of relevant core ontologies, vocabularies and reference documents

Now-a-days, it makes no sense to start a knowledge model from scratch. Decades of work have produced ontologies, vocabularies, terminologies, and taxonomies covering many of the elements identified in section 3. The aim of this section is to analyse the existing knowledge models that could be the most relevant to be considered in our modelling effort. The section starts with several, well-established core ontologies, and then it covers other reference material that, even if not in the form of ontologies, provide terminologies or even taxonomies of terms that may guide the model proposed in Section 5.

4.1.1. Dublin Core Metadata Initiative (DCMI)

The Dublin Core Metadata Initiative is a project of the Association for Information Science and Technology, (ASIS&T) which is responsible for formulating the *DCMI Metadata Element Set*. This Element Set consists of fifteen core properties for describing resources. These fifteen core elements were extended with several properties, classes, datatypes and vocabulary [2]. DCMI metadata terms are expressed in RDF vocabularies, where each term is identified with a Uniform Resource Identifier (URI) for use in Linked Data. The fifteen elements originally proposed were:

`contributor`	`coverage`	`creator`	`date`	`description`
`format`	`identifier`	`language`	`publisher`	`relation`
`rights`	`source`	`subject`	`title`	`type`

In StarwAI, DCMI could be used to define the basic resource information (e.g., defining concepts of AI Resources, Academic Resources, Courses) and also the type of the element, the author, the license behind a resource, etc. This reference RDF is used in AI4EU with the same purpose as in StairwAI, but only to deal with Resource information. The following is a list of some DCIM classes that may be relevant for the StairwAI model:

- `dc:Agent` - A resource that acts or has the power to act.

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- `dc:AgentClass` - A group of agents.
- `dc:BibliographicResource` - A book, article, or other documentary resource.
- `dc:FileFormat` - A digital resource format.
- `dc:LicenseDocument` - A legal document giving official permission to do something with a resource.
- `dc:Location` - A spatial region or named place.
- `dc:PeriodOfTime` - An interval of time that is named or defined by its start and end dates.
- `dc:PhysicalMedium` - A physical material or carrier.
- `dc:PhysicalResource` - A material thing.
- `dc:RightsStatement` - A statement about the intellectual property rights (IPR) held in or over a resource, a legal document giving official permission to do something with a resource, or a statement about access rights.
- `dc:SizeOfDuration` - A dimension or extent, or a time taken to play or execute.

This RDF contains interesting properties that could help us in StairwAI data model, like the first fifteen proposed Dublin Core terms with the addition of the following ones:

- `dc:abstract` - A summary of the resource.
- `dc:audience` - A class of agents for whom the resource is intended or useful.
- `dc:available` - Date that the resource became or will become available.
- `dc:bibliographicCitation` - A bibliographic reference for the resource.
- `dc:dateAccepted` - Date of acceptance of the resource.
- `dc:dateSubmited` - Date of submission of the resource.
- `dc:educationalLevel` - A class of agents, defined in terms of progression through an educational or training context, for which the described resource is intended.
- `dc:instructionalMethod` - A process, used to engender knowledge, attitudes and skills, that the described resource is designed to support.
- `dc:modified` - Date on which the resource was changed.
- `dc:replaces` - A related resource that is supplanted, displaced, or superseded by the described resource.
- `dc:requires` - A related resource that is required by the described resource to support its function, delivery, or coherence.
- `dc:tableOfContents` - A list of subunits of the resource.

4.1.2. Friends of a Friend (FOAF)

Friends of a Friend (FOAF) ontology describes the world using simple ideas inspired by the Web. It is a project that has been evolving since its creation in mid-2000. The main purpose of FOAF is to represent three kinds of networks: social networks, friendships, and associations [3].

Inside the StairwAI project, FOAF could be a good candidate for representing main assets characteristics as basic properties of People (e.g., experts, consultants, developers, job applicants) in the data model and some relations that we can establish between them. As explained in section 4.2.1, FOAF is used by AI4EU with the same purpose, and this will be a positive aspect to ease the linkage between the data models.

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Some initial classes identified are:

- `foaf:Agent` - class which represents entities (human or artificial) that do stuff.
- `foaf:Document` - class that represents those things which are, broadly conceived, 'documents'.
- `foaf:Group` - class that represents a collection of individual agents.
- `foaf:Image` - is a subclass of Document corresponding to those documents which are images.
- `foaf:Organization` - class that represents a kind of Agent corresponding to social institutions such as companies, societies etc.
- `foaf:Person` - class that represents people.
- `foaf:Project` - class that represents the class of things that are 'projects'. These may be formal or informal, collective or individual.

Properties:

- `foaf:account` - The account property relates an Agent to an OnlineAccount for which it is the sole account holder.
- `foaf:age` - The age in years of some agent.
- `foaf:currentProject` - This relationship indicates that the Person has some active role in the project, such as development, coordination, or support.
- `foaf:familyName` / `foaf:firstName` - The family name and first name of some person.
- `foaf:knows` - The *knows* property relates a Person to another Person that he or she knows.
- `foaf:member` - property relates a Group to an Agent that is a member of that group.
- `foaf:pastProject` - A project this person has previously worked on.
- `foaf:phone` - telephone of an Agent.
- `foaf:publications` - A link to the publications of a person.
- `foaf:title` - Title (Mr, Mrs, Ms, Dr. etc)
- `foaf:topic` - The topic property relates a document to a thing that the document is about.

4.1.3. Computer Science Ontology (CSO)

The *Computer Science Ontology (CSO)* is a large-scale ontology of research areas that was automatically generated using Klink-2 algorithm on the Reexplore dataset. The CSO model is an extension of the *Simple Knowledge Organization System (SKOS)*, a common data model for sharing and linking knowledge organization systems via the Semantic Web. The main purpose of the CSO model is to map all the concepts related to computer science, from the most specific one to the higher-level research areas. CSO consists of a main root `Computer Science` class, however, the ontology also includes a few secondary roots, such as `Geometry`, `Semantics`, etc [4].

In the StairwAI project, this ontology would be a central pillar to deal with AI Artifacts and Hardware Platforms' domain representation. CSO is also used in the AI4EU knowledge model, thus reducing the conflicts between AI4EU and StairwAI Knowledge Graphs.

As discussed in section 3.2, one of the requirements for the StairwAI Ontology is to incorporate the AI watch Taxonomy (described in section 4.2.2). There exists an intersection between the CSO knowledge representation and the AI watch Taxonomy. We have made an extensive revision and comparison between CSO and the AI watch Taxonomy, and we have been able to observe some concepts that did not coincide with the criteria of the working group. These misalignments are explained extensively in section 5.1.

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The main subcategorization of the Artificial Intelligence concept into CSO includes relevant concepts to AI Resources, such as:

- `cso:bayesian networks` - is a probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph.
- `cso:cognitive systems` - systems that use existing knowledge and generate new knowledge.
- `cso:decision support systems` - is a computer-based information system that supports business or organizational decision-making activities.
- `cso:decision theory` - is the study of the reasoning underlying an agent's choices.
- `cso:expert systems` - is a computer system that emulates the decision-making ability of a human expert.
- `cso:game theory` - the branch of mathematics concerned with the analysis of strategies for dealing with competitive situations.
- `cso:machine learning` - is the subfield of computer science that gives computers the ability to learn without being explicitly programmed.
- `cso:multiagent systems` - is a computerized system composed of multiple interacting intelligent agents.
- `cso:natural language processing` - field of research that aims to program computers to process and analyze large amounts of natural language data.
- `cso:soft computing` - is the use of inexact solutions to computationally hard tasks.
- `cso:system theory` - is the interdisciplinary study of systems in general, with the goal of discovering patterns.

Useful CSO concepts related to Hardware Infrastructure assets include:

- `cso:computer hardware` - is the collection of physical elements that constitutes a computer system.
- `cso:computer networks` - A computer network or data network is a telecommunications network that allows computers to exchange data.
- `cso:gpu` - graphical processing unit.
- `cso:platform as a service` - is a category of cloud computing services that allows customers to provision, instantiate, run, and manage a modular bundle of computing platforms.
- `cso:cloud computing` - Cloud computing is a type of Internet-based computing that provides shared computer processing resources.

CSO uses a web tool in order to allow the user to navigate through the ontology and get a graphical description of the subcategories below the chosen concept, or even a text explanation of it. You can see an example of the tool output when we searched “artificial intelligence” in the following Figure 4.1:

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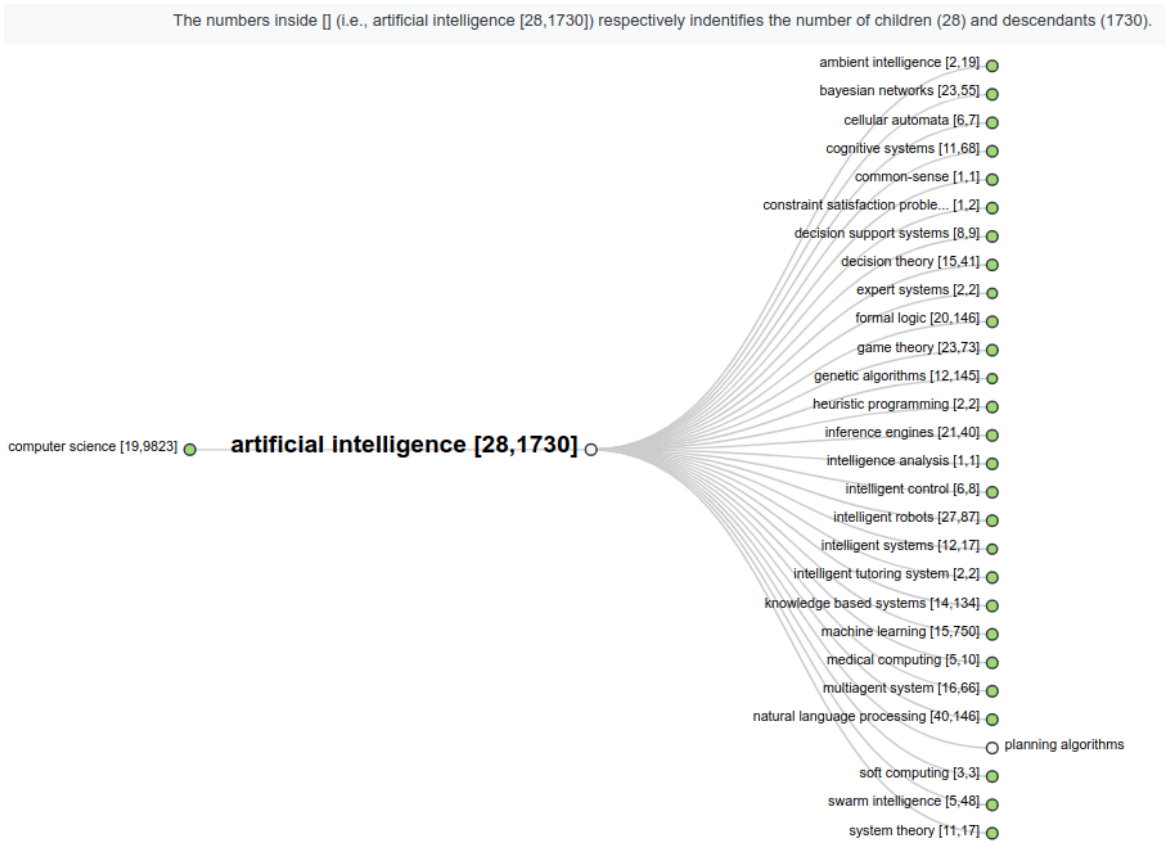

Figure 4.1 - Core terms in the CSO ontology [4]

4.1.4. Data Catalog Vocabulary (DCAT)

The *Data Catalog Vocabulary (DCAT)* is an RDF vocabulary designed to facilitate interoperability between data catalogues. A dataset in DCAT is defined as a "collection of data, published or curated by a single agent, and available for access or download in one or more serializations or formats" [5].

This ontology can provide a great description of Datasets, Distributions and Catalogues into StairwAI and can help in the definition of concepts, such as `Resource` or `DataService`.

DCAT is based on six main classes:

- `dcat:Catalog` - A curated collection of metadata about resources.
- `dcat:Resource` - Resource published or curated by a single agent.
- `dcat:Dataset` - A collection of data, published or curated by a single agent, and available for access or download in one or more representations.
- `dcat:Distribution` - An available distribution of the dataset.
- `dcat:DataService` - A collection of operations that provides access to one or more datasets or data processing functions.
- `dcat:CatalogRecord` - A record in a catalog, describing the registration of a single dcat:Resource.

In StairwAI, DCAT concept of `dcat:Dataset` can be used to describe the datasets in the platform, `dcat:Resource` can be used as an alternative, or even a generalization, of the *AI Resource* concept

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described by AI4EU. Another example that can be used as an AI4EU concept alternative is `dcat:Distribution`.

4.1.5. Description of a Project (DOAP)

Description of a Project (DOAP) [6] is an RDF Schema vocabulary created by Edd Dumbil for the purpose of describing software projects. Some interesting classes inside this ontology are:

- `foaf:Person` - imported FOAF ontology definition of a person.
- `foaf:Project` - imported FOAF ontology definition of a project.
- `doap:Repository` - Source code repository.
- `doap:Version` - information of the current version of a project.

In addition, some interesting Object properties are:

- `doap:category` - a category of a project.
- `doap:developer` - software developer for a project.
- `doap:documenter` - documentation contributor, property of a project.
- `doap:download-page` - Web page from which the project software can be downloaded.
- `doap:helper` - project contributor.
- `doap:homepage` - URL of a project's homepage.
- `doap:location` - repository location.
- `doap:maintainer` - maintainer of a project, similar concept of a project leader.
- `doap:module` - repository module name.
- `doap:release` - the project release.
- `doap:tester` - agent that collaborates in the testing phase of a project.
- `doap:translator` - contributor agent in the translation phase of a project.

In StairwAI this ontology could be a candidate to represent the concept of software project or the concept of research project.

4.1.6. EU Business Graph

This ontology was created by the euBusinessGraph project [7], which aims to aggregate and simplify company-related information from several authoritative and non-authoritative sources. The EU Business graph is based on two main classes (pillars); `Company` and `Identifier System`.

EU Business Graph imports some ontologies in order to define its own data model, such as Simple Knowledge Organization System (skos), Registered Organisation Vocabulary (rov), The Organisation Ontology (org), Semantically-Interlinked Online Communities (sioc), Friends of a Friends (foaf), Data catalog Vocabulary (dcat), Asset Description Metadata Schema (adms), Dublin Core (dc) and Vocabulary of Interlinked Datasets (void). The StairwAI project could be interested in the wide representation of the Company concept, in which we can find the following interesting concepts:

- `rov:RegisteredOrganization` - An organization that gains legal entity status by the act of registration.
- `rov:legalName` - The legal name of the business, i.e., official name of the company [ebg:].

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- `rov:orgType` - Company Type (Legal Form of the entity).
- `ebg:isStartup` - Whether the company is a startup [ebg:].
- `ebg:isStateOwned` - Whether this organisation is owned by the government, a government agency, community, city or other public entity.
- `ebg:isPubliclyTraded` - Whether the company is publicly traded (listed at a stock exchange) [ebg:].
- `rov:orgStatus` - Flag that identifies whether a company is active or not [ebg:].
- `rov:orgActivity` - Economic activity of the organization (NACE code).
- `schema:foundingDate` - Date when the organization was created.
- `ebg:foundingYear` - Year the organization was created, as an integer.
- `schema:dissolutionDate` - Date when the organization was dissolved or removed from the register.
- `ebg:dissolutionYear` - Year the organization was dissolved or deregistered, as integer.
- `schema:availableLanguage` - Languages used by the organization.
- `ebg:WebResource` - URL complemented with name, language and MIME type(s) to specify what the URL is about.
- `schema:email` - Email that is officially registered and with the same validity as certified mail.
- `sioc:feed` - RSS/Atom feed pertaining to the company.
- `dbo:jurisdiction` - Jurisdiction in which the company is registered or to which the identifier system applies.
- `org:hasRegisteredSite` - Public legal address where legal papers can be served.
- `rov:registration` - Identifier that holds the official company registration in its jurisdiction of registration.
- `adms:identifier` - Identifier of an entity (company, person) according to some identifier system.

Figure 4.2 - Core terms in the EU Business Graph ontology [7]

StairwAI could use the description of the Companies provided for this ontology in order to describe the concept of Company inside its knowledge model. The concept hierarchy inside `Company` concept can be seen in Figure 4.2, just above.

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4.1.7. European Skills, Competences, qualifications and Occupations (ESCO)

ESCO is the multilingual classification of *European Skills, Competences, Qualifications and Occupations*. ESCO is part of the Europe 2020 strategy. The ESCO classification identifies and categorises skills, competences, qualifications and occupations relevant for the EU labour market and education and training. It systematically shows the relationships between the different concepts [8].

