
# Report D2.8

# "MLOs Final Release"

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# Report D2.8

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| **Task** | T2.5 \| MLO Development/Harmonisation |
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| 0.1 | 15/06/2023 | Arkopaul Sarkar | Summary of the document |
| 0.2 | 10/07/2023 | Arkopaul Sarkar | Bridge concept |
| 0.3 | 20/09/2023 | Arkopaul Sarkar | Usage guide |
| 0.4 | 10/10/2023 | Hedi Karray | Peer review. |
| Vfinal | 12/10/2023 | Nadja Adamovic | Final approval and submission |

# Glossary of terms

| Item | Description |
|---|---|
| MLO | Middle level ontology |
| TLO | Top level ontology |
| DLO | Domain level ontology |

# Keywords

Alignment; Data; Harmonization; Ontology; Standardisation [...]

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# Executive Summary

OntoCommons aims at working toward interoperability by means of harmonization with respect to upper-level ontologies and facilitating agreement in domain ontology development. As part of the effort of work package 2, an objective of OntoCommons is to provide alignments among existing MLOs from different TLO branches. This task needs to perform several activities, such as identification of existing MLOs and corresponding disciplines that are to be covered by the alignment effort, the definition of the expected level of alignment that is to be performed for the MLOs and finding gaps in the disciplines which may be filled with new MLO development. In the 18th month of the project, D2.5 was published, describing the methodology, list of disciplines and MLOs considered and other technical details as a beta version of the MLOs. In the following months, the actual development were advanced resulting in several tangible outcomes. These outcomes are currently being served by GitHub repository. Considering these results as the primary content of the deliverable 2.8 and the theoretical part of MLO development strategy already defined as part of D2.5, this report only serves only as a short descriptions of the artefacts produced by 2.5 in terms of MLO harmonisation and how to access them for practical purposes.

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# 1. Introduction

As part of the overall goals of work package 2 of the OntoCommons project, a foundation for middle-level cross-discipline interoperability will be achieved by Task 2.5. To accomplish the broad outcome of terminological alignments among MLOs from different TLO branches, this task needs to perform several activities, such as the identification of existing MLOs and corresponding disciplines that are to be covered by the alignment effort, the definition of the expected level of alignment that is to be performed for the MLOs and finding gaps in the disciplines which may be filled with new MLO development. The beta version of the harmonized MLO, published in the 18th month of the project, described the methodology, list of disciplines and MLOs considered and other technical details. In the following sections the methodology described in beta version is recapped before the content of this report is introduced.

## 1.1 Summary of the beta version

The report D2.5 first made effort in characterising different levels of ontology to delineate the concerns of mid-level ontologies (MLOs) from the ontologies at other levels. Next it presented a state-of-the-art of the existing MLOs in the scope of topics that are identified as suitable to be covered by mid-level abstraction. These existing MLOs are analysed for their most common concepts, which is included as a list by classifying them under different topics in D2.5. As the most important part of the report on the beta version, the methodology to harmonise existing MLOs and support the interoperability of domain level ontologies in the downstream is presented along with several alternative considerations. The adopted strategy consists of the engineering of well-documented, and ontology-neutral, core "Bridge-Concepts", which are then connected to the top-level ontologies (TLOs) which make up the top-reference ontology (TRO – aligned set of TLOs) and come to constitute an extension of the latter, which is accessible, and directly usable, by domain experts. The concepts themselves are defined by referring to gold standards, state-of-the-art publications, and well-known and pervasively employed domain resources, also considering the actual usage of possibly related concepts in existing MLOs given tentative pre-emptive alignments.

## 1.2 Summary of the final version

Following the methodology proposed, several bridge concepts were developed along with their mappings to the TLOs. The bridge concepts were developed in two formats: bridge concept template as proposed in D2.5 and files encoded in OWL. The information in OWL contains detailed descriptions of the bridge concept in terms of annotations as well as the mappings to each top-level ontologies, e.g., BFO, DOLCE, and EMMO. These physical artefacts are available in the GitHub. This report only acts as pointers to these files, additionally discussing how to interpret these files and how to use them for practical use.

