STAIRWAI

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 - 1st version

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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

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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 SpecificationSimple Knowledge Organization System
ROV	Registered Organisation Vocabulary
SARO	Skills and Recruitment Ontology
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
VOID	Vocabulary of Interlinked Datasets
W3C	World Wide Web Consortium
WP	Work Package

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1. Executive Summary

Deliverable D3.1 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.

This deliverable reports a first version of the *AI Assets Conceptual Semantic Model*, prior to the actual data gathering made by WP3 in Task 3.3, Task 3.4, and Task 3.6 and to the updated requirements gathered by WP2 at the end of the first Open Call (M18). An updated version of the knowledge representation, integrating the lessons learned from the data gathering and the interactions with related EU initiatives will be provided in D3.2. "Design of the knowledge representation in the StairwAI AI Asset Management System - 2nd version", which will be delivered in M18.

The continuation of the work presented here will be described in D3.3 "StairwAI AI Asset Management System - 1st version" in M12 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.

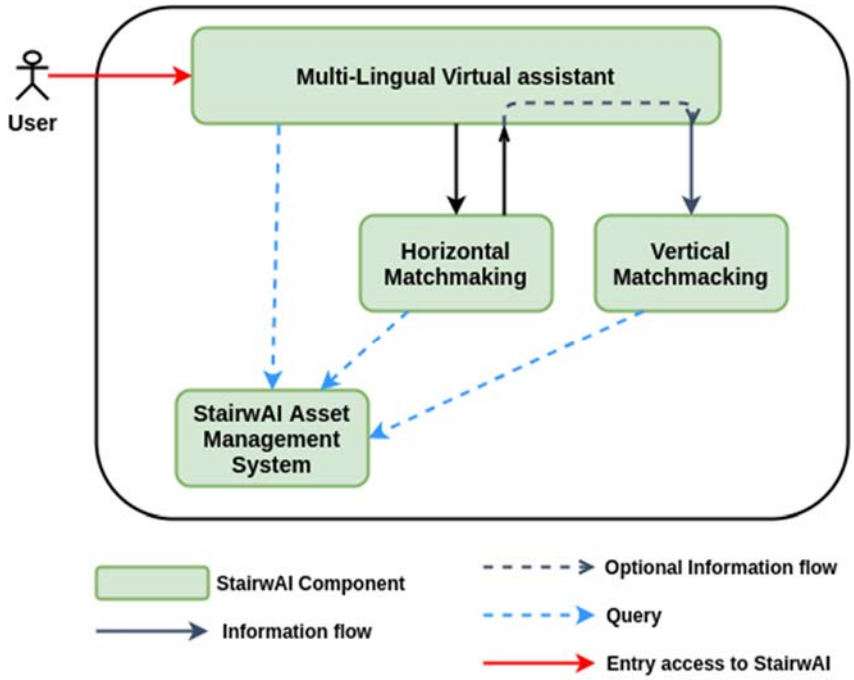

Figure 2.1 - Interactions between StairwAI's main components

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 3.1 towards the definition of the first 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) will be implemented as a knowledge graph within the first 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 D3.3 "StairwAI AI Asset Management System - 1st version" to be published in Month 12.

The first version of the *AI Assets Conceptual Semantic Model* is 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.

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

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

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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 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 working group is composed of representatives of the above-mentioned projects and some industrial companies. At the time of this report, the working group is starting its activity, but it is expected that in the next months some agreed changes to the AI4EU Conceptual Semantic Model will be available. Those changes will be reflected in Deliverable D3.2 “Design of the knowledge representation in the StairwAI AI Asset Management System - 2nd version”, which will be delivered in M18.

2.3. Structure of the document

Section 3 outlines the initial 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 and indicates which are the changes we expect on the *AI Assets Conceptual Semantic Model* from this version to the M18 one.

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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 a first version 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 (months M1 to M6).

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).

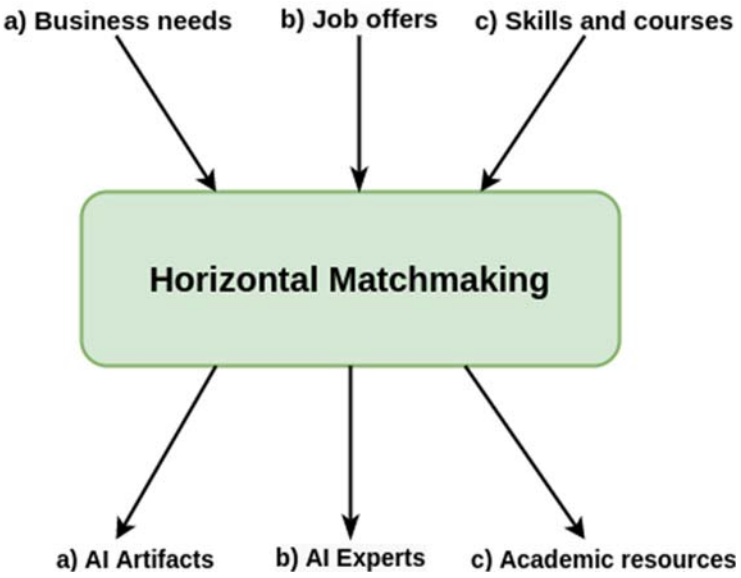

Figure 3.1 - Horizontal matchmaking

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. However, as the reputation mechanism has a strong dependence on the design of the matchmaking system, its specific requirements have not been specified in D2.1 and will be discussed in the forthcoming D2.2. Therefore, fairness will not be addressed in the first version of the *AI Assets Conceptual Semantic Model* reported in this deliverable, but in the one included in D3.2. "Design of the knowledge representation in the StairwAI AI Asset Management System - 2nd version", which will be delivered in M18.

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:

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- 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 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:

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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*

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.

D2.1 in section 3.4.2 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:

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 D2.1 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

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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.