This ontology considers three pillars (`Occupation`, `Skills` and `Competences`) and 2 registers (`Work Context` and `Awarding Bodies`). For the construction and use of the ESCO pillars, the following modelling artifacts are used:

- SKOS mapping properties to relate ESCO pillar concepts to concepts in other (external) taxonomies.
- Tagging ESCO pillar concepts by other (external) taxonomies.
- Capture gender specifics on the labels of the ESCO pillar concepts
- Rich ESCO concept relationships, holding a description and other specific characteristics of the relation between two ESCO pillar concepts.

The knowledge structure in ESCO can be seen in Figure 4.3:

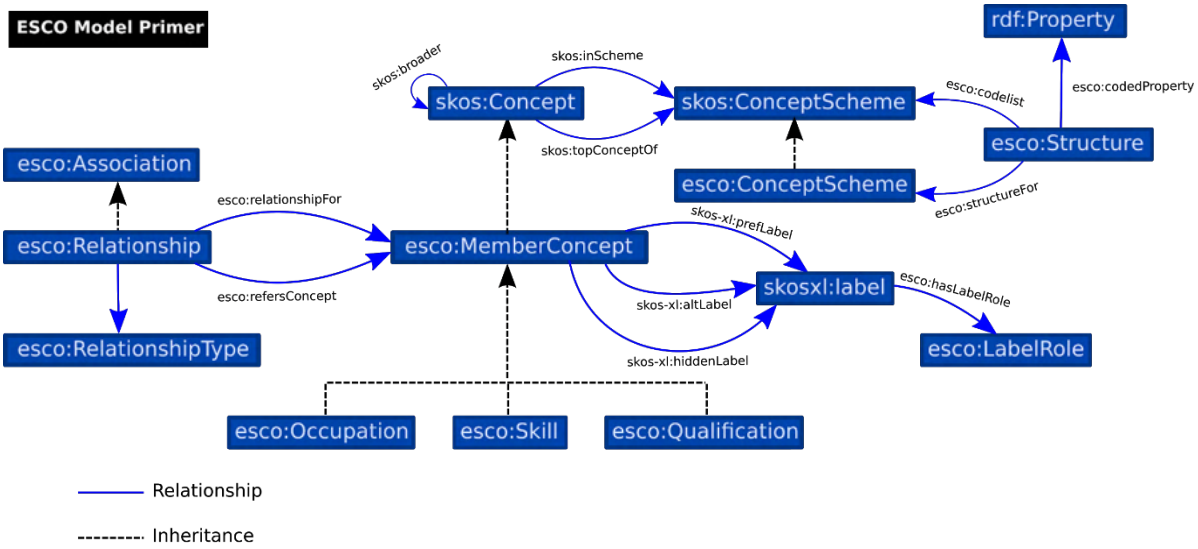

Figure 4.3 - Core terms in the ESCO ontology [9]

The ESCO ontology [9] defines some interesting classes for StairwAI model definition, such as,

- `esco:Occupation` - The class of ESCO Occupation concepts, it has the property of NACE codes and a context can be applied in it.
- `esco:Qualification` - A qualification is a formal outcome of an assessment and validation process.
- `esco:Skill` - The class of ESCO Skill concepts, skills are represented as a sub-typed class.
- `esco:Recognition` - The recognition class is used to specify information related to the formal recognition of some qualification and/or awarding body.
- `esco:Awarding activity` - An awarding activity represents an activity related to the awarding of a qualification.

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- `esco:entry requirement` - Entry requirements are structured into categories such as work experience, pre-assessment or a specific qualification.

As ontology, ESCO objects and data have some properties that could be useful in StairwAI horizontal matchmaking queries that focus on expert domain, abilities or qualifications, such as:

- Object Properties
  - is essential skill for
  - is optional skill for
  - has recognition
  - has awarding activity
- Data Properties
  - qualification expiration period
  - expiry period
  - ECTS credit points
  - language
  - is traversal
  - Reference language
  - status

In StairwAI, the knowledge provided by the ESCO ontology can help to describe relevant properties of people inside the model: occupations, skills, competences and accreditations. These properties can help to semantically label data used for horizontal matchmaking in the Job offer tasks.

4.1.8. Skills and Recruitment Ontology (SARO)

The Skills and Recruitment Ontology (SARO) is a domain ontology representing occupations, skills and recruitment. This ontology is structured along four dimensions: Job posts (it refers to job advertisements by organizations), skills, qualifications and Users. SARO is modelled using similar models in the field, but its main inspiration is European Skills, Competences, Qualifications and Occupations ontology (ESCO), explained in the above section.

SARO defines Job Posting as the job advertisements done by Organizations, it describes a Job Role that requires some skills. These Skills can be considered as Traversal or Specific, depending on the domain of the required Skill, the person that wants to apply to a Job Post must fulfil the required Skills for this post. This applicant has associated skills that could require Qualifications, or a Course done.

The ontology also considers and maintains two additional registers for Awarding Body (defined by ESCO) and Curriculum. The former is an official or otherwise recognized institution, organization or company that can provide qualifications and certifications. Based on these, curricula can be formed.

In the following Figure 4.4, a simplified section of model, modelling the concept of Job Posting, can be observed. The complete schema of the model could be found in the official SARO GitHub [10].

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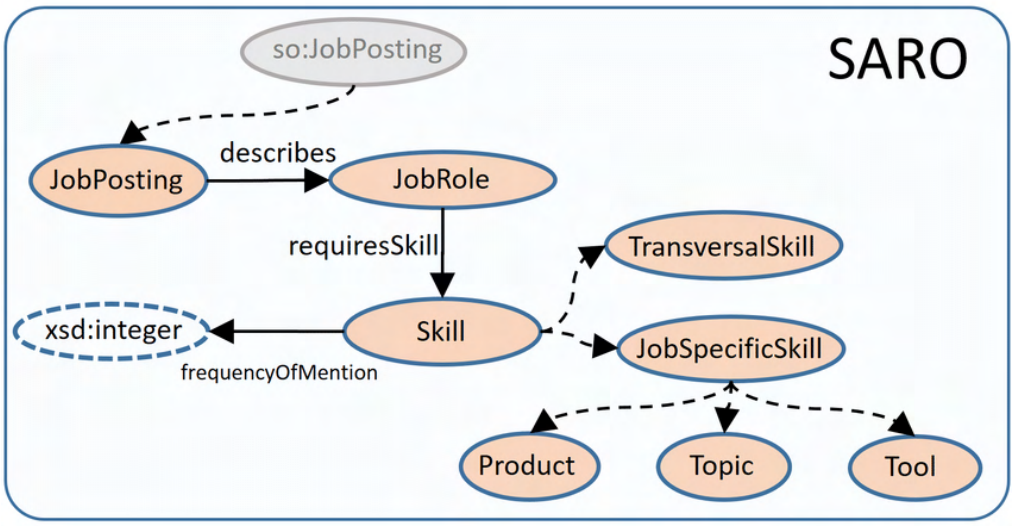

Figure 4.4 - Core SARO ontology Job posting representation [10]

Some represented classes in the ontologies that could be interesting for the StairwAI project are:

- `saro:Skill` - The skill class represents the ability to carry out managerial or technical tasks.
- `saro:Qualification` - The Qualification class represents the official or formal certification of one or more acquired skills or competences.
- `saro:User` - The User class represents people who can do one or more tasks.
- `saro:Curriculum` - This class represents a collection of courses to develop skills.
- `saro:JobPosting` - a listing that describes a job opening in a certain organization.
- `saro:TransversalSkill` - This class represents a list of skills that are relevant to a broad range of occupations and sectors. SARO propose the following core transversal Skills:
  - *WorkAsPartOfATeam*
  - *VerbalCommunication*
  - *ShowEnthusiasm*
  - *AnalyseTheProblem*
  - *PlanningOwnWork*
  - *GenerateNewIdeas*
  - *WorkingIndepently*
  - *CriticalThinking*
- `saro:JobSpecificSkill` - This class represents specialised and relevant skill for jobs within a specific economic sector, context or occupation.
- `saro:AwardingBody` - Recognized institution, organization or company which can provide qualifications and certifications. SARO propose the following Instances of Awarding Bodies:
  - *FHJoanneum*
  - *Aditec*
  - *Cisco*

The use of SARO will support the StairwAI project to represent important concepts in the platform, such as Job offers, connection between them, Organization and applicants, representation of the Skills required for

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an offer and required Qualifications. In StairwAI, these aspects have a huge importance in the horizontal matchmaking related tasks.

4.1.9. Semantic Publishing and Referencing Ontologies (SPAR)

Semantic Publishing and Referencing (SPAR) Ontologies is one of the first attempts to address the description of the whole publishing domain. SPAR is a suite of complementary OWL ontologies that enable all aspects of the publishing process to be described in metadata statements.

It is composed of the following Ontologies:

- **FRBR-aligned Bibliographic Ontology (FaBiO)** is an ontology for describing entities that are published or potentially publishable.
- **Citation Typing Ontology (CiTO)** is an ontology that enables characterization of the nature or type of citations.
- **Bibliographic Reference Ontology (BiRO)** is an ontology meant to define bibliographic records, bibliographic references, and their compilation into bibliographic collections and bibliographic lists.
- **Citation Counting and Context Characterisation Ontology (C4O)** is an ontology that permits the number of in-text citations of a cited source to be recorded
- **Document Components Ontology (DoCO)** is an ontology that provides a structured vocabulary written of document components.
- **Publishing Status Ontology (PSO)** is an ontology designed to characterise the publication status of documents at each stage of the publishing process.
- **Publishing Roles Ontology (PRO)** is an ontology for the characterisation of the roles of agents – people, corporate bodies and computational agents in the publication process.
- **Publishing Workflow Ontology (PWO)** is a simple ontology for describing the steps in the workflow associated with the publication of a document or other publication entity.
- **Scholarly Contributions and Roles Ontology (SCoRO)** is an ontology based on PRO for describing the contributions that may be made.
- **Funding, Research Administration and Projects Ontology (FRAPO)** is an ontology for describing the administrative information of research projects.
- **DataCite Ontology (DataCite)** is an ontology that enables the metadata properties of the DataCite Metadata Schema Specification.
- **Bibliometric Data Ontology (BiDO)** is a modular ontology that allows the description of numerical and categorical bibliometric data.
- **Five Stars of Online Research Articles Ontology (FiveStars)** is an ontology written in OWL 2 DL to enable characterization of the five attributes of an online journal article.
- **FAIR* Reviews Ontology (FR)** enables the description of reviews of scientific articles and other scholarly resources.

In Figure 4.5 below it is possible to observe a schema of the different ontologies that compose SPAR. StairwAI does not need a complete representation of the whole publishing domain, for this reason, StairwAI only requires FaBiO ontology which would represent entities that are published or potentially publishable (e.g., journal articles, conference papers, books).

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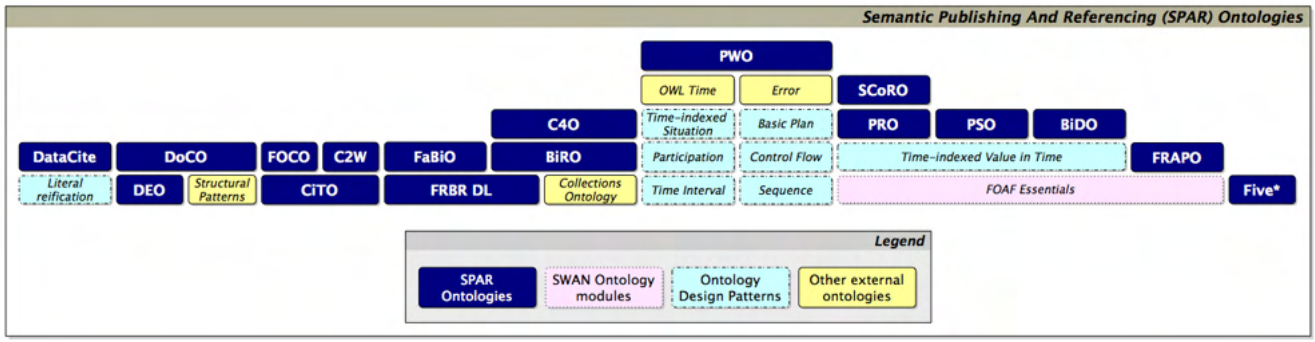

Figure 4.5 - SPAR ontologies high level schema [11]

4.1.10. FRBR-aligned Bibliographic Ontology (FaBiO)

FaBiO, the FRBR-aligned Bibliographic Ontology, is an ontology for recording and publishing on the Semantic Web descriptions of entities that are published or potentially publishable, and that contain or are referred to by bibliographic references, or entities used to define such bibliographic references. FaBiO entities are primarily textual publications such as books, magazines, newspapers and journals, and items of their content such as poems, conference papers and editorials. However, they also include blogs, web pages, datasets, computer algorithms, experimental protocols, formal specifications and vocabularies, legal records, governmental papers, technical and commercial reports and similar publications, and also anthologies, catalogues and similar collections [12].

FaBiO is based on 4 levels of abstraction: Work, Expression, Manifestation and Item (in the last update the concept of Agent is added) this schema is based on FRBR schema. The base data model could be seen in Figure 4.6.

- `fabio:Work` - restricted to works that are published or potentially publishable, and that contain or are referred to by bibliographic references, or entities used to define bibliographic references.
- `fabio:Expression` - expressions are the latest research paper, the preprint submitted to the publisher, and the final published version to which the publisher assigned a unique digital object identifier, are both expressions of the same work.
- `fabio:Manifestation` - specifically applies to electronic (digital) as well as to physical manifestations of expressions.
- `fabio:Item` - An example of a `fabio:Item` is a printed copy of a journal article on your desk or a PDF file of that article that you purchased from a publisher and that now resides in digital form on your computer hard drive.

In StairwAI, FaBiO can help to define many kinds of Academic Resources such as Presentations, report documents, letters, books, films, etc.

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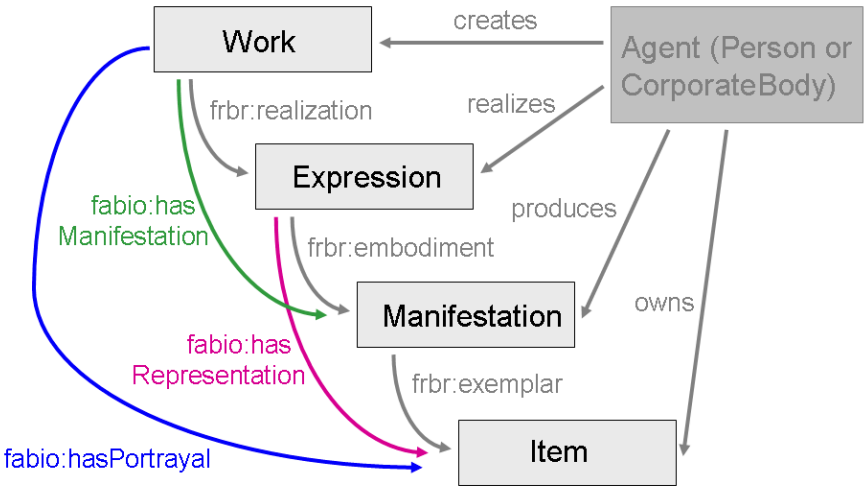

Figure 4.6 - FaBiO ontology base data model [12]

4.1.11. The AI watch Taxonomy

The AI watch is a Joint Research Center (JRC) initiative. It is designed to inform the AI landscape analysis and will expectedly detect AI applications in neighbour technological domains such as robotics, neuroscience, or the internet of things [13]. The starting point to develop the operational definition is the definition of AI adopted by the High-Level Expert Group on Artificial Intelligence. Then, with the usage of natural language processing methods to a large set of AI literature, the different concepts of this taxonomy were generated.

The operational definition is constituted by a concise taxonomy and a list of keywords that characterise the core domains of the AI research field. The proposed taxonomy presents a 3-level structure that aims to classify and model the AI activities in a broad sense. These AI activities are described as "*keywords*" and are grouped into AI subdomains, which at the same time are grouped into AI domains. AI watch Taxonomy proposes 8 different AI domains and 16 AI subdomains (Figure 4.7(a) and (b)).