In section 2, the locations of the files are given. In section 3, the scheme of metadata used to annotate the bridge concepts are discussed. In the last section (4), a brief description of using these bridge concepts is included.

# 2. Bridge Concept

As described in D2.5, the bridge concepts are domain-expert-friendly and ontology-neutral concepts that works as a bridge between lower level, either mid-level or domain reference ontologies to the top-level ontologies. The idea is to isolate the complexity of the top-level ontologies from the domain level concerns as by adopting the bridge concepts as root for their domain ontologies, the domain ontologies will be aligned to the top-level ontologies, thanks to the mappings of the bridge concepts to each top-level ontology. Although an extensive list (given in the appendix of D2.5) of bridge concept candidates is produced by comparing existing mid-level ontologies, only some of the concepts are shortlisted as an initial sample of bridge concepts to help in testing various utilities of bridge concept as part of WP2.

The bridge concepts are defined and then mapped to the TLOs by extensive analysis, which is documented using the Bridge Concept Template introduced in D2.5. Later, a separate OWL files are created for each bridge concept, containing the bridge concept as term and mapping to the TLOs. As an exception, the cluster concepts, that are bridge concepts which are closely related to each other, share the same OWL file.

All files are stored in the
https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO.

In the following Table 1, the analysis in Bridge Concept Template, the OWL file locations are given.

*Table 1: Bridge Concept locations in GItHub*

| Bridge concepts | Analysis | OWL |
|---|---|---|
| **Industrial Process** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/agent.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/industrial-process.owl |
| **Physical Quantity** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/physical-quantity.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/physical-process.owl |
| **System** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/system.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/system.owl |
| **Agent** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/agent.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/agent.owl |

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|---|---|---|
| **Document** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/document.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/document.owl |
| **Resource** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/resource.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/resource.owl |
| **Atom** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/atom.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/atom.owl |
| **Physical Field** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/physical-field.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/physical-field.owl |
| **Physical Matter** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/physical-matter.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/physical-matter.owl |
| **Commercial Product** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/commercial-product.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/product-cluster.owl |
| **Article** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/article.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/product-cluster.owl |
| **Good** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/good.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/product-cluster.owl |
| **Intellectual Article** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/intellectual-article.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/product-cluster.owl |
| **Material Device** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/material-device.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/machine-cluster.owl |
| **Machine** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/machine.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/machine-cluster.owl |
| **Equipment** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/equipment.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/machine-cluster.owl |
| **Tool** | https://github.com/OntoCommons/OntologyFramework/blob/main/owl/MRO/doc/tool.md | https://github.com/OntoCommons/OntologyFramework/tree/main/owl/MRO/CONCEPTS/machine-cluster.owl |

# 3. Encoding strategy

The bridge concepts are stored in separate files carefully setting their IRIs in such a way that the any number of bridge concepts can be combined in a single file as required. For this purpose, all bridge terms are encoded using the same IRI: http://www.ontolocommons.eu/mro/bridge.

In addition, the information from the analysis in Bridge Concept Template is transferred to the OWL file as annotations to the bridge term. The mappings to the top level ontologies are also annotated. In the following, Table 2 shows the mappings from the fields of Bridge Concept template and the annotation vocabulary that has been used. The prefix for the annotations are used as given below:

prefix emmo: http://emmo.info/emmo#

prefix iof-av: https://spec.industrialontologies.org/ontology/core/meta/AnnotationVocabulary/

prefix skos: http://www.w3.org/2004/02/skos/core#

prefix rdfs: http://www.w3.org/2000/01/rdf-schema#

| Bridge concept template field | Annotation vocabulary used |
|---|---|
| General Concept Info | |
| IRI | no annotation. IRI of the bridge term |
| OWL Type | not applicable as the terms are either Class or Object Property |
| Concept Elucidation | emmo:elucidation |
| Labels | skos:preferredLabel, skos:altLabel, skos:hiddenLabel (multiple for different labels) |
| Knowledge domain resource | |
| Related domain resource | rdfs:seeAlso (iof-av:excerptedFrom for source) |
| Comments | iof-av:explanatoryNote |
| Alignments To Existing Ontologies | |
| Target ontology | Not applicable |
| Mapping Elucidation | emmo:elucidation |

Additionally, every bridge concept file is annotated at the ontology level with only dcterm:description and dcterm:contributor, dcterm:created, dcterm:modified as a separate metadata file including dcterm:title, dcterm:creator, dcterm:license, iof-sv:copyright, dcterm:issued is created under IRI http://www.ontolocommons.eu/mro/bridge which can be used to curate a set of bridge terms for a specific purpose. The detailed guide on the use of the bridge terms is given in the next section.