3.2.2. 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. Actually, D2.1 explicitly states that these two additional services will be reported in D2.2 (due at month M18). 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.

[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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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 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.

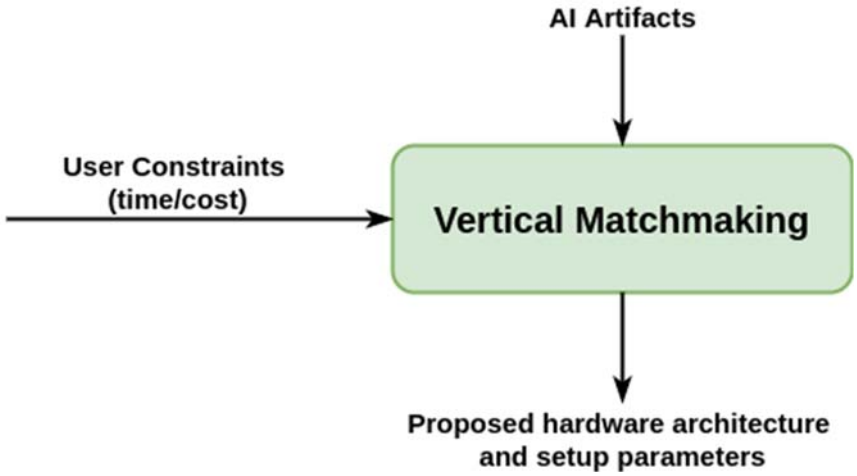

Figure 3.2 - Vertical Matchmaking

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

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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:

- 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:

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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*

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.

It is important to note here that the exact methods that will be used inside the user interface and the NLP engine have not been decided yet, as these will be selected in WP4 by analysing and testing different options in a set of Use cases provided by WP5 and WP6. Some of the methods that will be explored include neural machine translation (NMT)-based systems, multilingual knowledge bases, and cross-lingual word embeddings (for cross language knowledge transfer), and natural language generation methods (for query generation in the target language). 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 Rexplore 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 grafical descriptions 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 “artifical intelligence” in the following Figure 4.1:

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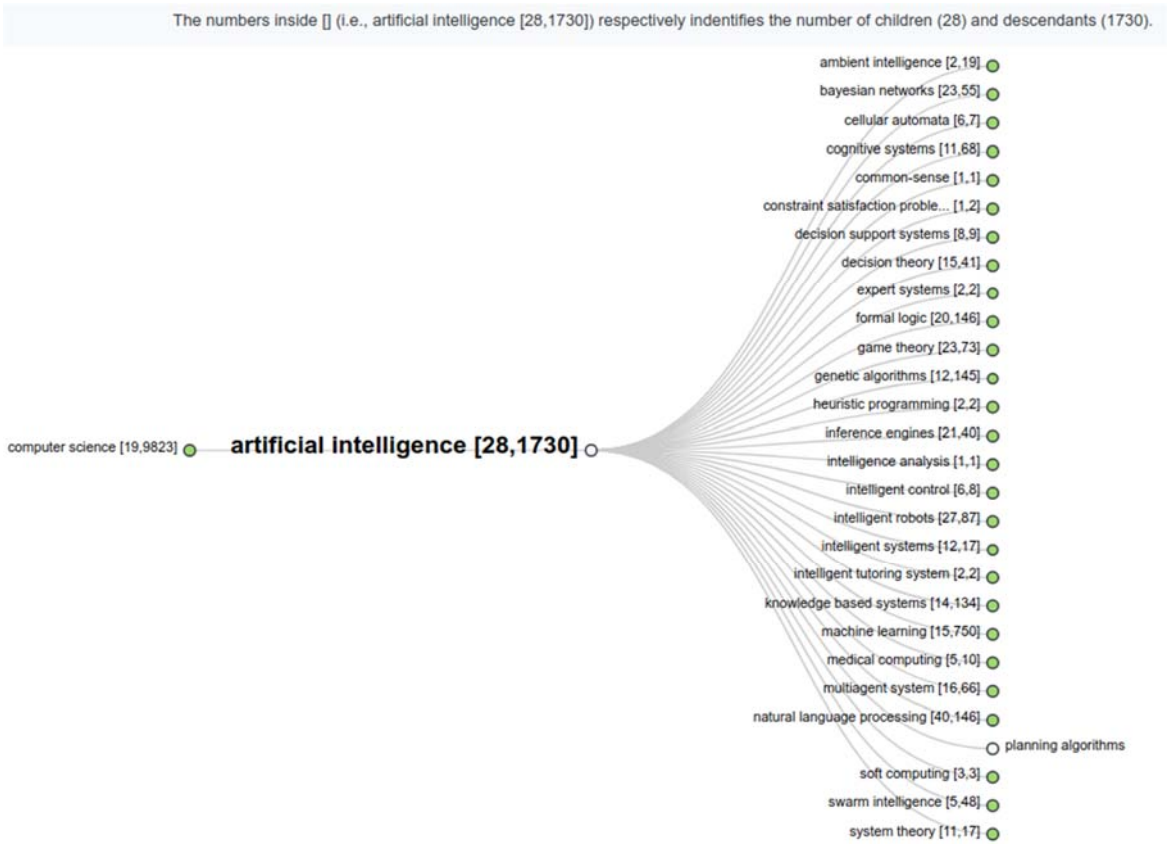

Figure 4.1 - Core terms in the CSO ontology [4]

4.1.4. Data Catalog Vocabulary (DCAT)

The *Data Catalog Vocabulary (DCAT)* is an RDF vocabulary designed to facilitate interoperability between data catalogs. 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:

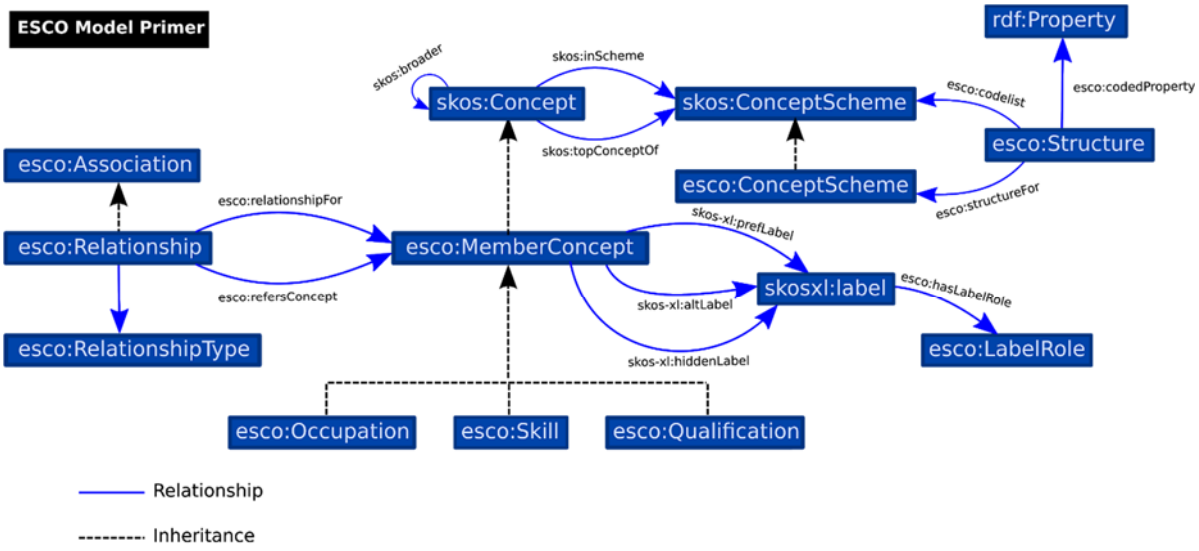

Figure 4.3 - Core terms in the ESCO ontology [9]

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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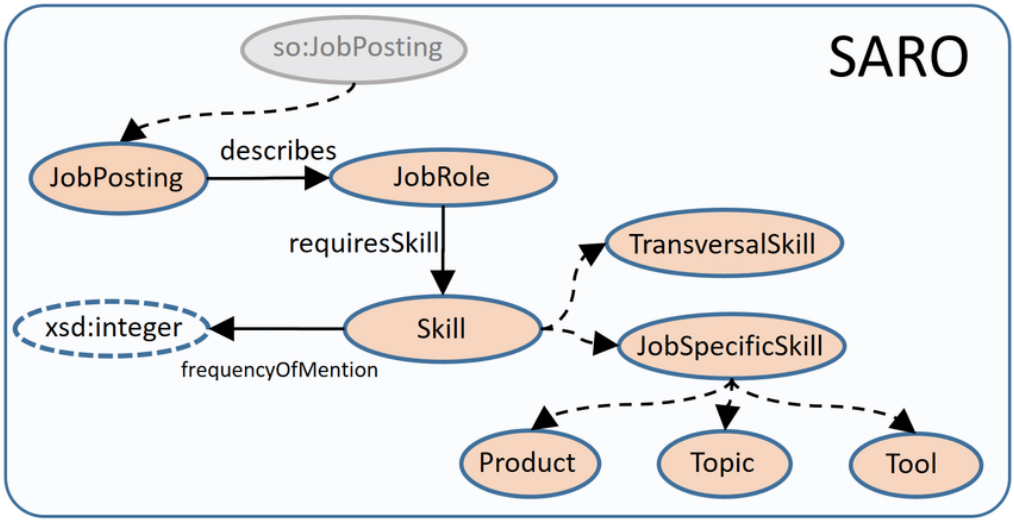

Figure 4.4 - Core SARO ontology Job posting representation [10]

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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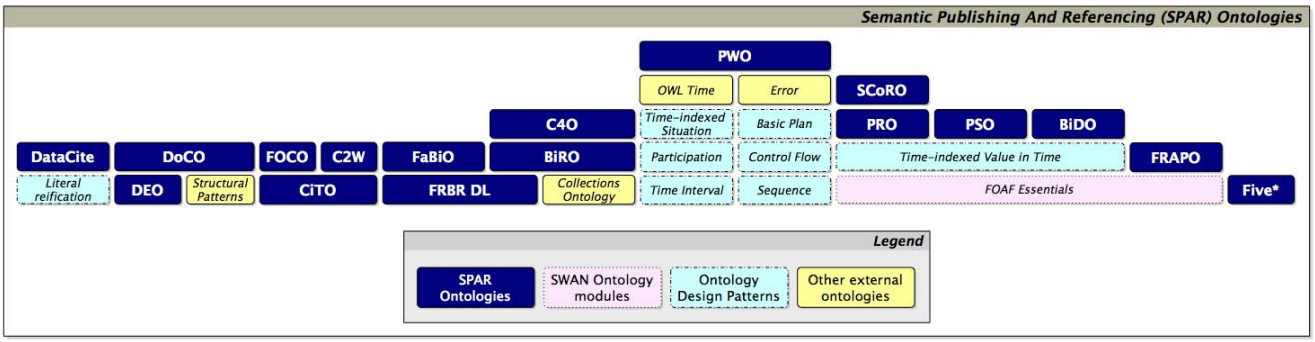

Figure 4.5 - SPAR ontologies high level schema [11]

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, catalogs 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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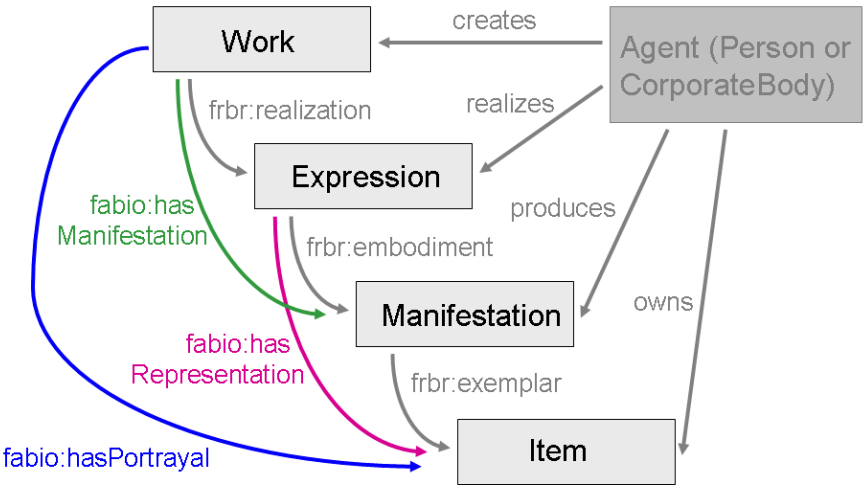

Figure 4.6 - FaBiO ontology base data model [12]

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.