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AI domain	AI subdomain	Keyword	
Reasoning	Knowledge representation; Automated reasoning; Common sense reasoning	case-based reasoning	inductive programming
		causal inference	information theory
		causal models	knowledge representation & reasoning
		common-sense reasoning	latent variable models
		expert system	semantic web
		fuzzy logic	uncertainty in artificial intelligence
		graphical models	
Planning	Planning and Scheduling; Searching; Optimisation	bayesian optimisation	hierarchical task network
		constraint satisfaction	metaheuristic optimisation
		evolutionary algorithm	planning graph
		genetic algorithm	stochastic optimisation
		gradient descent	
Learning	Machine learning	active learning	feature extraction
		adaptive learning	generative adversarial network
		adversarial machine learning	generative model
		adversarial network	multi-task learning
		anomaly detection	neural network
		artificial neural network	pattern recognition
		automated machine learning	probabilistic learning
		automatic classification	probabilistic model
		automatic recognition	recommender system
		bagging	recurrent neural network
		bayesian modelling	recursive neural network
		boosting	reinforcement learning
		classification	semi-supervised learning
		clustering	statistical learning
		collaborative filtering	statistical relational learning
		content-based filtering	supervised learning
		convolutional neural network	support vector machine
		data mining	transfer learning
		deep learning	unstructured data
		deep neural network	unsupervised learning
		ensemble method	
Communication	Natural language processing	chatbot	natural language generation
		computational linguistics	machine translation
		conversation model	question answering
		coreference resolution	sentiment analysis
		information extraction	text classification
		information retrieval	text mining
		natural language understanding	
Perception	Computer vision	action recognition	object recognition
		face recognition	recognition technology
		gesture recognition	sensor network
		image processing	visual search
		image retrieval	
	Audio processing	computational auditory scene	sound synthesis
		music information retrieval	speaker identification
		sound description	speech processing
		sound event recognition	speech recognition
		sound source separation	speech synthesis

Figure 4.7(a) - AI Watch proposed taxonomy [13]

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Integration and Interaction	**Multi-agent systems**	agent-based modelling	negotiation algorithm
		agreement technologies	network intelligence
		computational economics	q-learning
		game theory	swarm intelligence
		intelligent agent	
	Robotics and Automation	cognitive system	robot system
		control theory	service robot
		human-ai interaction	social robot
		industrial robot	
	Connected and Automated vehicles	autonomous driving	self-driving car
		autonomous system	unmanned vehicle
		autonomous vehicle	
Services	**AI Services**	ai application	intelligence software
		ai benchmark	intelligent control
		ai competition	intelligent control system
		ai software toolkit	intelligent hardware development
		analytics platform	intelligent software development
		big data	intelligent user interface
		business intelligence	internet of things
		central processing unit	machine learning framework
		computational creativity	machine learning library
		computational neuroscience	machine learning platform
		data analytics	personal assistant
		decision analytics	platform as a service
		decision support	tensor processing unit
		distributed computing	virtual environment
		graphics processing unit	virtual reality
AI Ethics and Philosophy	**AI Ethics**	accountability	safety
		explainability	security
		fairness	transparency
		privacy	
	Philosophy of AI	artificial general intelligence	weak artificial intelligence
		strong artificial intelligence	narrow artificial intelligence

Figure 4.7(b) - AI Watch proposed taxonomy

4.1.12. The German Standardization Roadmap on Artificial Intelligence Taxonomy

German Federal Ministry for Economic Affairs and Energy spent about a year working on the German Standardization Roadmap Artificial Intelligence in a joint project. The aim of the roadmap is the early development of a framework for action for standardization that will support the international competitiveness of German industry and will raise European values to international level. The present Standardization Roadmap AI was developed in a broad participation process with interdisciplinary actors and outlines the work and discussion results of the working groups.

In this document, the authors present different taxonomies in the AI field. First, they present a classification of methods according to AI topics in which we can distinguish a three-level categorization of the general concept, AI specific domain and some examples of each domain. An example of this classification can be seen with the concept of "*Representation of Knowledge*" that is divided into:

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- Knowledge representation languages:
  - RDF
  - RDFS
  - OWL
  - KIF
  - Structure and formality
- Ontological engineering:
  - Taxonomy
  - Ontology
  - Interpretation
  - Calculus
  - Deduction
  - Abduction
- Knowledge Graph and semantic networks:
  - Knowledge networks / graph
  - Existence graph
  - Graph traversing
  - Semantic web
- Modelling in formal logic:
  - Propositional logic
  - Higher-level logics, non-monotonic logics
  - Temporal and modal logic

Another taxonomy is made based on the AI capabilities where the authors used some human basic capabilities such as communication, action, understanding or perception to classify some specific capabilities used in AI methods. An example of these presented capabilities could be "*Perception*" which is defined as "sensor data processing and interpretation" and is divided into the following concepts:

- Image understanding (image analysis, object recognition, video analysis, etc.),
- Noise Interpretation (Language recognition and synthesis, noise recognition and synthesis, anomaly recognition),
- Haptics (movement, vibration, temperature, pressure and tension, etc.),
- Social signals (body posture, affects and mood, emotions, etc.),
- Smell and taste (recognition of smell anomalies, recognizing taste, etc.).

With both capabilities and AI methods, authors propose a matrix where they correlate which of previously presented capabilities are required in each AI method. An example of this correlation can be seen in the following image (Figure 4.8) extracted from the original document.

The last taxonomy presented is an overview of software markets and typical AI applications, in which they propose a general software market classification, defining some principles that can explain the typical AI products in it. An example could be the "*Business Intelligence & Decision Support Systems*" category, which principles are:

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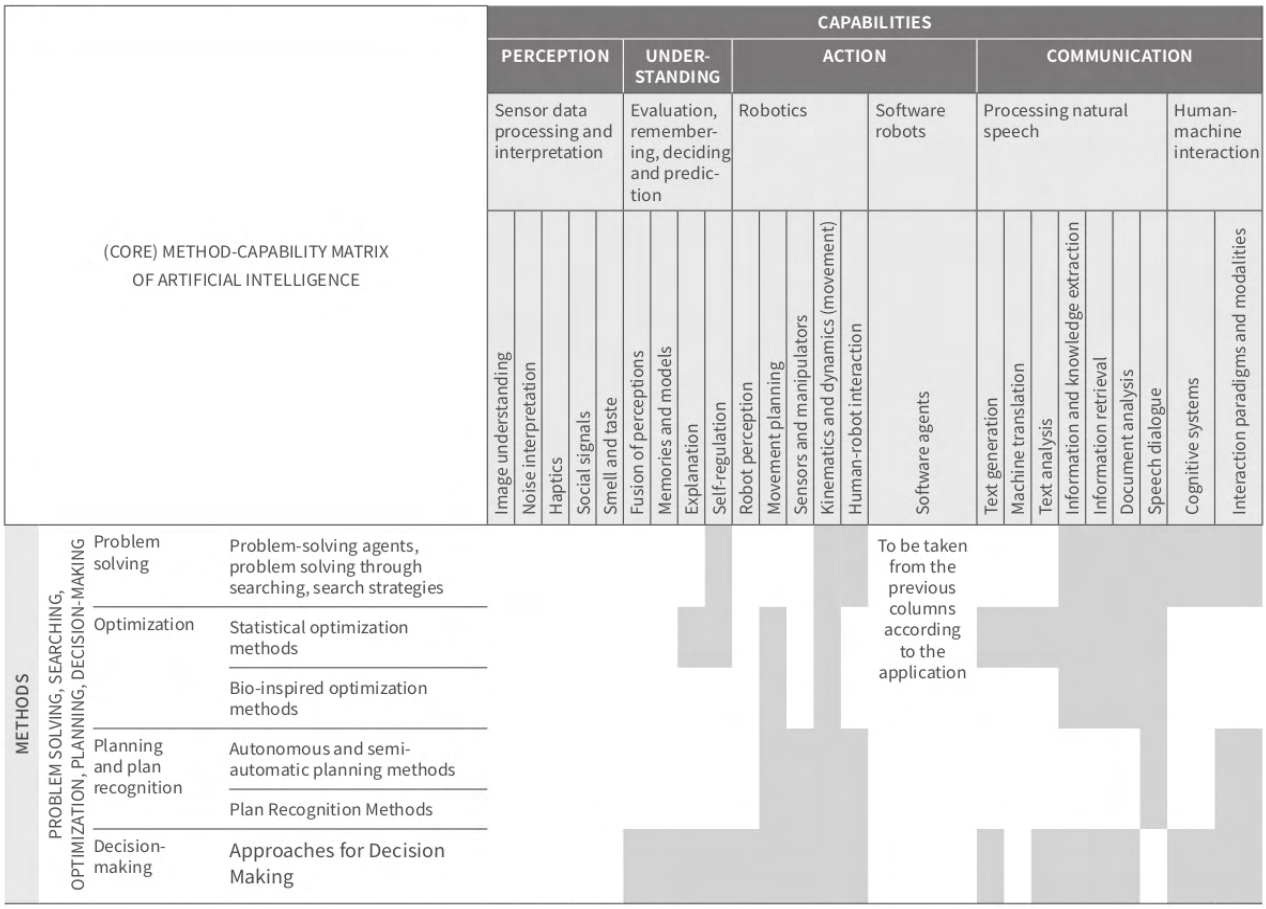

Figure 4.8 - Core terms in the German Standardization roadmap taxonomy [14]

- Autonomy & Control: in it, we can find some software products such as
  - Business Intelligence
  - Decision Support
  - Workflow systems
- Fairness: in it, we can find some software products such as
  - Prediction Capability
  - Real time Processing
  - Robotic Process Automation (Rule-based)

4.2. Analysis of ontologies, data models and taxonomies from related projects and initiatives

This section analyses a list of projects and initiatives that are developing or have already developed ontologies, taxonomies and data models that could be of interest for our knowledge representation. Special focus is given to EU-funded projects in the ICT-48 and ICT-49 calls.

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4.2.1. European Artificial Intelligence On-Demand Platform (AI4EU)

The main project connected with StairwAI is AI4EU, devoted to the development of the European AI-on-demand platform. The AI4EU platform aims to constitute a one-stop shop for European AI. The EU-funded AI4EU is working to change Europe's place in the global race to achieve an advantage in the artificial intelligence innovation field, trying to increase this innovation and technology transfer inside the EU.

The following concepts are represented in the AI4EU data model (core concept depicted in Figure 4.9):

- `ai:AI Resource` - central entity in AI4EU, an accessible and usable resource pertaining to AI research and applications.
    - `ai:SoftwareComponent` - A programmatic AI resource.
    - `ai:HardwareComponent` - A hardware AI resource (device/equipment).
    - `ai:KnowledgeComponent` - A resource that encapsulates knowledge or results relevant to AI research and applications.
        - `ai:Publication` - A published scholarly manuscript.
        - `ai:Dataset` - A collection of data.
        - `ai:Model` - An AI Model.
        - ai:Ontology - Ontology
        - `ai:Challenge` - A challenge organised in the context of an Event or Project.
        - `ai:Event` - A happening of note for the broader AI community.
    - `xsd:string` - used to represent names and short names of AI Resources.
    - `xsd:anyURI` - used to represent the AI Resource bibliographic citation.
    - `ai:Keyword` - representatives keywords about an AI Resource.
- `ai:ResearchArea` - AI field that an AI Resource adheres to. AI4EU proposed a plain list of Research Categories that can be a possible option for StairwAI but, as a plain list of concepts, it has no hierarchy and may be difficult to make some distance queries between fields. The list consists of the following terms:
    - 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
- `cso:Topic` - representative subject of an AI Resource entity.
- `ai:Computational Resource` - A hardware or software asset to be used by other entities like programs or models.
- `foaf:Agent` - class which represents entities (human or artificial) that do stuff.

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- `foaf:Project` - class that represents the class of things that are 'projects'. These may be formal or informal, collective or individual.
- `ai:Application Area` - An application or scientific domain where an AI resource is or can be of use (possibly in the context of a larger framework). AI4EU proposed a plain list of Application Areas in its data model that can be used by StairwAI in order to define the same concept in its Data model. The terms are the following:
    - AI for robotics
    - AI for industry and manufacturing
    - AI in autonomous driving and mobility
    - AI for art and music
    - AI for environment and sustainability
    - AI for IoT
    - AI for cybersecurity
    - AI for media
    - AI for telecommunication
    - AI for finance & insurance
    - AI for law
    - AI in retail and ecommerce
    - AI in software engineering
    - AI in Human Resources
    - Trusted and privacy preserving AI
    - AI for Ambient Intelligence
- `ai:Distribution` - A specific form of packaging and means of exposure and availability for an AI resource.
    - `dc:LicenseDocument` - Licence of distribution.
    - `ai:download` - A web address from where a distribution is made available.
    - `ai:Service` - An AI resource distribution accessible as a web service.
    - `ai:Notebook` - Distribution of an AI resource as a digital notebook.
    - `ai:Library` - A distribution meant to be incorporated as a module into a larger framework or application.
    - `ai:ModelBundle` - Distribution of an AI resource in an Acumos-ready onboarding format.
    - `ai:StandAlone` - A self-contained distribution of an AI resource.
        - `ai:DockerContainer` - A standalone distribution of an AI resource, bundled as a Docker container.
        - `ai:Application` - A distribution directly executable on the user's hardware.
- `ai:Documentation` - An entity that provides further information on the characteristics and usage of an AI Resource.
    - `ai:Manual` - A document that provides instructions on the installation, management or usage of an AI resource.
    - `ai:Tutorial` - A document that provides instructions on the usage of an AI resource.
    - `ai:Presentation` - A document providing information on an AI resource.
    - `ai:Website` - A group of web pages, under the same domain.
        - `ai:Forum` - A website where users can exchange information and feedback on an AI resource.
        - `ai:Wiki` - A collection of informative web pages dealing with different aspects of an AI resource and its usage.

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- `ai:TRL` - Technology Readiness Level instance.
- `ai:Embedded` - A distribution of an AI resource that is ingrained into a broader solution or system.
- `ai:SourceCode` - The source code distribution of an AI resource.
- `ai:SucessStory` - A significant outcome, event or product.
- ai:Quality - To examine adding specialization classes for explainability, trust.

One of the theoretical objectives of StairwAI is "*to act as a link between low-tech users to AI experts and consultants, training and education activities, assets/software/services/tools in the repository of AI4EU, and physical resources/technologies registered to the AI4EU platform*". As discussed in section 3.1, this is reified into requirement D1.1: to connect the StairwAI and the AI4EU Data Models and Ontologies. A first step in this direction, could be the compatibility of the terms used in the conceptual models. For this reason, StairwAI will try to use, if adequate, the same ontologies AI4EU imports to define similar concepts (the previously mentioned DCMI, CSO, and FOAF). Another common concept between both platforms is `AI Resource`, for which StairwAI can use a similar definition that the one defined in AI4EU.

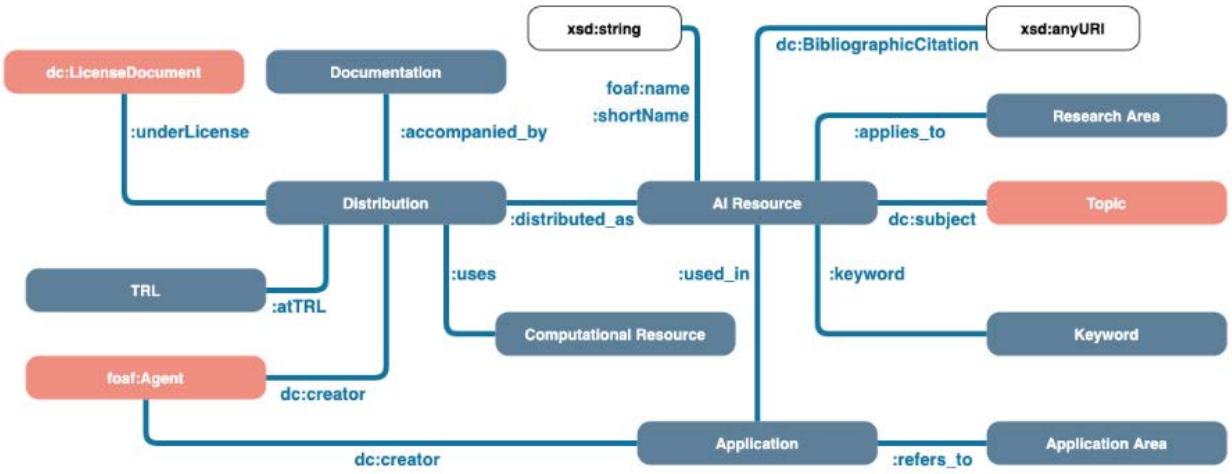

Figure 4.9 - Core terms in the AI4EU ontology

4.2.2. Platform for Open Development of Systems of Artificial Intelligence (BONSEYES), AI-as-a-Service for the Deep Edge (BonsAPPs)

The Bonseyes project has developed a platform consisting of a Data Marketplace, Deep Learning Toolbox, Developer Reference Platforms for organizations wanting to adopt Artificial Intelligence in low power IoT devices, embedded systems, or data centre servers. It aims to improve the efficiency, performance, reliability, security, productivity in the design and programming of Systems of Artificial Intelligence [15].

BonsAPPs is a running EU Project that will enhance the Bonseyes Marketplace to cover experimentation, benchmarking, deployment, and secure licensing of AI solutions at the Deep Edge [16]. BonsAPPs aims to be a scalable AI-as-a-Service layer that will interoperate with AI4EU's AI on demand platform as an external service.

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At the time of writing this report, there is no Conceptual Model or Ontology developed for Bonseyes and Bonsapps, but both projects have a well-defined data model that is shown in Figure 4.10.

