Semantic Interoperability in 1,200s

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My research topic is semantics for the Web of Things.
System Compatibility

Interoperability

Semantic Interoperability

Summary
System Compatibility

1,080s
System Compatibility

Figure: Power plug (in)compatibility across countries
System Compatibility

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System Compatibility

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The combination of compatible systems generally implies new functionalities.

Compatibility is achieved via standardization.
Interoperability

960s
Interoperability is an intangible form of **compatibility** between systems.
**Interoperability** is the ability of two or more systems or components to **exchange information** and **to use the information** that has been exchanged\(^1\).

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In theory, interoperability is realized via standard interaction protocols.
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In practice, interoperability is most commonly realized via (Web) APIs.
A good example of (lack of) interoperability is the **portability** of **personal data** on the Web.
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Web users should be able to **get access** to the data they produce on one platform and **give access** to that data to another platform.
We can either **force Facebook** to make it **more difficult** for [shadowy influence brokers] **to access your data** without Facebook’s explicit approval (...) or we can bar Facebook from using technical and legal countermeasures to shut out new companies, co-ops, and projects that offer to **let you talk to your Facebook friends without using Facebook’s tools**\(^2\).

\[^2\text{Cory Doctorow, “Competitive Compatibility: Let’s Fix the Internet, Not the Tech Giants,” Communications of the ACM, October 2021}\]
Interoperability

Microsoft Office  Google Docs  OnlyOffice

Google Drive  OneDrive  Dropbox  Evernote

Figure: (Lack of) interop. between text editors and document storage services
Interoperability

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The **Solid project** (Social Linked Data) aims to provide Web-based standards to produce and consume personal data.
Semantic Interoperability

660s
Semantic Interoperability

The European Telecommunication Standard Institute (ETSI) identified several levels of interoperability\(^3\).

Semantic Interoperability

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In that case, semantic interoperability is still not guaranteed.
Semantic Interoperability

For instance, an **address** may be the author’s personal address (administrative form), a professional contact point (academic publications) or a recipient’s address (letter).
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Semantic Interoperability

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```
time,hmdt,lumi,temp,location
1636954288932759918,,,19.9,emse/fayol/e4/S431H
1636954288981725847,54.7,,,emse/fayol/e4/S431H
...
```

**Figure:** Sensor measurements (CSV) with unresolved ref. to room S431H
**Semantic Interoperability**

Semantic interoperability is the ability of two or more systems or components to **share a common interpretation** of the information that has been exchanged.
If two systems agree on how to interpret data, they must use the **same concepts** to describe that data.
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The two systems have the same **ontology**.
An **ontology** is a formal description of **concepts and relationships** that can **exist for a community** of human and/or machine agents\(^4\).

\(^4\)Steffen Staab and Rudi Studer, Handbook on Ontologies, Springer, 2010
Ontologies are typically expressed as logical axioms over a well-defined vocabulary.

\(^5\)Aidan Hogan et al., Knowledge Graphs, Morgan & Claypool, 2021
Ontologies are typically expressed as logical axioms over a well-defined vocabulary.

They allow for ontology-based data access and ontology alignment, so that data from several sources is integrated into a single Knowledge Graph\textsuperscript{5}.

\textsuperscript{5}Aidan Hogan \textit{et al.}, Knowledge Graphs, Morgan & Claypool, 2021
Semantic Interoperability

Figure: Semantic interoperability via ontologies
Semantic Interoperability

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Semantic Interoperability

How to “formally describe” concepts and relationships?
Semantic Interoperability

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The World Wide Web Consortium (W3C) answers the question from a technical perspective with the Semantic Web technology stack.
The Resource Description Framework (RDF) provides a common framework for expressing [information about resources] so it can be exchanged between applications without loss of meaning.

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6 Frank Manola, Eric Miller and Brian McBride, RDF 1.1 Primer, W3C, June 2014.
Semantic Interoperability

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Resources can be anything, including documents, people, physical objects, and abstract concepts⁶.

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⁶Frank Manola, Eric Miller and Brian McBride, RDF 1.1 Primer, W3C, June 2014.
Semantic Interoperability

RDF triples can state e.g. the type of an online document and how its parts (such as an address) relate to other resources.
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Figure: RDF triples describing various documents with schema.org
RDF triples can also describe datasets (such as a CSV history of sensor measurements).
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Figure: RDF triples describing a CSV history with DCAT
Semantic Interoperability

Basics

resource rdf:type concept.

Intermediate

concept rdf:type rdfs:Class.
concept rdfs:subClassOf otherConcept.
property rdf:type rdfs:Property.
property rdfs:domain concept.

Advanced

concept rdf:type owl:Class.
concept owl:unionOf (concept1 concept2 ...).
property rdf:type owl:ObjectProperty.
property rdf:type owl:SymmetricProperty.
The Simple Knowledge Organization System (SKOS) standardizes how to define taxonomies (i.e. hierarchies of concepts).
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The RDF Schema (RDFS) standardizes how to define basic vocabularies (i.e. class names and property names) for Knowledge Graphs.
Semantic Interoperability

The Simple Knowledge Organization System (SKOS) standardizes how to define **taxonomies** (i.e. hierarchies of concepts).

The RDF Schema (RDFS) standardizes how to define **basic vocabularies** (i.e. class names and property names) for Knowledge Graphs.

The Web Ontology Language (OWL) standardizes how to define **expressive ontologies** (i.e. axioms) for any kind of logical theory.
Semantic interoperability is obtained when the resource descriptions of various data sources are **specializations** of a **common generic ontology**.
The International Data Space Association (IDSA) has created an ontology, based on DCAT, to ensure semantic interoperability across data spaces\(^7\).

\(^7\)Sebastian Bader et al., The International Data Spaces Information Model – An Ontology for Sovereign Exchange of Digital Content, ISWC, 2020
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Semantic interoperability is essential in data-intensive applications.
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Several degrees of interoperability can be achieved ‘as-you-go’ via incremental ontology engineering.
https://www.vcharpenay.link/talks/iot-semantics.html
Thank you. Questions?