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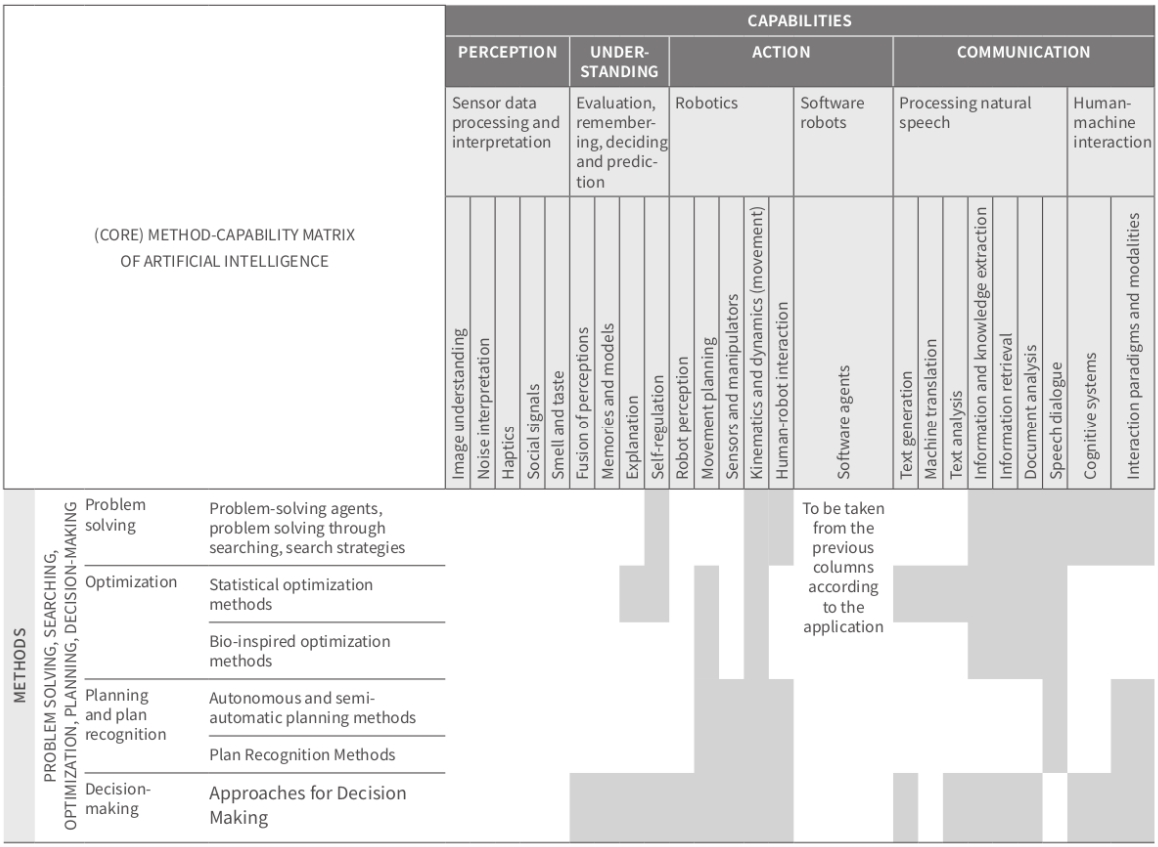

Figure 4.8 - Core terms in the German Standardization roadmap taxonomy [14]

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:

- 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.

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- `foaf:Agent` - class which represents entities (human or artificial) that do stuff.
- `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.

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    - ai:Wiki - A collection of informative web pages dealing with different aspects of an AI resource and its usage.
- 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.

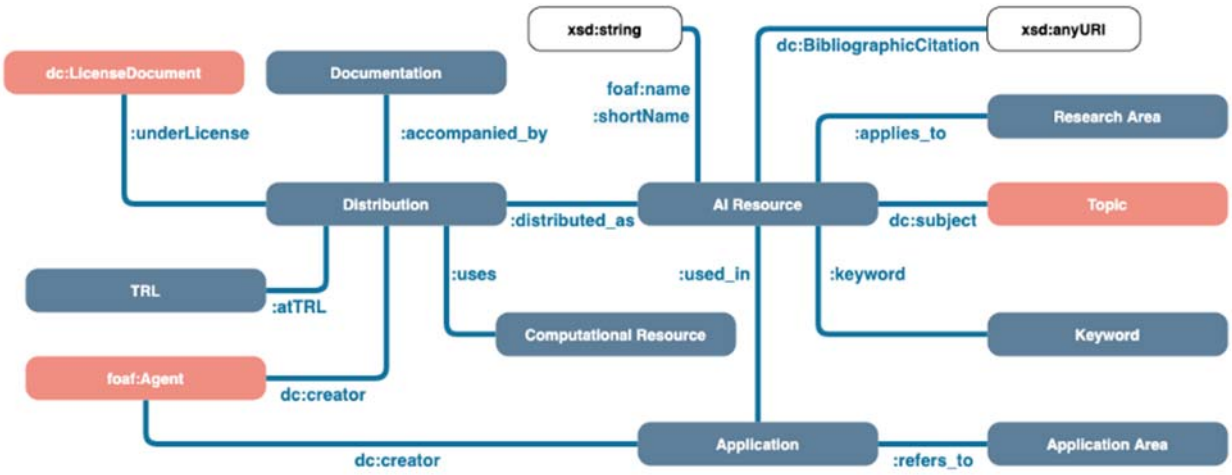

Figure 4.9 - Core terms in the AI4EU ontology

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.