A great synergy exists between StairwAI and Bonseyes platforms. The Resource Provider (or Hardware) Marketplace (initially developed by the Bonseyes project) was at first envisioned as a single marketplace that permits the exchange of AI artifacts – software and AI objects– and the vertical matchmaking of those artifacts into some Hardware architectures. StairwAI will make use of the outcomes of this research project to support the vertical matchmaking for a wider range of hardware types. Therefore, we envision the need to find ways to align StairwAI's AI Asset Conceptual Semantic Model with Bonseyes' Data model (e.g., StarwAI's AI Resource and Bonseyes' AI Artifact, and in other concepts such as Model, Algorithm, Tool, AI application, Inference Engine). Other possible alignments could be between the Benchmark and Measurement concepts that both platforms use. Finally, the Platform, Environment and Docker Container concepts defined by Bonseyes could be mapped as Hardware Infrastructure in StairwAI, as well as the Bonseyes concept of Organization and Company concept defined in StairwAI.

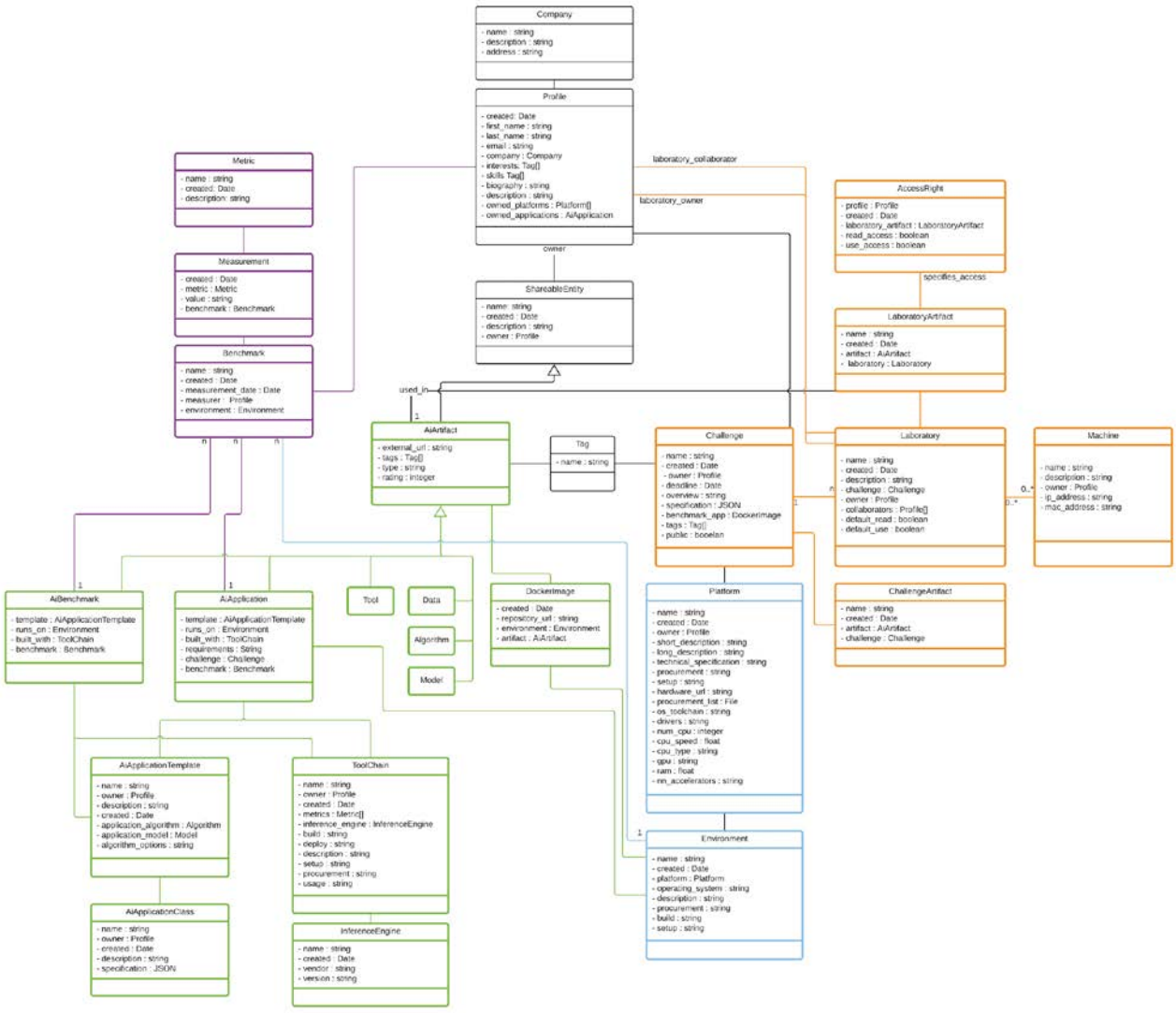

Figure 4.10 - Bonseyes' Data Model

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4.2.3. Biometrics Evaluations and Testing (BEAT)

Biometrics Evaluation and Testing (BEAT) is an open platform, whose purpose is to provide a framework for evaluations of biometric technologies. Biometric technology has become more prevalent in the last decade, even in our personal computers and smartphones. Unfortunately, the reliability of this technology is not always well-known and therefore can't be guaranteed. BEAT wants to establish a standard to be able to compare the performance, robustness to vulnerabilities and the strength of privacy preservation of these techniques [17].

BEAT main resource type is Experiments, which are defined as toolchains of datasets, blocks and analysers. Datasets are points of access to databases, blocks are algorithms that the user selects, these blocks use the data contained in datasets as an input. Finally, analysers are other algorithms that evaluate the performance of blocks.

In StairwAI, some concepts defined by BEAT can be interesting, concepts such as dataset model definition, algorithms used as blocks or even, some algorithms used as analysers could be interesting in order to structure both the dataset and benchmark assets in the StairwAI AMS.

4.2.4. European Language Grid (ELG)

The European Language Grid (ELG) is a European project that aims to create a European service platform for language technologies. This sector is the domain of interest for thousands of SMEs but is still quite fragmented due to the many nations and the various languages spoken across Europe [18].

ELG defines the "ELG-SHARE" Metadata Schema, which is linked to the META-SHARE and OMTD-SHARE [19] ontologies. This schema describes the variety of resources found in the ELG platform, i.e., functional, such as tools and services, non-functional, e.g., lexica, corpora, etc., as well as all the related entities e.g., persons, organizations, licenses, and projects.

The schema is implemented in the form of an XSD with the following metadata elements (they are the most representative, the full schema is available on the official website [20])

- MetadataRecord -
    - `ms:MetadataRecordIdentifier` - A string (e.g., PID, DOI, internal to an organization etc.) used to uniquely identify a metadata record.
    - `ms:metadataCreationDate` - Specifies the date when the metadata record was first created.
    - `ms:metadataLastDateUpdated` - Specifies the date when the last update of the metadata record was made.
    - `ms:compliesWith` - Specifies the vocabulary/standard/best practice to which a resource is compliant with.
    - `ms:sourceOfMetadataRecord` - Refers to the entity (repository, catalog, archive, etc.) from which the metadata record has been imported into the new catalog.
    - `ms:metadataCreator` - Introduces the person who has created the metadata record.
    - `ms:metadataCurator` - A person responsible for the creation, update, enrichment, etc. of a metadata record describing an entity.
    - `ms:sourceMetadataRecord` - Links, in some cases, to the metadata record that has been used as the basis for the creation of the metadata record.

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- `ms:revision` - Provides an account of the revisions in free text or a link to a document with revisions.
- describedEntity:
  - `ms:LanguageResource` - A resource composed of linguistic material used in the construction, improvement and/or evaluation of language processing applications.
  - `ms:LicenceTerms` - A legal document (license or terms of use/service) with which the language resource is distributed.
  - `ms:Document` - A piece of written, printed, or electronic matter that is primarily intended for reading.
  - `ms:Person` - A human being.
  - `ms:Organization` - A company or other group of people that works together for a particular purpose.
  - `ms:Group` - A set of persons related to some aspect of a language resource, that does not have a legal status.
  - `ms:Project` - A set of operations undertaken as a whole by an individual or organization and related to some aspect of the lifecycle of the language resource.

4.2.5. Open Machine Learning (OpenML)

OpenML is an online machine learning platform for sharing and organizing data, machine learning algorithms and experiments. It is designed to create a frictionless, networked ecosystem, that you can readily integrate into your existing processes/code/environments. Also, OpenML is at its core a database, from which entities can be downloaded and to which entities can be uploaded. In OpenML, Data (including Data features and Data Qualitive), Tasks, Flows, Runs and Evaluations are considered as entities. [21]

OpenML can contribute with some benefits to science, researchers and general society, such as, help the science community to organize, structure and analyse data online, open the results obtained to other scientific groups that can reinterpret the data finding new perspectives, help the scientists to tedious routines (finding data sets, tasks, flows and results), linking research results allowing other researchers to use them in order to achieve new discoveries and providing a useful learning and working environment for students, citizen scientists and practitioners.

In the StairwAi context, this platform can be a source of datasets, benchmarks and evaluations for our project, helping in the creation of resources for the horizontal matchmaking and helping with the training of this part of the system.

4.2.6. European Open Science Cloud (EOSC)

The European Open Science Cloud (EOSC) is an environment for hosting and processing research data to support EU science. In May 2015, the European Commission proposed creating the EOSC. The aim was to federate existing research data infrastructures in Europe and realise a web of FAIR data and related services for science. This project starts in the European Horizon 2020 program and it will be under development until 2022. [22]

The main gateway of this initiative is the EOSC Portal which puts into practice the European vision for Open Innovation and Open Science. In this portal Researchers can: I) discover and compare multiple resources, II)

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access services and resources, III) find information on access policies and IV) provide feedback about services and information of the platform.

On the other hand, Service providers can: I) publish, share and advertise services and resources, II) get statistics about requests and user's feedback, III) find a community of user's that can require their resources and services and IV) Contribute to the definition and maintenance of the EOSC Portal. [23]

Into StairwAI, the alignment with EOSC could be important because this initiative can contribute with its hardware resources and community that would be helpful for StairwAI's Vertical matchmaking.

4.3. Analysis of relevant projects and initiatives in StairwAI's Context

As explained in Section 2.2, in the context of StairwAI there are several projects in the ICT-48 and ICT-49 calls that are providing new services around the AI-on-demand platform. These projects are participating in the joint working group to explore the need to add new elements to the AI4EU Conceptual Semantic Model to better cover the needs of these projects.

Although most of them do not have ontological representations, the analysis we provide in the following sections allows us to foresee potential extensions within the StairwAI model that these projects could benefit from, thus, promoting synergies among them.

4.3.1. Bringing AI Planning to the European AI On-Demand Platform (AIPlan4EU)

The AIPlan4EU aims to develop a uniform user-centred framework to access the existing planning technology by devising concrete guidelines for innovators. The authors aim to develop a general and planner-agnostic AI that will be used in AI4EU and be available as a resource to be integrated into users' systems. This project will develop a taxonomy to represent the knowledge, focused on Planning [24].

AIPlan4EU already proposed a taxonomy of planning-related concepts. This project divides its taxonomy into 6 main classifications:

- Planning Problem Characteristics
    - Pure Scheduling (No or Yes)
    - Presence of Time (No, Discrete or Continuous)
    - Presence of numerical quantities (No, Discrete or Continuous)
    - Hierarchical structure (No, Yes or Recursive)
    - Motion planning (No, Topological or Continuous)
    - Simulated entities (None, Entire actions or Simulated resources)
    - Agents
        - Single
        - Multiple (Configuration, Agent relationship, Privacy preserving)
    - Discrete non-determinism (No, Initial state only, Effects)
    - Continuous non-determinism (No, Temporal uncertainty or Resource uncertainty)
    - Observability (None, Full or Partial)
    - Optimization objectives (None, Action costs, Makespan optimization or Continuous resource optimization)
    - Optimization kind (None, Satisfying, Optimal or Pareto-Optimal)

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- Solutions
  - Action Sequence
  - Partial-Order Plan
  - Simple Temporal Network
  - etc.
- Operation Modes
  - One-shot
  - Mixed initiative
  - Plain Repair
  - etc.
- Methods
  - Heuristic search
  - Local search
  - Symbolic search
  - etc.
- Use-cases
  - Underwater vehicles
  - Planning agricultural Operations
  - Planning for Space
  - etc.
- Tools
  - e.g., Fast Downward, TFD, LPG, ARIES, Tamer, FF, ENHSP, Scikit-decide

The complete classification can be found in the following GitHub repository [25].

Although AIPlan4EU does not have plans for the conversion of their proposed taxonomy into an ontology sharable with the other projects, this is something that is now under discussion in the Ontology working group (see section 2.2).

4.3.2. Reinforcing the AI4EU Platform by Advancing Earth Observation Intelligence, Innovation and Adoption (AI4Copernicus)

AI4Copernicus aims to make the AI4EU AI-on-demand platform the platform of choice for users of Copernicus data along the value chain (scientists, SMEs, non-tech sector). AI4Copernicus aims to expand the integration of AI4EU with DIAS platforms, incentivize the AI4EU and Copernicus communities to solve real business or social problems with societal value, and promote the usage of AE4EU and the DIAS platforms, especially WEkEO, CREODIAS and MUNDI [26].

AI4Copernicus extends the AI4EU Conceptual Data Model by adding some extra concepts such as `EO Equipment`, `EO Platform`, or `EO Collection`, and redefining others such as `AIAlgorithm`.

4.3.3. Artificial Intelligence for Next Generation Energy (I-NERGY)

I-NERGY aims to evolve, scale up and demonstrate innovative AI-as-a-Service (AIaaS) Energy Analytics Applications and digital twins' services. I-NERGY will develop new AI-based energy services with a full alignment to AI4EU service requirements and maximizing SME competitiveness on AI for energy. I-NERGY

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will consist of a machine learning library with the purpose of analysing heterogeneous data sources related to energy [27].

I-NERGY uses existing ontologies to build its knowledge model [27]:

- **BRICK**: is an open-source ontology that wants to standardize semantic descriptions of the physical, logical and virtual assets in buildings and the relationships between them.
- **HAYSTACK**: is an ontology for describing building assets using semi-structured sets of tags. HAYSTACK aims to model the vast quantity of data being generated by the smart devices that permeate homes, buildings, factories, and cities.
- **BIM**: is a semi-structured ontology used for knowledge acquisition and communication between people, it is intended for human-human communications.
- **SAREF**: is an ontology capturing high level aspects of smart and connected appliances.

4.3.4. AI On-Demand platform for regional interoperable Digital Innovation Hubs Networks (DIH4AI)

The EU-funded DIH4AI project aims to encourage AI applications across the economy, supporting joint development and provision of ecosystems, business, technology, and transformation services through a sustainable network of digital innovation hubs specialised in AI and targeting SMEs [28].

DIHs (Digital Innovation Hubs) are a fundamental European instrument that have emerged over the last decade to address SMEs' limitations when adopting new technologies, AI-based products (processes and services) based on European ethical values. DIH4AI aims to link DIH engines and the AI4EU service platform. DIH4AI has defined a taxonomy of services for SMEs.

The project has no plans to define or refine ontologies. However, at the time of writing this report, DIH4AI is working on the definition of a taxonomy of services for SMEs. We are contacting the developers of that taxonomy in DIH4AI to see if it may be relevant to take it into account in the StairwAI model or, even, in the core AI4EU model.

4.3.5. Foundations of Trustworthy AI-Integrating, Reasoning, Learning and Optimization (TAILOR)

During the AI boom in the last decade, non-AI-experts, SMEs, and all the society have seen some amazing applications of AI in several fields, which have been able to benefit from all the new possibilities opened by advanced Artificial Intelligence techniques. However, some misbehaviours have also been observed. Along this line, the European Union has been creating a set of guidelines to ensure a trustworthy and ethical use of AI. The Foundations of Trustworthy AI not only give AI-users [29].

The purpose of TAILOR is to build a strong academic-public-industrial research network with the capacity of providing the scientific basis for Trustworthy AI leveraging and combining learning, optimization, and reasoning for realizing AI systems that incorporate the safeguards that make them reliable, safe, transparent, and respectful of human agency and expectations.

At the time of writing this report, there are no plans in TAILOR to develop an ontology or taxonomy of Trustworthy AI concepts. But StairwAI is working in close contact with TAILOR to check their advances on the

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definition of Trustworthy AI elements and mechanisms, as those could be the basis for the fairness matching in WP5 and may guide the addition of some trustworthiness properties in the StairwAI AI Asset Conceptual Semantic Model.

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5. StairwAI's AI Asset Conceptual Semantic Model

In Section 3 the main modelling requirements to be covered were presented. After the analysis given in Section 4 on existing ontologies, taxonomies, and vocabularies that could be used as basis or inspiration to our model, this section presents our proposal for the second version of the AI Asset Conceptual Semantic Model.