# 4. Usage guide

The bridge concepts act as anchors for the lower-level ontologies (core references and domain level) to top level ontologies. For this purpose, the mid-reference ontology (MRO) level of the OntoCommons EcoSystem (OCES) is part of the overall organisation structure of the ontology stack, which is given in Figure 1. The 'bridge' ontology file (http://www.ontolocommons.eu/mro/bridge) may contain one or more bridge concept files as required by the project. Every bridge concept file will contain mapping to some terms from each top-level ontology. The tro file (http://www.ontolocommons.eu/tro) will contain these TLOs as import (it is performed by first importing them to an intermediate file called tlo). Note that it is not necessary to import all TLOs in the tro file. If more than one TLO is imported in the TRO file, then the mapping between those TLOs may also need to be imported in the TRO. The mapping files between TLOs are curated by meta file (http://www.ontolocommons.eu/tro/meta) which may import one or many mapping files as required. For example, if TRO file contains BFO and DOLCE then meta file should import bfo-dolce mapping file. Please see D2.9 for more details on TRO level organisation.

The bridge file containing one or more bridge concepts will be imported by a domain reference or domain ontology. The structure in Figure 1 shows an example in which they are imported by some domain reference ontologies, e.g., IOF-Core and Chebi. The ontologies importing the bridge file will have their own organisation to embed mapping to the bridge concepts. These ontologies with their mapping to bridge concepts forms the mro (http://www.ontolocommons.eu/mro), then in turn can be imported by domain or application level ontologies for further reuse. The organisation provides a general guideline to structure any other project which may of course replace the host of the IRIs from http://www.ontolocommons.eu to their own.