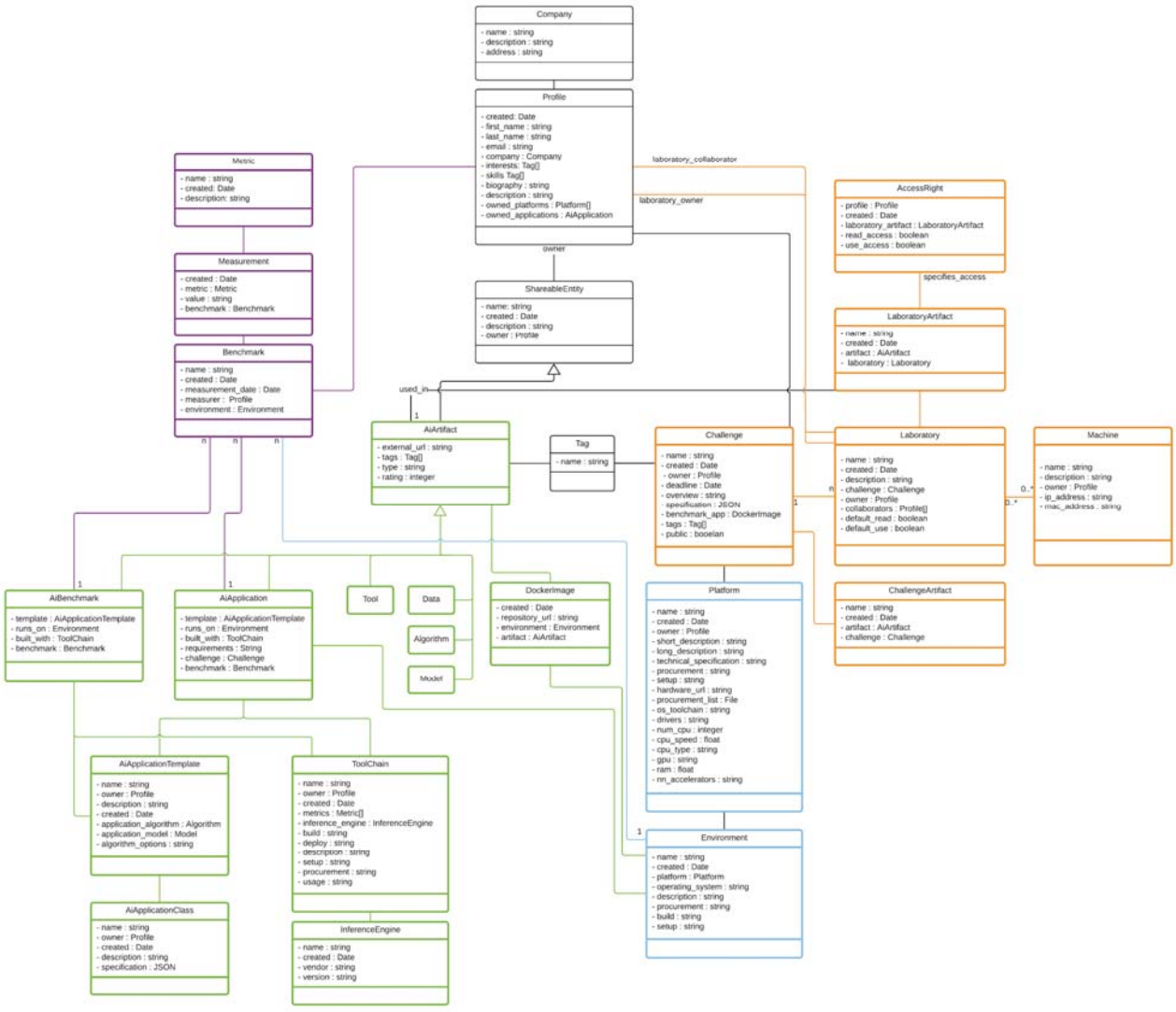

Figure 4.10 - Bonseyes' Data Model

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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 first 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.