At the beginning of the section, the approach adopted to model the Conceptual Semantic Model is explained. Then an overview of the model is given, followed by a detailed description of all its elements (classes and properties). Finally, the model is verified checking if and how the different requirements are met.

5.1. Top Ontology and Imported Ontologies

In order to meet requirement R2.4 (which asks for a Conceptual Model that is sufficiently general and flexible to ensure longevity and wide applicability), the AI Asset Conceptual Semantic Model (swai) is defined as a top ontology that defines only some few concepts and properties, which are then connected to other existing ontologies and taxonomies. Figure 5.1 depicts the set of models that are connected to StairwAI's Asset Conceptual Semantic Model.

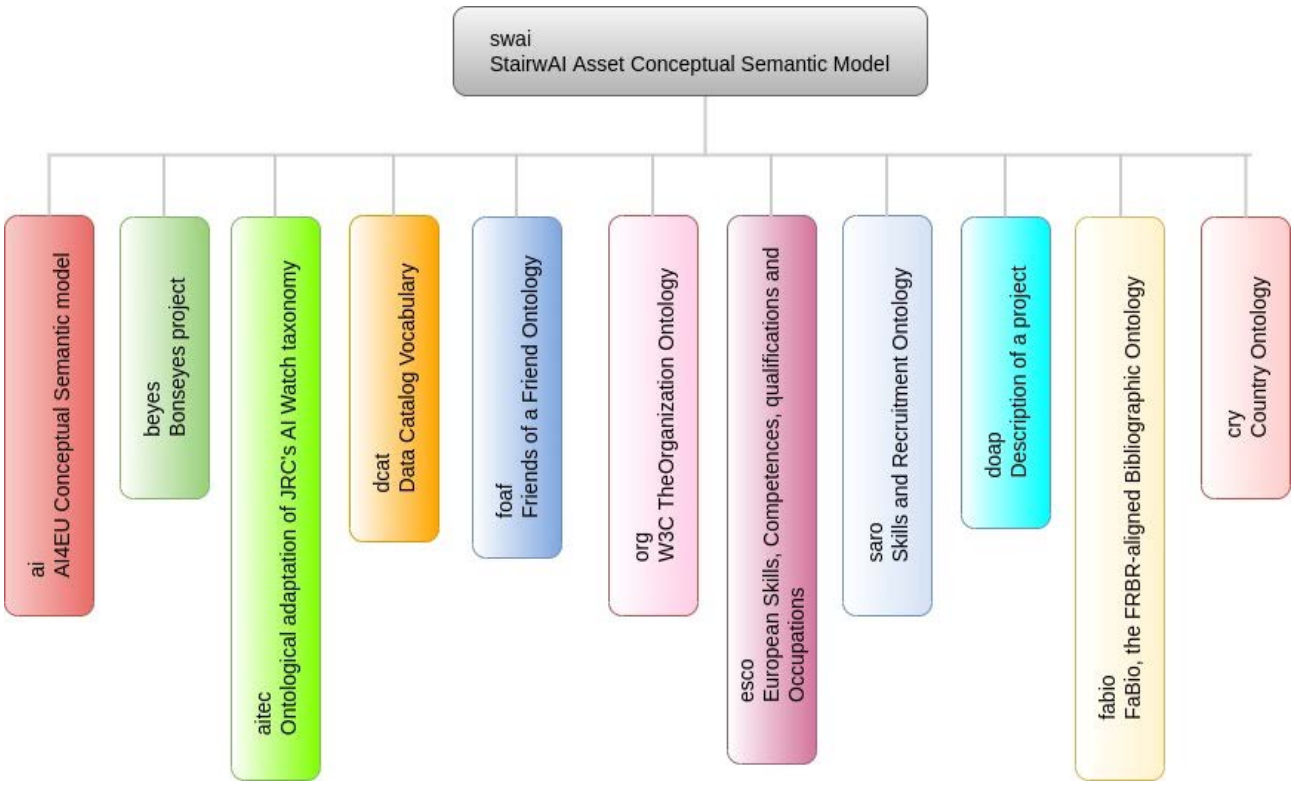

Figure 5.1 - Top Ontology and Imported Ontologies

- The ***AI4EU Ontology*** has been chosen to interoperate with the AI-On-demand platform. It also provides some relevant concepts to describe AI models, libraries, hardware components, educational

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resources, or publications. It contributes to R1.1, R2.1, R2.7. There are several concepts in the AI4EU Ontology that have been re-defined in the AI Asset Conceptual Semantic Model to be able to add new properties to them.

- The ***Bonseyes Data Model*** has been chosen to interoperate with the BonsApps Marketplace. It also provides some relevant concepts such as benchmarks, metrics, environments, and hardware infrastructures, and it contributes to R3.2. At the time of writing this report, there is only a well-defined data model, but not an actual ontology. Therefore, in this version of the AI Assets Conceptual Semantic Model, we have defined many concepts in the Bonseyes data model as part of the swai Ontology. A collaboration with the BonsApps project to explore the creation of a Bonseyes Ontology that could be directly imported by the swai Ontology is planned.
- JRC's AI Watch taxonomy: during the last year we decided to move the definition of the AI Techniques from the one proposed by the CSO ontology to an ontological version of the AI Watch taxonomy proposed by JRC. There are two main motivations of this change: firstly JRC AI Watch taxonomy is used by AI4EU to define the its list of technical categories increasing our alignment; and CSO does not fully satisfy our necessities. Accordingly, the StairwAI hierarchical ontology is now based on domains and subdomains proposed in the AI Watch document (as first and second level of concepts). To refine some second level concepts, which are sometimes too general, we are developing a third level in the hierarchy. The third level, more granular, exploits some keywords proposed in this document and others defined by experts in each field.
- The ***Data Catalog Vocabulary*** has been chosen to incorporate a well-defined concept of Dataset. This ontology provides an interesting definition of this term and, in addition, it defines the concept of Distribution that is used in StairwAI Asset ontology, and we are able to analyse this representation in order to improve our own representation. For these reasons, we can say that it contributes to R2.1.
- The ***Friends of a Friend*** ontology has been chosen to represent the relationships between people and AI assets (e.g., experts, consultants, developers, job applicants), and it contributes to R2.1. As explained in section 4.2.1, FOAF is used in the AI4EU Conceptual Semantic Model with the same purpose, thus promoting both the alignment between StairwAI and AI4EU models (contributes to R1.1) and the linkage between the data models.
- The ***W3C Organization Ontology*** has been chosen in order to model a complete definition of the concept of Organisation and all the related properties that this concept requires. In addition, it helps the job post field with the definition of the concept of Post as a position within an organization that exists independently of the person or persons filling it. For these reasons, we can say that it contributes to R2.2 requirement.
- The ***European Skills, Competences, qualifications and Occupations*** ontology has been chosen to represent the relationships between people and job posts and to enable the modelling of concepts such as qualifications, occupations, skill, and recruitment obtained by passing a course. Its representations of these concepts become fundamental to represent the requirements expressed in R2.6 and R2.7
- The ***Skills and Recruitment Ontology*** has been chosen to represent occupations, skill and recruitment, based on the Job post concept and its environment. This concept is strictly related to requirement R2.6, for this reason this ontology helps to the definition of concepts and model structure of this job offer part.
- The ***Description of a Project*** ontology has been chosen to be able to model concepts related to software projects' environment such as project, repository or version, just to name a few. In this version of the Top Asset semantic model, it is only used to specify the version of an AI Artifact, but it

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is ready to be used to specify the concept of repository or project if required. It helps to contribute to R2.2.

- The ***FRBR_aligned Bibliographic Ontology*** has been chosen to represent all the Academic Resource requirements. These ontology concepts are primarily textual publications such as books, magazines, newspapers and journals, and items of their content such as conference papers and editorials. However, they also include blogs, web pages, experimental protocols, formal specifications and technical reports. In addition, it defines bibliographic references, for these reasons we can affirm that it contributes to R2.1.

- The ***Country Ontology***: the updated version of the StairwAI Asset Conceptual Model requires the country concept modelling, which has all the current countries of the world. To model this concept, we used a simplified mapping of the one presented by Countries Ontology [i]

5.2. Model Description

This section provides the full description of the AI Asset Conceptual Semantic Model. It starts with an overview of the model (including a model diagram and the criteria used in the creation of a model) in section 5.2.1. Then subsequent sections describe the namespaces of the external ontologies (5.2.2), the classes (5.2.3), object properties (5.2.4) and datatype properties (5.2.5).

5.2.1. Criteria for creating a model

Figure 5.2 depicts the proposed ontology: classes are represented as boxes and relations as labelled arrows among concepts. This is only a graphical representation and follows no normative. The normative technical description of the ontology is developed in the rest of Section 5.

As a first milestone of Task 3.1, the manifold objective has been to *i)* produce an interconnected top ontology covering and connecting the domains of all the concepts available in the information handled by the different StairwAI components (formalized as Coverage requirements in section 3), *ii)* provide them with a representation of the different domains inputs and outputs and *iii)* provide semantic connections among information produced and consumed by those components.

According to this perspective, there are different regions in the diagram to support these different domains. Focusing only on the grey boxes in the diagram, the main central concept of the StairwAI Conceptual Semantic Model (swai) is AIAsset. The different regions inherit from it, although the regions are also interconnected via object properties:

- One region can be identified around the concepts Skill, Course, Certification, AcademicResource; this region models the educational domain.
- Through the Person concept, another region is reached, articulated around JobPosting, Organization and BusinessCategories; the job enrolment domain is developed here.
- The Agent concept connects the previous regions (in the upper part of the diagram) with the lower region, where three other domains are developed:
- The AIArtifact class and its related classes develop the software/code domain. This region links with the hardware domain via Container and AITechnique classes.
- Both hardware and software domains link to the Solution concept, which opens to the open-call and benchmarking domains.

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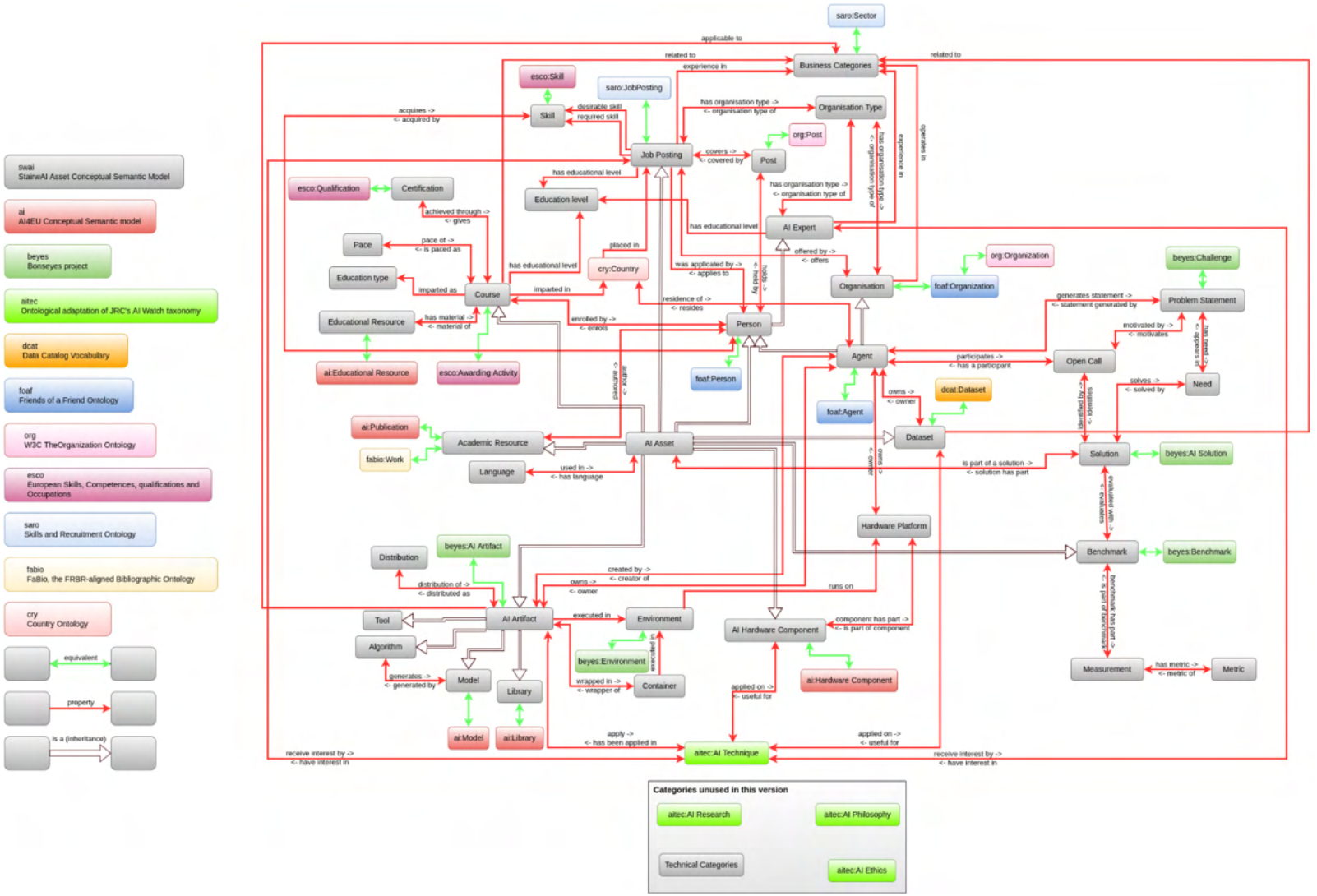

Figure 5.2 - The AI Asset Conceptual Semantic Model

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The StairwAI Conceptual Semantic Model relies on the pre-existence of other domain ontologies that will be used as support. Concepts of external ontologies are coloured in the diagram following the colour key blocks on the left. For the educational domain, *esco* is the chosen ontology. For the recruitment region, *saro*, *org and foaf* are the chosen ontologies, although *ebg* will likely also be needed in the future. For the technical regions of coding, hardware, and benchmarking, *beyes* has been chosen, although *doap* is also being considered. The OpenCall domain still needs some clear candidates for becoming a supporting ontology.

When a swai concept is defined as equivalent to an external ontology concept, it is always due to the need of specifying additional properties—not included in the external ontology concept specification.

5.2.2. Namespaces

Namespace	Ontology complete name
swai http://purl.org/swai/spec#	StairwAI
ai http://www.ai4eu.eu/ontologies/0.9.5/core	AI4EU
dc http://purl.org/dc/elements/1.1/	Dublin Core
dcat http://www.w3.org/ns/dcat#	Data Catalog Vocabulary
doap http://usefulinc.com/ns/doap#	Description of a Project
esco http://data.europa.eu/esco/model#	European Skills, competences, Qualifications and Occupations
fabio http://purl.org/spar/fabio/2019-02-19	FaBiO, the FRBR-aligned Bibliographic Ontology
foaf http://xmlns.com/foaf/0.1/	Friend of a friend
org http://www.w3.org/ns/org#	W3C The organization Ontology
saro http://w3id.org/saro	Skills and Recruitment Ontology

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5.2.3. Classes

Awarding activity

Property	Value
URI	http://data.europa.eu/esco/model#AwardingActivity
Is Defined By	http://data.europa.eu/esco/model
Description	An awarding activity represents an activity related to the awarding of a qualification. It is used to specify an awarding body, a country or region where the qualification is awarded and optionally an awarding period.

Qualification

Property	Value
URI	http://data.europa.eu/esco/model#Qualification
Is Defined By	http://data.europa.eu/esco/model
Description	List of properties on a qualification defined by the QMS application profile: - adms:identifier (1..n) - esco:referenceLanguage (0..n) - skos:prefLabel (1..n) - skos:altLabel (0..n) - skos:definition (0..n) - dcterms:description (1..n) - esco:hasISCED-FCode (1..n) - esco:hasAssociation (0..n) - esco:hasECTSCreditPoints (0..1) - esco:volumeOfLearning (0..1) - esco:isPartialQualification (0..1) - esco:waysToAcquire (0..n) - esco:expiryPeriod (0..n) - esco:hasRecognition (0..n) - esco:hasAwardingActivity (0..n) - esco:hasAccreditation (0..n) - foaf:homepage (0..n) - dcat:landingPage (0..n) - esco:supplementaryDoc (0..n) - dcterms:issued (1..1) - dcterms:modified (1..1) - skos:changeNote (0..1) - skos:historyNote (0..1) - esco:additionalNote (0..n) - dcterms:replaces (0..n) - dcterms:isReplacedBy (0..n) - iso-thes:status (0..1) - dcterms:creator (0..1) - dcterms:rightsHolder (0..1) - dcterms:publisher (1..1)

Skill

Property	Value
URI	http://data.europa.eu/esco/model#Skill
Is Defined By	http://data.europa.eu/esco/model
Description	A skill may also be an informal recognition of a competence. The recognition typically is obtained by experience, practice or informal tests.

AI Artifact

Property	Value
URI	http://purl.org/swai/spec#AIArtifact
Description	An accessible, using a distribution, and usable artifact pertaining to AI research field.