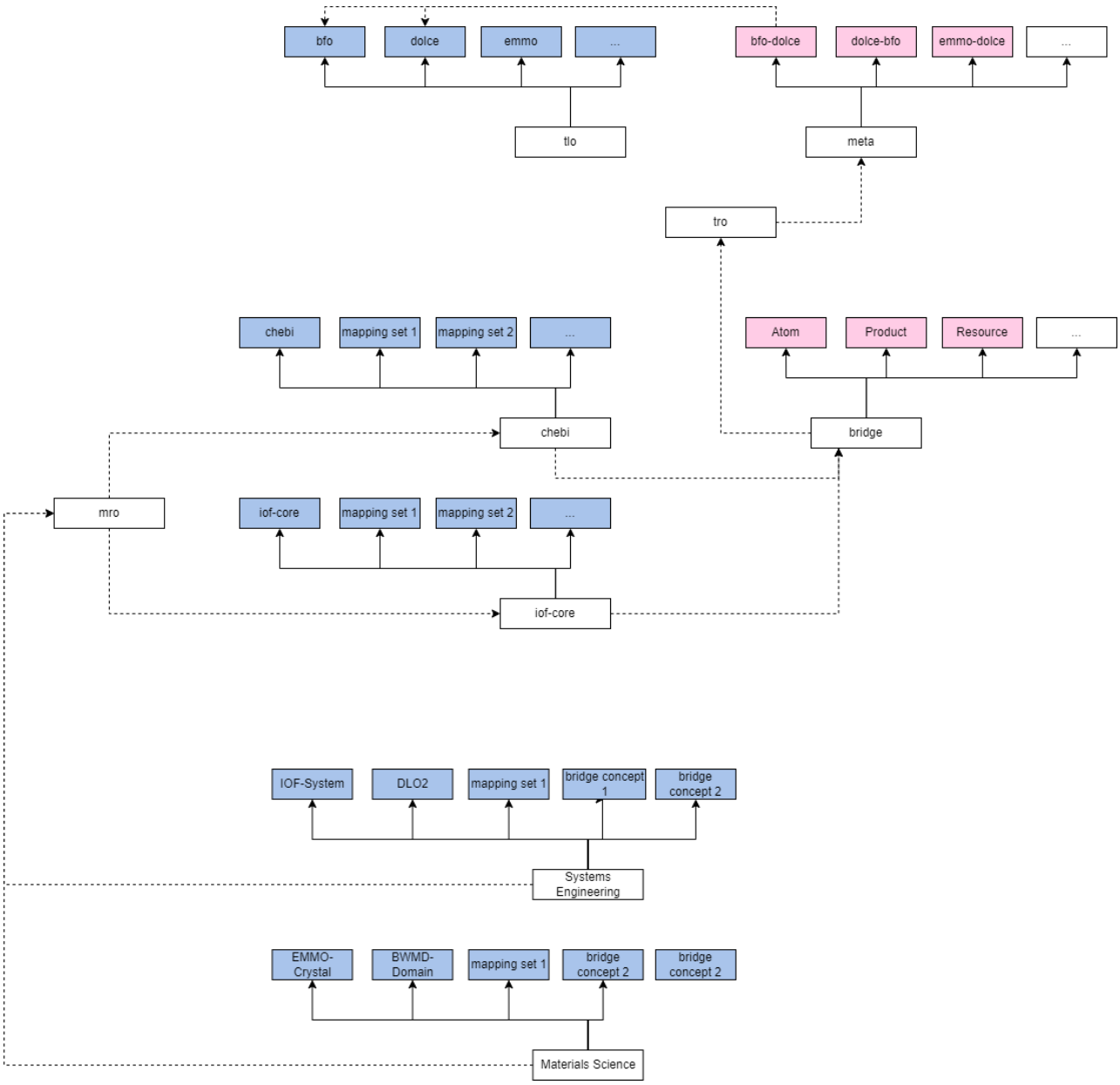


*Figure 1: Organisation and import structure of OntoCommons Ecosystem ontology stack (solid line denote the sharing of IRI and the dashed lines denotes import*

An example is available at https://github.com/OntoCommons/OntologyFramework/tree/test demonstrating how to perform the imports for a specific case. In this example a sensor measurement application reuses both IOF-Core and SAREF ontology to model their application level classes, e.g., temperature sensor, turbidity sensors, and various measurements. The mapping of IOF-Core and SAREF to some of the bridge terms along with their mappings to the TLOs are shown in Figure 2. Sensor-core.owl and measure-core.owl are two files containing bridge terms oc:37a74125-b08c-4edc-9540-4d064034a440 and oc:6518bddd-6e4c-486a-911c-554014ff9e74 respectively along with their corresponding mappings to BFO and DOLCE. iof-core-mapping.owl contains the mapping of IOF-Core terms to bridge terms. saref-mapping.owl contains the mapping of SAREF-Core to the bridge terms. sensor-measures-iof.owl and sensor-measures-saref.owl are application ontologies

declaring some terms under the IOF-Core and Saref-core respectively. BFO and DOLCE source ontologies can be found at
https://github.com/OntoCommons/OntologyFramework/tree/main/owl/TRO/TLOs

and the mappings between them at
https://github.com/OntoCommons/OntologyFramework/tree/main/owl/TRO/META

IOF-Core can be imported from https://spec.industrialontologies.org/iof/ontology/core/Core/.