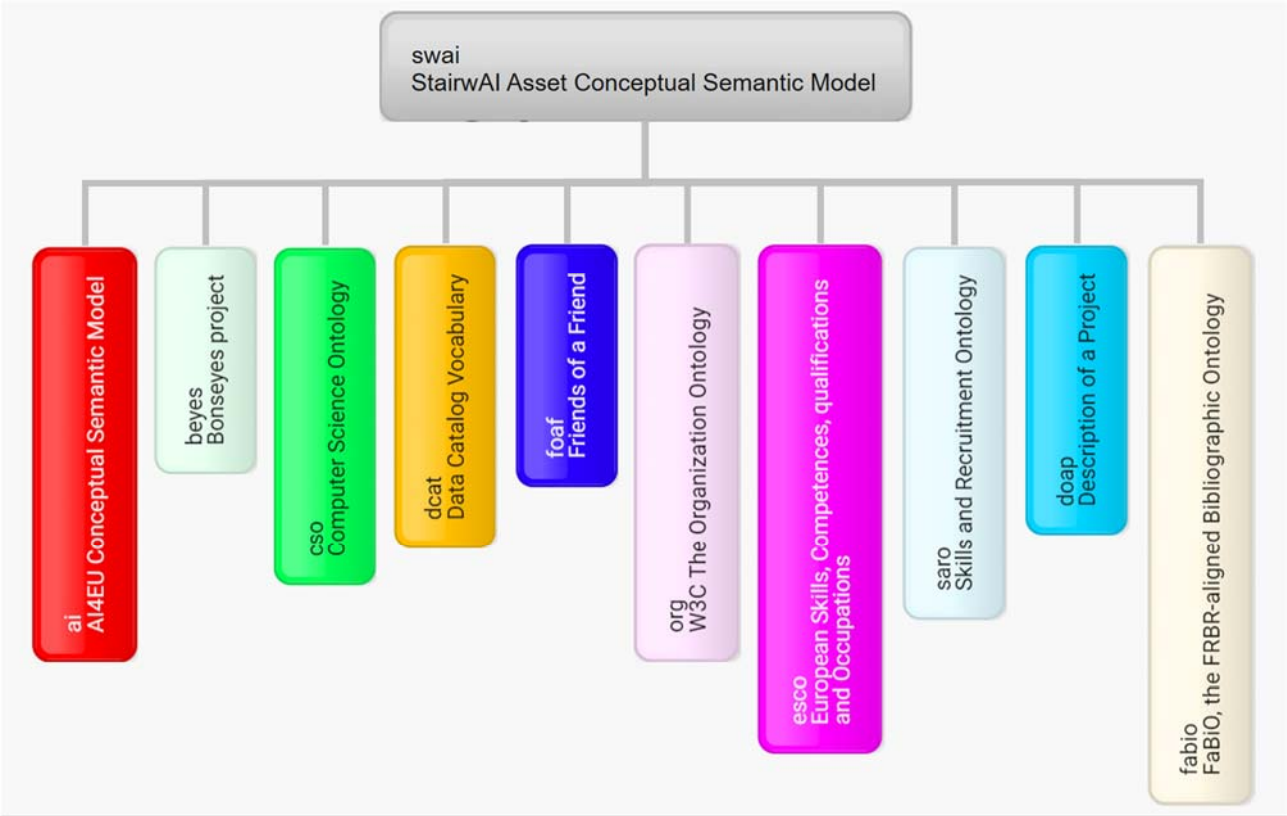

Figure 5.1 - Top Ontology and Imported Ontologies

- 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.
- The ***Computer Science Ontology*** has been chosen to reference general computer-science terms such as concepts related to Artificial Intelligence and hardware components, this ontology contributes to R2.1. During the analysis of CSO ontology we detected that the algorithm that auto-generates this ontology has some concepts not correctly classified from our point of view, for this reason, the classification of this ontology should be revised in the future.
- 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 StarwAI 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 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 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.

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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.

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 1.3, 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)* try to 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 BusinessArea; the job enrollment 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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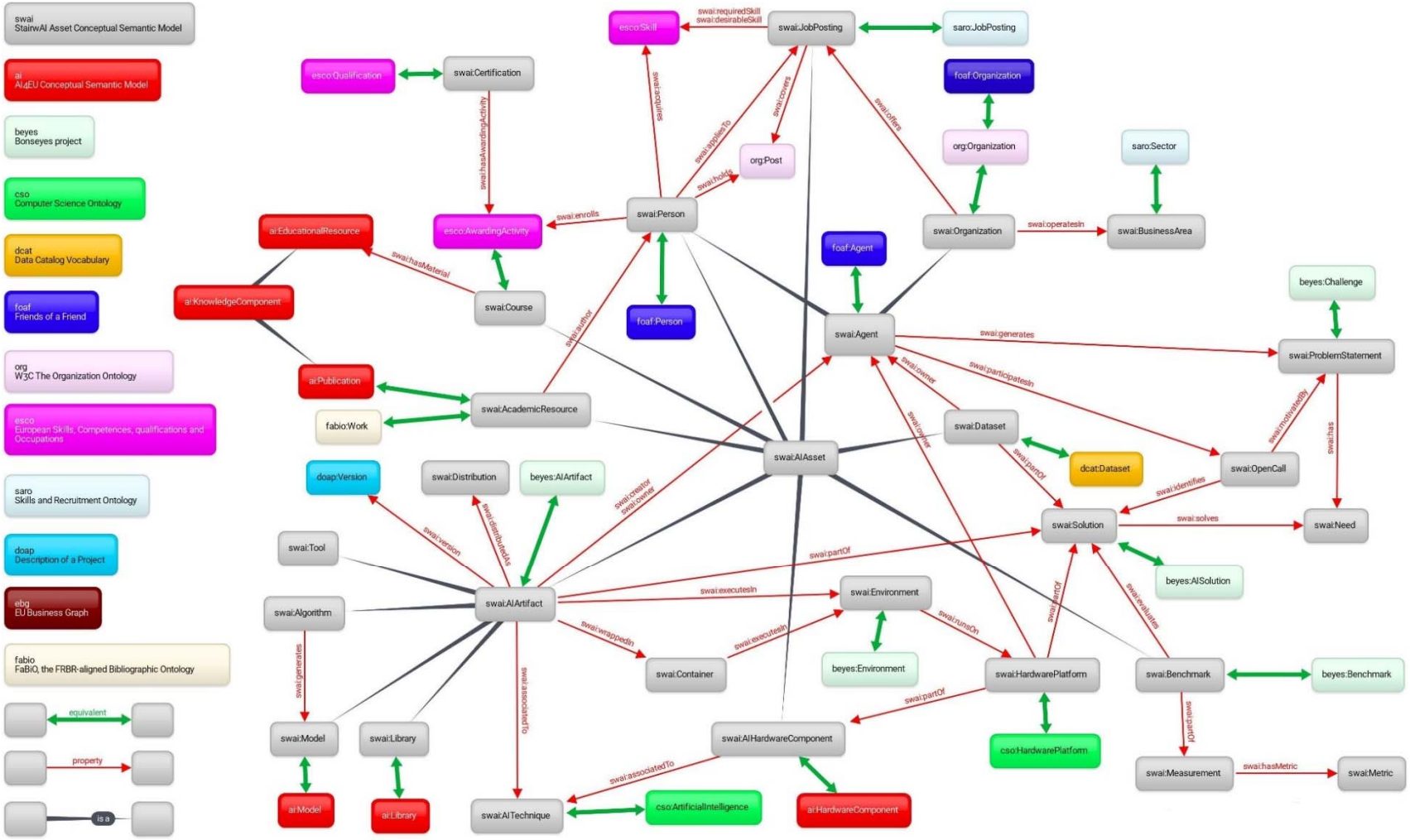