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Super-classes	AI Asset
Restrictions	executed in **some** Environment owner **some** Agent
Sub-classes	Tool Library Model Algorithm
In domain of	created by doap:programminglanguage distributed as doap:platform wrapped in applicable to doap:os
In range of	creator of wrapper of distribution of

AI Asset

Property	Value
URI	http://purl.org/swai/spec#AIAsset
Description	The AI-related elements that StairwAI offers to users.
Sub-classes	Academic Resource Job Posting Course AI Hardware Component Person Dataset AI Artifact Benchmark
In domain of	doap:created version doap:audience doap:shortdesc contact details identifier license of distribution name language

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AI expert

Property	Value
URI	http://purl.org/swai/spec#AIExpert
Description	Person with expertise in the field of AI
Super-classes	Person
In domain of	available expert current organisation

AI Hardware Component

Property	Value
URI	http://purl.org/swai/spec#AIHardwareComponent
Description	A hardware AI resource (device/equipment).
Super-classes	AI Asset
In domain of	has whole component
In range of	is part of a component

Academic Resource

Property	Value
URI	http://purl.org/swai/spec#AcademicResource
Description	A published or potentially publishable, scholarly resource.
Super-classes	AI Asset
In domain of	author year of publication DOI (Digital Object Identifier)
In range of	authored

Agent

Property	Value
URI	http://purl.org/swai/spec#Agent
Description	Any entity (either persons, organizations, or software processes) having the capability to pro-actively act.
Restrictions	linkedin url **some** xsd:anyURI email **min** 1

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Sub-classes	Person Organisation
In domain of	participates in linkedin url generates statement org:location owns resides email creator of
In range of	residence of created by owner has a participant statement generated by

Algorithm

Property	Value
URI	http://purl.org/swai/spec#Algorithm
Description	A recipe to perform a computational task, a finite sequence of instructions.
Super-classes	AI Artifact
In domain of	generates
In range of	generated by

Benchmark

Property	Value
URI	http://purl.org/swai/spec#Benchmark
Description	Evaluation by comparison with a standard metric.
Super-classes	AI Asset
In domain of	evaluates is part of a measurement
In range of	has whole measurement evaluated with

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Certification

Property	Value
URI	http://purl.org/swai/spec#Certification
Description	A document that certifies that a person has received specific education.
In domain of	achieved Through
In range of	gives

Container

Property	Value
URI	http://purl.org/swai/spec#Container
Description	A project that automates the deployment of applications within software containers, providing an additional layer of abstraction and application virtualization automation across multiple operating systems on top of a variety of locations, such as on-premises, in a public cloud, and/or in a private cloud.
Restrictions	executed in **some** Environment
In domain of	wrapper of
In range of	wrapped in
Has members	jupyterNotebook dockerContainer

Course

Property	Value
URI	http://purl.org/swai/spec#Course
Description	A unit of teaching that typically lasts one academic term, is led by one or more instructors, and has a fixed roster of students.
Super-classes	AI Asset
In domain of	credits imparted as gives has material subject enrolled by imparted in
In range of	achieved Through enrols material of

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Dataset

Property	Value
URI	http://purl.org/swai/spec#Dataset
Description	A collection of data that is treated as a single unit by a computer
Super-classes	AI Asset
Restrictions	owner **some** Agent
In domain of	useful for related to

Distribution

Property	Value
URI	http://purl.org/swai/spec#Distribution
Description	A specific form of packaging and means of exposure and availability for an AI Artifact.
In domain of	distribution of
In range of	distributed as
Has members	executable saas container

Education level

Property	Value
URI	http://purl.org/swai/spec#EducationLevel
Description	Describe a standardization of the possible education level that a person can achieve
In range of	has educational level
Has members	Advanced Master Bachelor Basic

Education type

Property	Value
URI	http://purl.org/swai/spec#EducationType
Description	The methodology used in order to teach a course

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In range of	imparted as
Has members	OnSite Tutorial MOOC BlendedLearning DistanceLearning

Educational Resource

Property	Value
URI	http://purl.org/swai/spec#EducationalResource
Description	A resource built and distributed for educational purposes.
In domain of	material of
In range of	has material

Environment

Property	Value
URI	http://purl.org/swai/spec#Environment
Description	The set of facilities, such as operating system, windows management, database, etc., that is available to a program when it is being executed.
In domain of	runs on
In range of	executed in

Hardware Platform

Property	Value
URI	http://purl.org/swai/spec#HardwarePlatform
Description	A set of compatible hardware on which software applications can be run.
Restrictions	owner **some** Agent
In domain of	is part of a component
In range of	runs on has whole component

Job Posting

Property	Value
URI	http://purl.org/swai/spec#JobPosting

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Description	Primary means through which companies recruit new applicants for available positions.
Super-classes	AI Asset
In domain of	placed in preferences publication date desired technology offered by required skill desirable skill covers was applicated by
In range of	covered by applies to offers

Language

Property	Value
URI	http://purl.org/swai/spec#Language
Description	Class that maps the different languages in Europe (adapted source:AI4EU platform)
In domain of	used in
In range of	has language
Has members	Portuguese Lithuanian Italian Danish Irish Catalan International Swedish Spanish Czech Bulgarian Greek German Latvian Croatian Polish Romanian Finnish Estonian Slovenian

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	Slovak Hungarian French Maltese Dutch English

Library

Property	Value
URI	http://purl.org/swai/spec#Library
Description	A suite of data and programming code that is used to develop software programs and applications, designed to assist both the programmer and the programming language compiler in building and executing software.
Super-classes	AI Artifact

Measurement

Property	Value
URI	http://purl.org/swai/spec#Measurement
Description	The size, length, or amount of something, in terms of a measure unit.
In domain of	has whole measurement has metric
In range of	metric of is part of a measurement

Metric

Property	Value
URI	http://purl.org/swai/spec#Metric
Description	A system or standard of measurement.
In domain of	metric of
In range of	has metric

Model

Property	Value
URI	http://purl.org/swai/spec#Model
Description	A simplified representation of a system or a software process.
Super-classes	AI Artifact

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In domain of	generated by
In range of	generates

Need

Property	Value
URI	http://purl.org/swai/spec#Need
Description	Something that is desired or required. It is distilled from a Problem Statement.
In domain of	solved by appears in
In range of	has need solves

Open Call

Property	Value
URI	http://purl.org/swai/spec#OpenCall
Description	A local, national, or international competition open to SMEs, start-ups, scaleups, and mid-cap companies for the purpose of procuring the commissioning and provision of technology as part of the development.
In domain of	has a participant motivated by identifies
In range of	motivates identified by participates in

Organisation

Property	Value
URI	http://purl.org/swai/spec#Organisation
Description	An organized group of people with a particular purpose, such as a business or government department.
Super-classes	Agent
In domain of	operates in offers
In range of	offered by

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Organisation Type

Property	Value
URI	http://purl.org/swai/spec#OrganisationType
Description	Categorisation of different types of organisations.
In domain of	organisation type of
In range of	has organisation type
Has members	smeCompany digitalInnovationHub largeCompany publicBody consortium researchOrganisation startupCompany nonGovernamentalOrganisation

Pace

Property	Value
URI	http://purl.org/swai/spec#Pace
Description	Describes the different paces in which a course is taught.
In domain of	pace of
In range of	is paced as
Has members	FullTime PartTime SelfPaced

Person

Property	Value
URI	http://purl.org/swai/spec#Person
Description	People.
Super-classes	Agent AI Asset
Sub-classes	AI expert
In domain of	enrols holds applies to acquires surname

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	authored
In range of	was applicated by author acquired by enrolled by held by

Post

Property	Value
URI	http://purl.org/swai/spec#Post
Description	A Post represents some position within an organization that exists independently of the person or persons filling it.
In domain of	covered by held by
In range of	covers holds

Problem Statement

Property	Value
URI	http://purl.org/swai/spec#ProblemStatement
Description	Formal description of a problem that can be solved using AI.
In domain of	objective motivation data availability has need motivates statement generated by
In range of	appears in motivated by generates statement

Skill

Property	Value
URI	http://purl.org/swai/spec#Skill
Description	The ability to do something well; expertise.
In domain of	aquired by
In range of	required skill acquires

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	desiderable skill

Solution

Property	Value
URI	http://purl.org/swai/spec#Solution
Description	The software that addresses an industry use case and is a fully executable application that can be deployed to the target hardware.
In domain of	identified by solves evaluated with has whole solution
In range of	is part of a solution solved by identifies evaluates

Tool

Property	Value
URI	http://purl.org/swai/spec#Tool
Description	A software that assists in activities such as, and not limited to, data analysis, decision support, recommendation, etc.
Super-classes	AI Artifact

Job Posting

Property	Value
URI	http://w3id.org/saro#JobPosting
Description	a listing that describes a job opening in a certain organization

Sector

Property	Value
URI	http://w3id.org/saro#Sector
Description	The sector associated with the job position

Educational Resource

Property	Value
URI	http://www.ai4eu.eu/ontologies/core#EducationalResource
Description	A resource built and distributed for educational purposes

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Hardware Component

Property	Value
URI	http://www.ai4eu.eu/ontologies/core#HardwareComponent
Description	A hardware AI resource (device/equipment).

Library

Property	Value
URI	http://www.ai4eu.eu/ontologies/core#Library
Description	A distribution meant to be incorporated as a module into a larger framework or application.

Model

Property	Value
URI	http://www.ai4eu.eu/ontologies/core#Model
Description	An AI Model.

Publication

Property	Value
URI	http://www.ai4eu.eu/ontologies/core#Publication
Description	A published scholar manuscript.

Dataset

Property	Value
URI	http://www.w3.org/ns/dcat#Dataset
Description	A collection of data, published or curated by a sole source, and available for access or download in one or more representations.
Scope Notes	The notion of dataset in DCAT is broad and inclusive, with the intention of accommodating resource types arising from all communities. Data comes in many forms including numbers, text, pixels, imagery, sound and other multi-media, and potentially other types, any of which might be collected into a dataset.

Organization

Property	Value
URI	http://www.w3.org/ns/org#Organization
Description	Represents a collection of people organized together into a community or other social, commercial or political structure. The group has some common purpose or reason for existence which goes beyond the set of people belonging to it and can act as an Agent. Organizations are often decomposable into hierarchical

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	structures. It is recommended that SKOS lexical labels should be used to label the Organization. In particular skos:prefLabel for the primary (possibly legally recognized name), skos:altLabel for alternative names (trading names, colloquial names) and skos:notation to denote a code from a code list. Alternative names: *Collective Body Org Group*
Super-classes	foaf:Agent

Post

Property	Value
URI	http://www.w3.org/ns/org#Post
Description	A Post represents some position within an organization that exists independently of the person or persons filling it. Posts may be used to represent situations where a person is a member of an organization ex officio (for example the Secretary of State for Scotland is part of UK Cabinet by virtue of being Secretary of State for Scotland, not as an individual person). A post can be held by multiple people and hence can be treated as a organization in its own right.

Agent

Property	Value
URI	http://xmlns.com/foaf/0.1/Agent
Description	An agent (e.g., person, group, software, or physical artifact).
Sub-classes	foaf:Person foaf:Organization org:Organization

Organization

Property	Value
URI	http://xmlns.com/foaf/0.1/Organization
Description	An organization.
Super-classes	foaf:Agent

Person

Property	Value
URI	http://xmlns.com/foaf/0.1/Person
Description	A person.
Super-classes	foaf:Agent

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5.2.4. Object properties

achieved Through

Property	Value
URI	http://purl.org/swai/spec#achievedThrough
Description	Denotes the giver of an official recognition.
Domain(s)	Certification
Range(s)	Course

acquired by

Property	Value
URI	http://purl.org/swai/spec#acquiredBy
Description	Denotes the person that acquire a specific skill
Domain(s)	Skill
Range(s)	Person

acquires

Property	Value
URI	http://purl.org/swai/spec#acquires
Description	Someone learnt or developed a skill, habit, or quality.
Domain(s)	Person
Range(s)	Skill

appears in

Property	Value
URI	http://purl.org/swai/spec#appearsIn
Description	Denotes the problem statements that have a specific need
Domain(s)	Need
Range(s)	ProblemStatement

applicable to

Property	Value
URI	http://purl.org/swai/spec#applicableTo
Description	Defines the applicability that has a specific AI Artifact to a business area.

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Domain(s)	AI Artifact
Range(s)	aicat:BusinessCategories

applies to

Property	Value
URI	http://purl.org/swai/spec#appliesTo
Description	Someone sent a formal request to be considered for a position or to be allowed to do or have something, submitted to an authority, institution, or organization.
Domain(s)	Person
Range(s)	JobPosting

associated to

Property	Value
URI	http://purl.org/swai/spec#associatedTo
Description	Indicates that an Artifact or Hardware component should be associated to, at least, one AITechnique
Domain(s)	(AI Artifact or AI Hardware Component)
Range(s)	aicat:TechnicalCategories

author

Property	Value
URI	http://purl.org/swai/spec#author
Description	Person that created an educational resource
Domain(s)	Academic Resource
Range(s)	Person

authored

Property	Value
URI	http://purl.org/swai/spec#authored
Description	Denotes the academic resources authored for a specific author
Domain(s)	Person
Range(s)	AcademicResource

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covered by

Property	Value
URI	http://purl.org/swai/spec#coveredBy
Description	Denotates the job posts that cover a specific post.
Domain(s)	Post
Range(s)	JobPosting

covers

Property	Value
URI	http://purl.org/swai/spec#covers
Description	Indicates the available position.
Domain(s)	Job Posting
Range(s)	Post

created by

Property	Value
URI	http://purl.org/swai/spec#createdBy
Description	The person, or thing, that brings something into existence.
Domain(s)	AI Artifact
Range(s)	Agent

creator of

Property	Value
URI	http://purl.org/swai/spec#creatorOf
Description	Denotates the artifacts that an Agent created
Domain(s)	Agent
Range(s)	AIArtifact

desirable skill

Property	Value
URI	http://purl.org/swai/spec#desiderableSkill
Description	Indicates the desirable abilities.
Domain(s)	Job Posting

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Range(s)	Skill

distributed as

Property	Value
URI	http://purl.org/swai/spec#distributedAs
Description	Indicates packaging conditions (licence, documentation, etc.).
Domain(s)	AI Artifact
Range(s)	Distribution

distribution of

Property	Value
URI	http://purl.org/swai/spec#distributionOf
Description	Indicates the AIArtifacts that are distributed under a specific distribution.
Domain(s)	Distribution
Range(s)	AIArtifact

enrolled by

Property	Value
URI	http://purl.org/swai/spec#enroledBy
Description	Indicates the persons that are enrolled in a specific course
Domain(s)	Course
Range(s)	Person

enrols

Property	Value
URI	http://purl.org/swai/spec#enrolls
Description	Someone officially registered as a student on a course.
Domain(s)	Person
Range(s)	Course

evaluated with

Property	Value
URI	http://purl.org/swai/spec#evaluatedWith

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Description	Indicates the benchmarks used to evaluate a Solution.
Domain(s)	Solution
Range(s)	Benchmark

evaluates

Property	Value
URI	http://purl.org/swai/spec#evaluates
Description	Indicates a judgement or assessment.
Domain(s)	Benchmark
Range(s)	Solution

executed in

Property	Value
URI	http://purl.org/swai/spec#executedIn
Description	Indicates the place of performance of an instruction or program.
Domain(s)	(AI Artifact or Container)
Range(s)	Environment

experience in

Property	Value
URI	http://purl.org/swai/spec#experienceIn
Description	Indicates the experience that an expert has in, or the experience required for, a Job Posting in a business field.
Domain(s)	(AI expert or Job Posting)
Range(s)	aicat:BusinessCategories

generated by

Property	Value
URI	http://purl.org/swai/spec#generatedBy
Description	Indicates the algorithms used to generate a Model
Domain(s)	Model
Range(s)	Algorithm

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generates

Property	Value
URI	http://purl.org/swai/spec#generates
Description	Indicates the producer of a set or sequence of items by performing specified mathematical or logistical operations on an initial set.
Domain(s)	Algorithm
Range(s)	Model

generates statement

Property	Value
URI	http://purl.org/swai/spec#generatesStatement
Description	An Agent that creates a new Problem Statement.
Domain(s)	Agent
Range(s)	ProblemStatement

gives

Property	Value
URI	http://purl.org/swai/spec#gives
Description	Indicates the Certifications that a Course gives to the pupils.
Domain(s)	Course
Range(s)	Certification

has educational level

Property	Value
URI	http://purl.org/swai/spec#hasEducationLevel
Description	Indicates the maximum educational level achieved by a person or the educational level of a Course
Domain(s)	(AI expert or Course or Job Posting)
Range(s)	EducationLevel

has language

Property	Value
URI	http://purl.org/swai/spec#hasLanguage
Description	Indicates a language used in an Asset