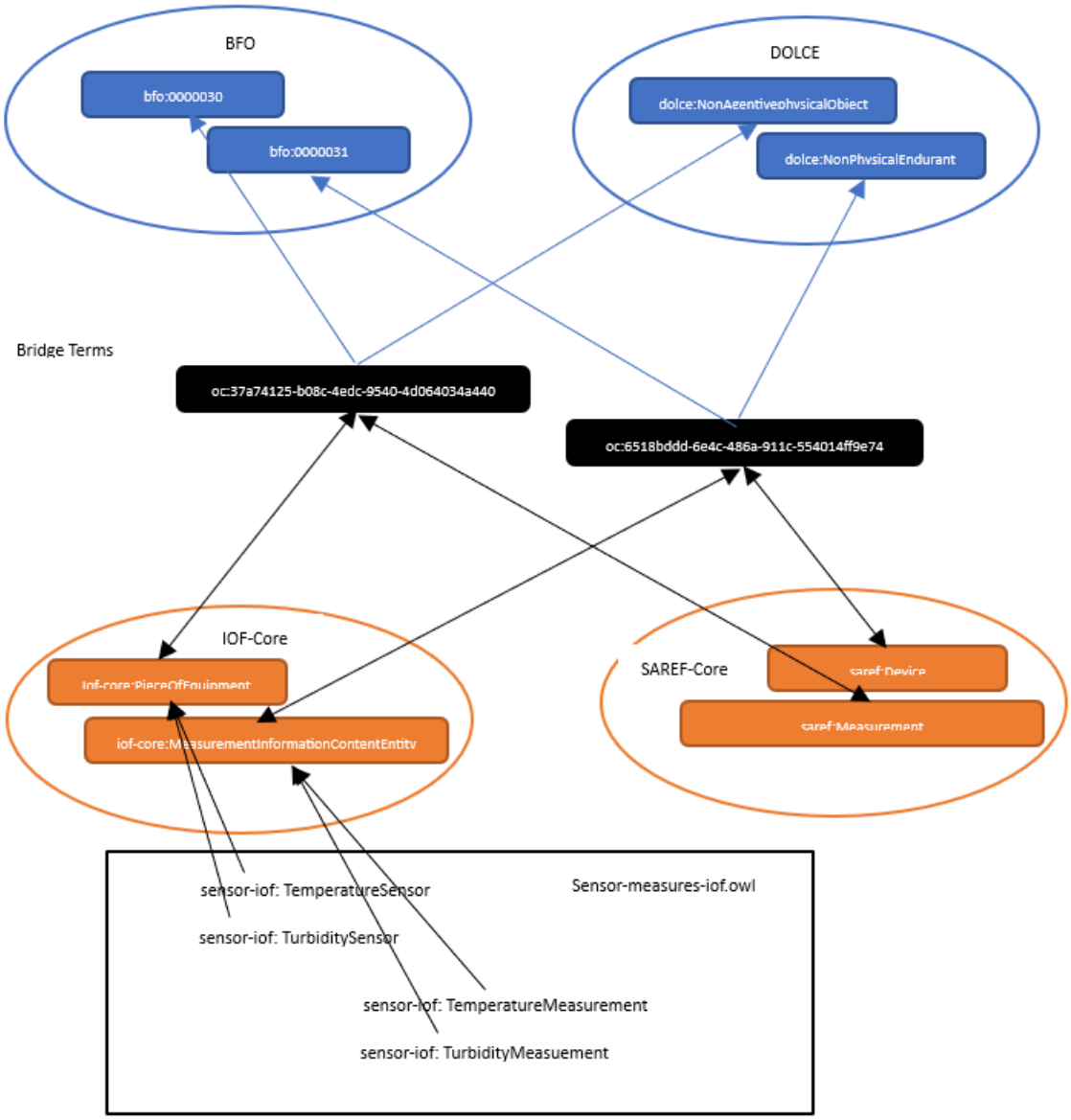


*Figure 2: Example of the use of bridge concepts in sensor applications*

# 5. Conclusion

The final version of MRO of OCES is now available via GitHub repository as described in this report. However, the maturity of the module needs to be enhanced by curating more bridge concepts. The coverage of the bridge concepts needs to be substantial to cover many mid-level and domain-level ontologies. A list of these ontologies and a detailed list of candidate concepts are already available in D2.5. However, this report D2.8 presents the pilot study conducted under T2.5 which sets out the path to interoperability among ontologies via bridge concepts as detailed in the earlier deliverable D2.5. In future, this methodology needs to be replicated for new batch of bridge concepts, their analysis and mapping to TLOs. Additionally, the efficacy of the bridge concept methodology needs to be demonstrated by use cases from various domains and applications.