Figure 5.2 - The AI Asset Conceptual Semantic Model

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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* and *cso* have 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://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#	StairwAI
ai http://www.ai4eu.eu/ontologies/0.9.5/core	AI4EU
cso http://cso.kmi.open.ac.uk/schema/cso#	Computer Science Ontology
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

AIArtifact

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#AIArtifact
Description	An accessible, using a distribution, and usable artifact pertaining to AI research field.
Super-classes	AIAsset
Restrictions	associatedTo *some* AITechnique partOf *some* Solution owner *some* Agent executesIn *some* Environment
Sub-classes	Algorithm Tool Library Model
In domain of	distributedAs version wrappedIn creator

AIAsset

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#AIAsset
Description	The AI-related elements that StairwAI offers to users.
Sub-classes	AcademicResource AIArtifact Course Person Benchmark Dataset AIHardwareComponent JobPosting

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AIHardwareComponent

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#AIHardwareComponent
Description	Physical components that an AI system requires to function (device/equipment).
Super-classes	AIAsset
Restrictions	associatedTo *some* AITechnique

AITechnique

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#AITechnique
Description	A manner to organize and use the knowledge efficiently in such a way that it should be perceivable by the people who provide it, easily modifiable to correct errors, and useful in many situations though it is incomplete or inaccurate.
In range of	associatedTo

AcademicResource

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#AcademicResource
Description	A published or potentially publishable, scholarly resource.
Super-classes	AIAsset
Restrictions	schema:identifier *exactly* 1 schema:name *exactly* 1
In domain of	author

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Agent

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Agent
Description	Any entity (either persons, organizations, or software processes) having the capability to pro-actively act.
Restrictions	linkedinURL *some* xsd:anyURI email *min* 1
Sub-classes	Organization Person
In domain of	participatesIn generatesStatement email linkedinURL
In range of	owner creator

Algorithm

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Algorithm
Description	A recipe to perform a computational task, a finite sequence of instructions.
Super-classes	AIArtifact
In domain of	Generates

Benchmark

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Benchmark
Description	Evaluation by comparison with a standard metric.
Super-classes	AIAsset
In domain of	Evaluates

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BusinessArea

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#BusinessArea
Description	Sector in which an organization can be specialized.
In range of	operatesIn

Certification

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Certification
Description	A document that certifies that a person has received specific education.
In domain of	hasAwardingActivity

Container

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#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	executesIn *some* Environment
In range of	wrappedIn

Course

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#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	AIAsset

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In domain of	hasMaterial

Dataset

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Dataset
Description	A collection of data that is treated as a single unit by a computer.
Super-classes	AIAsset
Restrictions	owner *some* Agent partOf *some* Solution

Distribution

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Distribution
Description	A specific form of packaging and means of exposure and availability for an AI Artifact.
In range of	distributedAs

Environment

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#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	runsOn
In range of	executesIn

HardwarePlatform

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#HardwarePlatform
Description	A set of compatible hardware on which software applications can be run.

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Restrictions	partOf *some* Solution partOf *some* AIHardwareComponent owner *some* Agent
In range of	runsOn

JobPosting

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#JobPosting
Description	Primary means through which companies recruit new applicants for available positions.
Super-classes	AIAsset
In domain of	covers desiderableSkill requiredSkill
In range of	appliesTo offers

Library

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#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	AIArtifact

Measurement

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Measurement
Description	The size, length, or amount of something, in terms of a measuring unit.
Restrictions	partOf *some* Benchmark

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In domain of	hasMetric

Metric

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Metric
Description	A system or standard of measurement.
In range of	hasMetric

Model

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Model
Description	A simplified representation of a system or a software process.
Super-classes	AIArtifact
In range of	generates

Need

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Need
Description	Something that is desired or required. It is distilled from a Problem Statement.
In range of	hasNeed solves

OpenCall

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#OpenCall
Description	A local, national or international competition open to SMEs, startups, scaleups, and mid-cap companies for the purpose of procuring the commissioning and provision of technology as part of the development.

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In domain of	identifies motivatedBy
In range of	participatesIn

Organization

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Organization
Description	An organized group of people with a particular purpose, such as a business or government department.
Super-classes	Agent
Restrictions	org:location *some* xsd:anyURI
In domain of	operatesIn offers

Person

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Person
Description	People.
Super-classes	AIAsset Agent
In domain of	appliesTo holds enrolls acquires
In range of	author

ProblemStatement

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#ProblemStatement

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Description	Formal description of a problem that can be solved using AI.
In domain of	hasNeed
In range of	motivatedBy generatesStatement

Solution

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#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	solves
In range of	identifies evaluates

Tool

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#Tool
Description	A software that assists in activities such as, and not limited to, data analysis, decision support, recommendation, etc.
Super-classes	AIArtifact

5.2.4. Object properties

acquires

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#acquires
Description	Someone who learned or developed a skill, habit, or quality.
Domain(s)	Person

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Range(s)	esco:Skill

appliesTo

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#appliesTo
Description	Someone who 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

associatedTo

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#associatedTo
Description	Indicates that an Artifact or Hardware component should be associated to, at least, one AITechnique
Domain(s)	(AIArtifact or AIHardwareComponent)
Range(s)	AITechnique

author

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#author
Description	Someone who is the writer of a text.
Domain(s)	AcademicResource
Range(s)	Person