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Domain(s)	AI Asset
Range(s)	Language

has material

Property	Value
URI	http://purl.org/swai/spec#hasMaterial
Description	Indicates didactic resources offered in a course.
Domain(s)	Course
Range(s)	EducationalResource

has metric

Property	Value
URI	http://purl.org/swai/spec#hasMetric
Description	Indicates a standard of measurement to be applied.
Domain(s)	Measurement
Range(s)	Metric

has need

Property	Value
URI	http://purl.org/swai/spec#hasNeed
Description	Indicates an indispensable thing.
Domain(s)	Problem Statement
Range(s)	Need

has organisation type

Property	Value
URI	http://purl.org/swai/spec#hasOrganisationType
Description	An Organisation type relation
Domain(s)	(AI expert or Job Posting or Organisation)
Range(s)	OrganisationType

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has a participant

Property	Value
URI	http://purl.org/swai/spec#hasParticipant
Description	Indicates the participants of an Open Call
Domain(s)	Open Call
Range(s)	Agent

has part

Property	Value
URI	http://purl.org/swai/spec#hasPart
Description	Indicates the parts of an entity.

solution has part

Property	Value
URI	http://purl.org/swai/spec#solutionHasPart
Description	Indicates the Solution that contains, as a part, a specific artifact, dataset or hardware platform.
Super-properties	has part
Domain(s)	Solution
Range(s)	(AI Artifact or Dataset or Hardware Platform)

benchmark has part

Property	Value
URI	http://purl.org/swai/spec#benchmarkHasPart
Description	Indicates a measurement of a Benchmark.
Super-properties	has part
Domain(s)	Benchmark
Range(s)	Measurement

component has part

Property	Value
URI	http://purl.org/swai/spec#componentHasPart
Description	Indicates the platform that contains, as a part, a specific AI Hardware component
Super-properties	has part

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Domain(s)	AI Hardware Component
Range(s)	HardwarePlatform

held by

Property	Value
URI	http://purl.org/swai/spec#heldBy
Description	Indicates the person that holds a Post
Domain(s)	Post
Range(s)	Person

holds

Property	Value
URI	http://purl.org/swai/spec#holds
Description	Indicates a Post held by some Agent
Domain(s)	Person
Range(s)	Post

identified by

Property	Value
URI	http://purl.org/swai/spec#identifiedBy
Description	Indicates the Open Call that generates a specific solution
Domain(s)	Solution
Range(s)	OpenCall

identifies

Property	Value
URI	http://purl.org/swai/spec#identifies
Description	Indicates the results that solve the requirements.
Domain(s)	Open Call
Range(s)	Solution

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imparted as

Property	Value
URI	http://purl.org/swai/spec#impartedAs
Description	Indicates the methodology used in a Course
Domain(s)	Course
Range(s)	EducationType

imparted in

Property	Value
URI	http://purl.org/swai/spec#impartedIn
Description	Indicates the Country in where a course is imparted
Domain(s)	Course
Range(s)	cry:Country

interested in

Property	Value
URI	http://purl.org/swai/spec#interestIn
Description	Indicates a technical area of interest for an Expert or a Job post.
Domain(s)	(AI expert or Job Posting)
Range(s)	aicat:TechnicalCategories

is paced as

Property	Value
URI	http://purl.org/swai/spec#isPacedAs
Description	Describe in which manner is paced a course
Domain(s)	Course
Range(s)	Pace

is part of

Property	Value
URI	http://purl.org/swai/spec#isPartOf
Description	Indicates the general entity that has another entity as its own part.

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is part of a component

Property	Value
URI	http://purl.org/swai/spec#isPartOfComponent
Description	Indicates that a hardware platform is a part of a Hardware Component.
Super-properties	is part of
Domain(s)	Hardware Platform
Range(s)	AIHardwareComponent

is part of a benchmark

Property	Value
URI	http://purl.org/swai/spec#isPartOfMeasurement
Description	Indicates that a benchmark is a part of a Measurement.
Super-properties	is part of
Domain(s)	Measurement
Range(s)	Benchmark

is part of a solution

Property	Value
URI	http://purl.org/swai/spec#isPartOfSolution
Description	Indicates that an artifact, dataset, or hardware platform is a part of a Solution.
Super-properties	is part of
Domain(s)	(AI Artifact or Dataset or Hardware Platform)
Range(s)	Solution

material of

Property	Value
URI	http://purl.org/swai/spec#materialOf
Description	Indicates the Course that uses a specific educational resource
Domain(s)	Educational Resource
Range(s)	Course

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metric of

Property	Value
URI	http://purl.org/swai/spec#metricOf
Description	Indicates the measurements that uses a metric
Domain(s)	Metric
Range(s)	Measurement

motivated by

Property	Value
URI	http://purl.org/swai/spec#motivatedBy
Description	Indicates facts and arguments used in support of a something.
Domain(s)	Open Call
Range(s)	Problem Statement

motivates

Property	Value
URI	http://purl.org/swai/spec#motivates
Description	to cause someone to behave in a particular way
Domain(s)	Problem Statement
Range(s)	OpenCall

offered by

Property	Value
URI	http://purl.org/swai/spec#offeredBy
Description	Indicates the Organisation that offer a Job posting
Domain(s)	Job Posting
Range(s)	Organisation

offers

Property	Value
URI	http://purl.org/swai/spec#offers
Description	Indicates a job opportunity.
Domain(s)	Organisation

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Range(s)	JobPosting

operates in

Property	Value
URI	http://purl.org/swai/spec#operatesIn
Description	Indicates the area in which an organization develops its effort.
Domain(s)	Organisation
Range(s)	aicat:BusinessCategories

organisation type of

Property	Value
URI	http://purl.org/swai/spec#organisationTypeOf
Description	Indicates the experts, jobs offers and organisations related to a specific type of organisation
Domain(s)	Organisation Type
Range(s)	(AIExpert or JobPosting or Organisation)

owner

Property	Value
URI	http://purl.org/swai/spec#owner
Description	Proprietary of something.
Domain(s)	(AI Artifact or Dataset or Hardware Platform)
Range(s)	Agent

owns

Property	Value
URI	http://purl.org/swai/spec#owns
Description	Indicates the items that an agent owns
Domain(s)	Agent
Range(s)	(AIArtifact or Dataset or HardwarePlatform)

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pace of

Property	Value
URI	http://purl.org/swai/spec#paceOf
Description	Describe all the courses that are paced in a specific manner.
Domain(s)	Pace
Range(s)	Course

participates in

Property	Value
URI	http://purl.org/swai/spec#participatesIn
Description	Indicates someone taking part in something.
Domain(s)	Agent
Range(s)	OpenCall

placed in

Property	Value
URI	http://purl.org/swai/spec#placedIn
Description	Indicates the country where a job posting is placed
Domain(s)	Job Posting
Range(s)	cry:Country

related to

Property	Value
URI	http://purl.org/swai/spec#relatedTo
Description	Indicates economical area that a dataset belongs to
Domain(s)	Dataset
Range(s)	aicat:BusinessCategories

required skill

Property	Value
URI	http://purl.org/swai/spec#requiredSkill
Description	Indicates the abilities that must be fulfilled to the partaker to be considered as a candidate.
Domain(s)	Job Posting

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Range(s)	Skill

residence of

Property	Value
URI	http://purl.org/swai/spec#residenceOf
Description	Indicates the agents that live in a country
Domain(s)	cry:Country
Range(s)	Agent

resides

Property	Value
URI	http://purl.org/swai/spec#resides
Description	Indicates the country of origin of an Agent.
Domain(s)	Agent
Range(s)	cry:Country

runs on

Property	Value
URI	http://purl.org/swai/spec#runsOn
Description	Indicates the execution platform
Domain(s)	Environment
Range(s)	HardwarePlatform

solved by

Property	Value
URI	http://purl.org/swai/spec#solvedBy
Description	Indicates the solutions that solve a need
Domain(s)	Need
Range(s)	Solution

solves

Property	Value
URI	http://purl.org/swai/spec#solves

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Description	Indicates something is a means of effectively dealing with a problem.
Domain(s)	Solution
Range(s)	Need

statement generated by

Property	Value
URI	http://purl.org/swai/spec#statementGeneratedBy
Description	Indicates the agent that generates a problem statement
Domain(s)	Problem Statement
Range(s)	Agent

used in

Property	Value
URI	http://purl.org/swai/spec#usedIn
Description	Describe the Assets that use a specific language
Domain(s)	Language
Range(s)	AIAsset

useful for

Property	Value
URI	http://purl.org/swai/spec#usefulFor
Description	Describe the relation that can exists between a Dataset and the AI Techniques with which could be used.
Domain(s)	Dataset
Range(s)	aicat:TechnicalCategories

was applicated by

Property	Value
URI	http://purl.org/swai/spec#wasApplicatedBy
Description	Indicates the person that applies to a Job post
Domain(s)	Job Posting
Range(s)	Person

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wrapped in

Property	Value
URI	http://purl.org/swai/spec#wrappedIn
Description	Indicates an enclosure.
Domain(s)	AI Artifact
Range(s)	Container

wrapper of

Property	Value
URI	http://purl.org/swai/spec#wrapperOf
Description	Indicates the artifacts that are wrapped in a container
Domain(s)	Container
Range(s)	AIArtifact

5.2.5. Datatype properties

DOI (Digital Object Identifier)

Property	Value
URI	http://purl.org/swai/spec#DOI
Description	Standard identifier of the academic resource
Domain(s)	Academic Resource
Range(s)	xsd:string

GDPR requirements

Property	Value
URI	http://purl.org/swai/spec#GDPRrequirements
Domain(s)	(AI Artifact or Dataset)
Range(s)	xsd:string

available expert

Property	Value
URI	http://purl.org/swai/spec#availableExpert
Description	Indicates if an AI expert wants to be discovered

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Domain(s)	AI expert
Range(s)	xsd:boolean

contact details

Property	Value
URI	http://purl.org/swai/spec#contactDetails
Description	Indicates the contact details of an Asset (e.g., email, contact person name, phone number)
Domain(s)	AI Asset
Range(s)	xsd:string

credits

Property	Value
URI	http://purl.org/swai/spec#credits
Description	Indicates the number of credits ects of a course
Domain(s)	Course
Range(s)	xsd:integer

current organisation

Property	Value
URI	http://purl.org/swai/spec#currentOrganisation
Description	Indicates the current organisation which an expert is currently working for.
Domain(s)	AI expert
Range(s)	xsd:string

data availability

Property	Value
URI	http://purl.org/swai/spec#dataAvailability
Description	Description of the data provisioning of the problem statement
Domain(s)	Problem Statement
Range(s)	xsd:string

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detailed description

Property	Value
URI	http://purl.org/swai/spec#detailedDescription
Description	Auxiliar information related to AI Asset.
Domain(s)	(AI Artifact or Dataset)
Range(s)	xsd:string

identifier

Property	Value
URI	http://purl.org/swai/spec#identifier
Description	Sequence of ASCII characters that uniclly identify an individual.
Domain(s)	AI Asset
Range(s)	xsd:string

license of distribution

Property	Value
URI	http://purl.org/swai/spec#licenseDistribution
Domain(s)	AI Asset
Range(s)	xsd:string

linkedin url

Property	Value
URI	http://purl.org/swai/spec#linkedinURL
Description	Agents LinkedIn link, to share the account.
Domain(s)	Agent
Range(s)	xsd:anyURI

motivation

Property	Value
URI	http://purl.org/swai/spec#motivation
Description	The motivation behind the statement of the problem.
Domain(s)	Problem Statement
Range(s)	xsd:string

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name

Property	Value
URI	http://purl.org/swai/spec#name
Domain(s)	AI Asset
Range(s)	xsd:string

objective

Property	Value
URI	http://purl.org/swai/spec#objective
Description	The aim of the statement of the problem.
Domain(s)	Problem Statement
Range(s)	xsd:string

preferences

Property	Value
URI	http://purl.org/swai/spec#preferences
Description	Indicate the company's preferences in a job post
Domain(s)	Job Posting
Range(s)	xsd:string

publication date

Property	Value
URI	http://purl.org/swai/spec#publicationDate
Description	Indicates he date that a Job post was publicated
Domain(s)	Job Posting
Range(s)	xsd:dateTime

requirements

Property	Value
URI	http://purl.org/swai/spec#requirements
Description	Indicates the requisites or requirements necessary for a task
Domain(s)	(Course or Problem Statement)

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Range(s)	xsd:string

surname

Property	Value
URI	http://purl.org/swai/spec#surname
Domain(s)	Person
Range(s)	xsd:string

trustworthy AI

Property	Value
URI	http://purl.org/swai/spec#trustworthyAI
Domain(s)	(AI Artifact or Dataset)
Range(s)	xsd:string

version

Property	Value
URI	http://purl.org/swai/spec#version
Domain(s)	AI Asset
Range(s)	xsd:string

year of publication

Property	Value
URI	http://purl.org/swai/spec#yearPublication
Description	Academic resource's year of publication
Domain(s)	Academic Resource
Range(s)	xsd:date

audience

Property	Value
URI	http://usefulinc.com/ns/doap#audience
Description	Description of target user base
Domain(s)	AI Asset

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Range(s)	rdfs:Literal

created

Property	Value
URI	http://usefulinc.com/ns/doap#created
Description	Date when something was created, in YYYY-MM-DD form. e.g., 2004-04-05
Domain(s)	AI Asset
Range(s)	rdfs:Literal

description

Property	Value
URI	http://usefulinc.com/ns/doap#description
Description	Plain text description of a project, of 2-4 sentences in length.
Domain(s)	(AI Asset or Problem Statement)
Range(s)	rdfs:Literal

location

Property	Value
URI	http://www.w3.org/ns/org#location
Description	Gives a location description for a person within the organization, for example a *Mail Stop* for internal posting purposes.
Domain(s)	Agent
Range(s)	xsd:string

desired technology

Property	Value
URI	http://purl.org/swai/spec#desiredTechnology
Description	Indicates the technologies that a company searches for a Job posting
Domain(s)	Job Posting
Range(s)	xsd:string

email

Property	Value
URI	http://purl.org/swai/spec#email

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Description	Email associated to an Agent
Domain(s)	Agent
Range(s)	xsd:anyURI

keyword

Property	Value
URI	http://purl.org/swai/spec#keyword
Description	Describing word of the area of application of an asset.
Domain(s)	(AI Artifact or Course or Dataset)
Range(s)	xsd:string

review comment

Property	Value
URI	http://purl.org/swai/spec#reviewComment
Description	Comment left by another platform member on the item.
Domain(s)	(AI Artifact or Academic Resource or Dataset)
Range(s)	xsd:string

subject

Property	Value
URI	http://purl.org/swai/spec#subject
Description	Indicates a subject, or subject category, of a course
Domain(s)	Course
Range(s)	xsd:string

url

Property	Value
URI	http://purl.org/swai/spec#url
Description	Link with information associated to a resource
Domain(s)	(AI Asset or Agent)
Range(s)	xsd:anyURI

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operating system

Property	Value
URI	http://usefulinc.com/ns/doap#os
Description	Operating system that a project is limited to. Omit this property if the project is not OS-specific.
Domain(s)	AI Artifact
Range(s)	rdfs:Literal

platform

Property	Value
URI	http://usefulinc.com/ns/doap#platform
Description	Indicator of software platform (non-OS specific), e.g. Java, Firefox, ECMA CLR
Domain(s)	AI Artifact
Range(s)	rdfs:Literal

programming language

Property	Value
URI	http://usefulinc.com/ns/doap#programminglanguage
Description	Programming language a project is implemented in or intended for use with.
Domain(s)	AI Artifact
Range(s)	rdfs:Literal

short description

Property	Value
URI	http://usefulinc.com/ns/doap#shortdesc
Description	Short (8 or 9 words) plain text description of a project.
Domain(s)	AI Asset
Range(s)	rdfs:Literal

5.3. Requirements Coverage Analysis

This section analyses how the model requirements (defined in Section 3) are covered by the StairwAI Asset Conceptual Semantic Model described in section 5.2.

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R1.1 Alignment with the AI4EU Conceptual Semantic Model
The AI Assets Conceptual Semantic Model should be semantically aligned to the concepts related to AI Assets in the AI4EU Conceptual Semantic Model *essential*
How this is covered: StairwAI relates to AI4EU, we can distinguish three types of relations between both platforms: a) Direct usage of AI4EU ontology concepts, like in the case of educational resources. b) Equivalences, when we use a concept that is directly equivalent to the one in AI4EU, such as, Library, Model, or Publication. c) Indirect matching when there is not a direct relation between StairwAI and AI4EU concepts.

R2.1 Coverage: Essential AI Assets
The AI Assets Conceptual Semantic Model should cover at least the following concepts: algorithms, tools, libraries, data sets, benchmarks, courses, academic resources, experts, and job positions. *essential*
How this is covered: StairwAI semantic model uses the AI Asset class in which we can find concepts as benchmarks, AI artifacts, hardware components, datasets, courses, academic resources, or job offers.