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covers

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#covers
Description	Indicates the available position.
Domain(s)	JobPosting
Range(s)	org:Post

creator

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#creator
Description	The person, or thing, that brings something into existence.
Domain(s)	AIArtifact
Range(s)	Agent

desiderableSkill

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#desiderableSkill
Description	Indicates the desirable habilities.
Domain(s)	JobPosting
Range(s)	esco:Skill

distributedAs

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#distributedAs
Description	Indicates packaging conditions (licence, documentation, etc.).
Domain(s)	AIArtifact

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Range(s)	Distribution

enrolls

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#enrolls
Description	Someone officially registered as a student on a course.
Domain(s)	Person
Range(s)	esco:AwardingActivity

evaluates

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#evaluates
Description	Indicates a judgement or assessment.
Domain(s)	Benchmark
Range(s)	Solution

executesIn

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#executesIn
Description	Indicates the place of performance of an instruction or program.
Domain(s)	(AIArtifact or Container)
Range(s)	Environment

generates

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#generates

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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

generatesStatement

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#generatesStatement
Description	An Agent that creates a new Problem Statement.
Domain(s)	Agent
Range(s)	ProblemStatement

hasAwardingActivity

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#hasAwardingActivity
Description	Denotes the giver of an official recognition.
Domain(s)	Certification
Range(s)	esco:AwardingActivity

hasMaterial

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#hasMaterial
Description	Indicates didactic resources offered in a course.
Domain(s)	Course
Range(s)	http://www.ai4eu.eu/ontologies/core#EducationalResource

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hasMetric

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#hasMetric
Description	Indicates a standard of measurement to be applied.
Domain(s)	Measurement
Range(s)	Metric

hasNeed

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#hasNeed
Description	Indicates an indispensable thing.
Domain(s)	ProblemStatement
Range(s)	Need

hasPart

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#hasPart
Description	Indicates the parts of an entity.
Inverse properties	partOf

holds

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#holds
Description	Indicates the occupier of a job
Super-properties	org:holds

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Domain(s)	Person
Range(s)	org:Post

identifies

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#identifies
Description	Indicates the results that solve the requirements.
Domain(s)	OpenCall
Range(s)	Solution

motivatedBy

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#motivatedBy
Description	Indicates facts and arguments used in support of a something.
Domain(s)	OpenCall
Range(s)	ProblemStatement

offers

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#offers
Description	Indicates a job opportunity.
Domain(s)	Organization
Range(s)	JobPosting

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operatesIn

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#operatesIn
Description	Indicates the area in which an organization develops its effort.
Domain(s)	Organization
Range(s)	BusinessArea

owner

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#owner
Description	Proprietary of something.
Domain(s)	(AIArtifact or Dataset or HardwarePlatform)
Range(s)	Agent

partOf

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#partOf
Description	Indicates the general entity that has another entity as its own part.

participatesIn

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#participatesIn
Description	Indicates someone taking part in something.
Domain(s)	Agent
Range(s)	OpenCall

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requiredSkill

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#requiredSkill
Description	Indicates the abilities that must be fulfilled for the partaker to be considered as a candidate.
Domain(s)	JobPosting
Range(s)	esco:Skill

runsOn

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#runsOn
Description	Indicates the execution platform.
Domain(s)	Environment
Range(s)	HardwarePlatform

solves

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#solves
Description	Indicates something is a means of effectively dealing with a problem.
Domain(s)	Solution
Range(s)	Need

version

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#version
Description	Unique name or number of a unique state.
Domain(s)	AIArtifact

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Range(s)	doap:Version

wrappedIn

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#wrappedIn
Description	Indicates an enclosure.
Domain(s)	AIArtifact
Range(s)	Container

5.2.5. Datatype properties

email

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#email
Description	Email associated to an Agent.
Domain(s)	Agent
Range(s)	xsd:anyURI

LinkedInURL

URI	http://www.semanticweb.org/StairwAI/ontologies/2021/6/swai#linkedinURL
Description	Agent's LinkedIn link, to share the account.
Domain(s)	Agent
Range(s)	xsd:anyURI

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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.

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, people and job positions. *essential*
How this is covered: StairwAI semantic model uses the AI Asset class in which we are able to 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*

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How this is covered: in order 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 possible solutions to the problem.

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*
How this is covered: in order 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: in order 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 not covered in the current version of the Model, as it clashes with requirement R1.1. Currently, the AI4EU Conceptual Semantic Model uses the taxonomy in the Computer Science Ontology (CSO) to define the different kinds of AI Resources. If StairwAI decides to structure the AI Assets following the AI watch taxonomy, this could create some misalignment with the AI4EU model. Furthermore, the taxonomy to be used in an updated AI4EU model is currently under discussion, with the AI Watch taxonomy being one of several alternatives. We expect a consensus to be reached on this topic

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in the next months, and its implications to be introduced in the next version of the AI Asset Conceptual Semantic Model.

R2.6 Coverage: Job positions and expertise
The AI Assets Conceptual Semantic Model should adapt the semantic tagging of a joboffer 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*
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*

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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
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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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* will support 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

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

- The collection of requirements within Phase 1 of the StairwAI project (months M1 to M6), 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" and Deliverable D2.1 "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* will be implemented as a knowledge graph within the first StairwAI AMS working prototype. The instantiation of the Conceptual Semantic Model into the knowledge graph and the implementation of the StairwAI AMS prototype will be reported as part of D3.3 "StairwAI AI Asset Management System - 1st version" to be published in Month 12.

In parallel, we expect to get new model requirements in the next months, coming from the data gathering made by WP3 in Task 3.3, Task 3.4, and Task 3.6, the precise definition of the StairwAI module interfaces in Task 2.4, and the updated requirements gathered by WP2 at the end of the first Open Call (M18). An updated

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version of the knowledge representation will be provided in D3.2. “Design of the knowledge representation in the StairwAI AI Asset Management System - 2nd version”, which will be delivered in M18.

Furthermore, the ongoing cooperation activity with the ICT 49 projects that plan to extend the AI4EU Concepttual 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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