R2.2 Coverage: Industrial Use Case Needs
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of a problem statement coming from an industrial use case. It should have some core entities that can be extended to represent the use case context (the company, the business sector), the use case motivation and objective (the problem to solve), the data required, and other requirements (such as time or cost) *essential*
How this is covered: to cover this requirement, we model the concept of Problem Statement that enables us to establish a description of the problem that is required to solve, the need that this problem requires and generate a related Open Call-in order to find viable solutions to the problem.

R2.3 Coverage: Industrial Use Case Solutions

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The AI Assets Conceptual Semantic Model should adapt the semantic tagging of solved industrial use cases. It should connect the problem statement with the proposed Ai Assets to solve it. *essential*
How this is covered: to store and tag solved industrial use cases, the StairwAI data model proposes the concept of Solution. This class will be the generalization of all the software that addresses an industry use case and is a fully executable application that can be deployed to the target hardware.

R2.4 Genericity and Flexibility
The Conceptual Model used for the characterization of both use case descriptions and AI resources should be sufficiently general and flexible to ensure longevity and wide applicability for the WP5 matchmaking system. *essential*
How this is covered: to fulfil this requirement, this deliverable proposes a Top Ontology, in which the most general aspects, knowledge structure, and interconnections between concepts are defined, this ontology will serve as a baseline and on it, we will build the final semantic model of the project, using the specific requirements that will appear in the next project phases.

R2.5 AI Watch taxonomy alignment
The Conceptual Model used for the characterization of AI resources may be aligned with the taxonomy of AI techniques defined by JRC's AI Watch. *optional*
How this is covered: this requirement is partially covered. During the development of the second version of the ontology we have developed an ontological version of the AI Watch taxonomy (see section 5.4). This developed hierarchical taxonomy is imported into the current version of the StairwAI ontology but, being it still under development, the mapping of the AI techniques is performed with the technical categories of AI4EU, which in fact are a subset of the taxonomy proposed by the JRC.

R2.6 Coverage: Job positions and expertise
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of a job offer and the expertise of people. It should have some core entities that can be extended to represent, on one side, concepts related to a job offer (including, but not limited to the position to be covered, the skills and

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capacities required, the expected years of experience in a similar job) and to a person's expertise (skills and capacities, previous job positions) *essential*
How this is covered: to model this part of the StairwAI Semantic Model, we use two existing ontologies in the field, namely, ESCO (see in section 4.1.7) and SARO (see in section 4.1.8). These ontologies provide us some concepts such as qualifications, skills, awarding, or even, a complete predefined model in the field. We propose the main concept of Job Posting, which is the representation of the job offers supplied for an organization and to which any expert in the field can apply to.

R2.7 Coverage: Training requests, professors, academic material and on-line courses
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of training requests from users and different ways to provide such training. It should have some core entities that can be extended to represent concepts related to a training request (including, but not limited to, the skills to be obtained) but also, the different AI assets that the Horizontal Matchmaker may suggest (including, but not limited to, academic resources, courses and people with experience in the field) *essential*
How this is covered: the semantic model fulfils this requirement modelling concepts such as Course, Certification, or Skill. For example, using these concepts, we can generate courses that have obtained an official certification that enables any person that passes it to accredit the knowledge and the associated skills. The system can use these skills to find possible applicators to a Job offer that requires these skills.

R3.1 Coverage: user restrictions to the vertical matchmaking
The AI Assets Conceptual Semantic Model should represent the semantic tagging of the restrictions users may send through the multilingual interface to the Vertical Matchmaking service. It should have some core entities to represent restrictions (including, but not limited to, time consumption and hardware costs) *essential*
How this is covered: this requirement is directly satisfied using imported core ontologies such as DCIM or DCAT that able us to represent concepts of time consumption and hardware costs, such as `prov:endedAtTime`, `prov:startedAtTime`, `dcat:temporalResolution` or `dcterms:Period`.

R3.2 Coverage: Parametrized Hardware Solutions

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The AI Assets Conceptual Semantic Model should represent the semantic tagging of sets of hardware architectures (and their configuration parameters) *essential*
How this is covered: in order to fulfil this requirement current AI Assets Conceptual Semantic Model proposes the concept of Hardware Platform, in which, we can model some technical aspects related to a specific hardware that runs an AI Artifact, generating a solution (modelized in the concept of Solution) which we can benchmark.

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5.4. Summary of changes in StairwAI Asset Conceptual Semantic Model version 2

During the period between the first and second version of the StairwAI Ontology, we have developed said ontology, applying changes and adding new fields to it in order to adapt it as much as possible to the needs of the project. Below we will summarize the main aspects added since the first delivery.

5.4.1. Creation and usage of a stable PURL for the ontology

offering the possibility to make some files public, such as the ontology itself. With that stable URL, we were able to change the basic IRI of the ontology to a fixed URL. Finally, and as part of the refinement of the ontology, we have established a PURL (or permanent URL) to permanently stabilize it.

By defining a PURL, the position of the StairwAI ontology can be changed transparently and independently of the URL. Another good practice in ontology development is a conditional redirection of the ontology URL. That is, if the URL is used in a web browser, the URL will show the ontology documentation generated in an HTML file, or if it is used via any other tool, such as an ontology editor such as Protegé, the URL will show the TTL file. In our case, since we are using a server in GitLab, this redirect is not enabled.

5.4.2. New classes generated

In the development period of this second version of the Conceptual Semantic Model, new classes have been added, due to the requirements that we have been collecting from other WPs. The central part of our model, that is, the concept of AI Asset and its subclasses has not been modified. The new classes added contain static categorizations of individuals, born to represent previously categorized concepts, e.g., country, pace, distribution, etc.

5.4.3. Changes in object and data properties

During the development of the second version of the Conceptual Semantic Model, we added several object properties and data properties. These additions have the aim to augment the semantic connections of the classes of our model and give support to the project needs.

To determine the new data properties and object properties of the model we used the feedback from other WPs (WP4, WP5, WP6) during the Phase 2 of the project (Development), gathering new representational needs (new properties, new relations).

Another source of new object properties was the definition of the inverse relationships. An inverse relation is defined as if an individual x is connected by relation1 to an individual y, then y is also connected by relation2 to x, and vice versa. First, we analysed in which object property made syntactically sense an inverse relation, then with this subset determined, we defined the inverse relations of the relations that may require them. The definition of inverse relations is considered as a good praxis and can be very useful when we want to query the StairwAI AMS (that follows the Conceptual Semantic Model structure).

5.4.4. Creation of auxiliary importable ontologies

In this recent version of the StairwAI Conceptual Semantic Model, there are many changes in what is imported and how the concepts of other ontologies are imported. We can distinguish two different import methods:

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1. Import entire ontology: this is the main method to import terms from other ontologies, with it, the whole ontology will be imported. In the first version of the model this method was used to import all the required ontologies, even if we only require a single concept of them, causing an exponential increment of the axioms. This issue decreases the readiness of our model, adding many concepts that will not be used. It also causes a huge increment in the number of axioms, and this may disable the possibility to use a reasoner to check the correctness of our ontology. In the updated version, this method is restricted to only the ontologies that are entirely required, and currently all of them are auxiliary ontologies that we create to isolate some concepts of our ontology.
2. Copy only the axioms required: using this method (proposed in [ii]) We can select only the concepts that we want to use from other ontologies, copying only the selected concepts and all their related axioms (e.g., classes, subclasses, relations, annotations). This method becomes crucial to avoid the exponential increase of the knowledge model and increase their readiness. We use this methodology to copy many concepts from a large group of different external and well-known ontologies, such as; foaf, saro, dc or doap.

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6. Summary and next steps

The main objective of WP3 is the design of *AI Assets Conceptual Semantic Model* and the implementation of a dynamic and interoperable *StairwAI Asset Management System* that structures all information related to the different AI assets covered in StairwAI (libraries, models, tools, algorithms, datasets, hardware, experts, academic resources, job positions, etc). This *StairwAI Asset Management System* supports the operation of the three main blocks in StairwAI (namely the *Multi-Lingual Virtual Assistant* engine, the *Horizontal Matchmaking* module and the *Vertical Matchmaking* module).

The *AI Assets Conceptual Semantic Model* is the semantic knowledge representation that structures the knowledge within the StairwAI AMS, and its definition is the main purpose of this document.

6.1. Summary of results

These deliverable reports a second version of the *AI Assets Conceptual Semantic Model*. It is based on:

- The collection of requirements within Phase 1 (months M1 to M6) and Phase 2 (months M7 to M18) of the StairwAI project, described in Section 3. This initial set of requirements has been collected by direct interaction with Task participants within the Work Package 3, and through the analysis of Deliverable D1.1 “Data management plan”, Deliverable D2.1 “Requirements for the AI-on-demand platform” and Deliverable D2.2 “Requirements for the AI-on-demand platform”.
- The analysis of relevant models, described in Section 4.1. We have analysed existing ontologies, vocabularies, terminologies, taxonomies, and reference documents in literature to identify those that could be directly used by the *AI Assets Conceptual Semantic Model* or that could be the inspiration for some parts of it.
- The analysis of relevant projects and initiatives, described in Section 4.2. We have analysed projects and initiatives that are developing ontologies and data models that could be relevant for our knowledge representation, including some ICT-48 and ICT-49 projects that could influence the future evolution of our model, or that may become users.

Section 5 thoroughly describes the proposed *AI Assets Conceptual Semantic Model*. It has been defined as a top ontology that integrates concepts from other existing ontologies into a single, coherent, semantic model. We also show (section 5.3) how the proposed model covers the requirements.

6.2. Next steps

The first version of the *AI Assets Conceptual Semantic Model* was implemented as a knowledge graph within the first StairwAI AMS working prototype, reported as part of D3.3 “StairwAI AI Asset Management System - 1st version” to be published in Month 12. The instantiation of the second version of the Conceptual Semantic Model into the knowledge graph reporting in this deliverable has been almost done in the current implementation of the StairwAI AMS prototype.

In parallel, we expect to get new model requirements in the next months, coming from further data gathering made by WP3 in Task 3.3, Task 3.4, and Task 3.6 and the precise definition of the StairwAI module interfaces

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in Task 2.4. The *AI Assets Conceptual Semantic Model*, is thus not a static model, but a living one, that will be extended and adapted to new representational needs that may appear in the project lifetime.

Furthermore, the ongoing cooperation activity with the ICT 49 projects that plan to extend the AI4EU Conceptual semantic Model (AI4Copernicus, AIPlan4EU, and I-Nergy) and the projects that want to align with the AI-on-demand platform in different ways (ELG, Tailor, AI4Media, among others) may lead to consensus on the modelling of some of the AI Assets included in our model. As theses consensuses are reached, we will include them in the *AI Assets Conceptual Semantic Model.*

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Bibliography

[1] OWL Working Group, “Web Ontology Language (OWL),” The World Wide Web Consortium, 11 12 2012. [Online]. Available: https://www.w3.org/OWL/.

[2] DCMI Usage Board, “DCMI Metadata Terms,” Dublin Core Metadata Initiative, 20 1 2020. [Online]. Available: https://www.dublincore.org/specifications/dublin-core/dcmi-terms/.

[3] D. Brickley and L. Miller, “FOAF Vocabulary Specification 0.99,” 1 2014. [Online]. Available: http://xmlns.com/foaf/spec/.

[4] A. A. T. T. A. M. F. O. a. E. M. Salatino, “The Computer Science Ontology: A Large-Scale Taxonomy of Research Areas.,” in *International Semantic Web Conference* , Monterey, 2018.

[5] R. Albertoni, D. Browning, S. Cox, A. Gonzalez Beltran, A. Perego and P. Winstanley, “Data Catalog Vocabulary (DCAT) - Version 2,” The World Wide Web Consortium, 4 2 2020. [Online]. Available: https://www.w3.org/TR/vocab-dcat-2/.

[6] E. Dumbill, “The Description of a Project (DOAP) vocabulary, described using W3C RDF Schema and the Web Ontology Language.,” 2004. [Online]. Available: https://files.ifi.uzh.ch/ddis/oldweb/ddis/evoont/2008/11/vom/doc/ontologies/doap.html.

[7] euBusinessGraph Project, “Ontology for Company Data,” 2019. [Online]. Available: https://www.eubusinessgraph.eu/eubusinessgraph-ontology-for-company-data/.

[8] Directorate General Employment, Social Affairs and Inclusion, “European Skills, Competences, Qualifications and Occupations,” European Commission, 2020. [Online]. Available: https://ec.europa.eu/esco/portal/occupation.

[9] J. De Smedt, A. Papantoniou, B. Vatan, K. Kremer, L. Bégin, M. Le Vrang, M. Molinari, N. Vandekeybus and P. Fannes, “The ESCO ontology,” European Commission, [Online]. Available: https://ec.europa.eu/esco/resources/data/static/model/html/model.xhtml.

[10] E. M. Sibarani, S. Scerri and A.-S. Dadzie, “Skills and Recruitment Ontology,” EDSA Project, 9 2020. [Online]. Available: https://elisasibarani.github.io/SARO/.

[11] S. Peroni and D. Shotton, “The SPAR Ontologies,” in *In Proceedings of the 17th International Semantic Web Conference (ISWC 2018)*, 2018.

[12] S. Peroni and D. Shotton, “FaBiO and CiTO: ontologies for describing bibliographic resources and citations,” *Journal of Web Semantics,* no. 17, pp. 33-43, 2012.

[13] S. L. C. M. G. G. E. D. P. G. M.-P. F. a. D. B. Samoili, “AI WATCH. Defining Artificial Intelligence, EUR 30117 EN,” Publications Office of the European Union, Luxembourg, 2020.

[14] DKE German Commission for Electrical, Electronic & Information Technologies of DIN and VDE, “German Standardization Roadmap on Artificial Intelligence,” Wolfgang Wahlster and Christoph Winterhalter, Berlin, 2020.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101017142

[15] Bonseyes, “Platform for Open Development of Systems of Artificial Intelligence,” European Commission, 2020. [Online]. Available: https://cordis.europa.eu/project/id/732204.

[16] BonsAPPs, “AI-as-a-Service for the Deep Edge,” European Commission, 2021. [Online]. Available: https://cordis.europa.eu/project/id/101015848.

[17] BEAT, “Biometrics Evaluation and Testing,” European Commission, 2016. [Online]. Available: https://cordis.europa.eu/project/id/284989.

[18] ELG, “European Language Grid,” European Commission, 2019. [Online]. Available: https://cordis.europa.eu/project/id/825627.

[19] C. Nedellec, D. Galanis, K. Gkirtzou, M. Villegas, P. Labropoulou, P. Knoth and S. Aubin, “OMTD-SHARE ontology,” 2015. [Online]. Available: http://www.meta-share.org/ontologies/omtd-share/omtd-share-ontology.owl/documentation/index-en.html.

[20] ELG, “European Language Grid - Metadata,” 2021. [Online]. Available: https://www.european-language-grid.eu/metadata/.

[21] J. Vanschoren, J. N. van Rijn, B. Bischl and L. Torgo, “OpenML: networked science in machine learning,” *SIGKDD Explorations,* vol. 15, no. 2, pp. 49-60, 2013.

[22] European Commission, “The European Open Science Cloud (EOSC),” 2020. [Online]. Available: https://eosc-portal.eu/about/eosc.

[23] European Commission, “The EOSC Portal,” 2020. [Online]. Available: https://eosc-portal.eu/sites/default/files/EOSC%20Portal%20Booklet.pdf.

[24] AI4Plan, “Bringing AI Planning to the European AI On-Demand Platform,” European Commission, 1 January 2021. [Online]. Available: https://cordis.europa.eu/project/id/101016442.

[25] AI4Plan, “The AIPlan4EU Unified Planning Framework,” 2021. [Online]. Available: https://github.com/aiplan4eu/upf.

[26] AI4Copernicus, “Reinforcing the AI4EU Platform by Advancing Earth Observation Intelligence, Innovation and Adoption,” European Commission, 1 1 2021. [Online]. Available: https://cordis.europa.eu/project/id/101016798.

[27] I-ENERGY, “Artificial Intelligence for Next Generation Energy,” European Commission, 1 1 2021. [Online]. Available: https://cordis.europa.eu/project/id/101016508.

[28] DIH4AI , “AI on-demand platform for regional interoperable Digital Innovation Hubs Network,” European Commission, 1 1 2021. [Online]. Available: https://cordis.europa.eu/project/id/101017057.

[29] TAILOR, “Foundations of Trustworthy AI - Integrating Reasoning, Learning and Optimization,” European Commission, 1 1 2021. [Online]. Available: https://cordis.europa.eu/project/id/952215.

[30] The Brick Consortium, “Brick A uniform metadata schema for buildings,” 2021. [Online]. Available: https://brickschema.org/.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101017142

[i] Countries ontology: http://eulersharp.sourceforge.net/2003/03swap/countries
[ii] https://linkingresearch.wordpress.com/2013/10/07/how-to-properly-publish-a-vocabulary-or-ontology-in-the-web-part-4-of-6/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017142