Emotions, Money and Other Amorphous Things. An initial exploration of "Substance".

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Abstract
Embodied Cognition and cognitive metaphors theory take their origin from our use of language: sensorimotor triggers are disseminated in our daily communication, expression and commonsense knowledge. In this work, we extend the existing ImageSchemaNet ontology, an ontology representing knowledge about image schemas, focusing on a specification of the notion of "object": Substance. The investigation is intended as an extension of ImageSchemaNet, extending the Image Schematic layer developed on top of FrameNet and integrated in the Framester resource. Finally, this methodology allows the extraction of sensorimotor triggers for Substance from WordNet, VerbNet, MetaNet, BabelNet and many more.

Keywords
image schemas, ontology, knowledge representation, cognitive metaphors, embodied cognition

1. Introduction

Image schemas (IS) are conceptual structures proposed within the framework of embodied cognition. They capture sensorimotor experiences and influence abstract cognition, including commonsense reasoning and the semantic structures of natural language (see e.g. Mandler and Hampe [1, 2]). Image schemas are internally structured gestalts [3] composed of spatial primitives (SP). These spatial primitives form unified wholes of meaning, constituting more complex image schemas [4, 1, 5]. Some of the main relevant attempts to formalise image schemas and their compositionality are Image Schema Logic $\texttt{ISL}^{FOL}$ [6], and the ImageSchemaNet ontology [7].

For instance, in the expression "They're filled with jealousy," or "She's overflowing with love," the emotions are conceptualized as amorphous entities occupying a physical space, restricted in movement by a CONTAINER, which is the body. This is a well-established conceptual metaphor, namely EMOTIONS ARE SUBSTANCES, for which the CONTAINMENT image schema is activated. Our proposal to focus the investigation on the concept of "Substance" is, in fact, supported by the reuse of this notion in several conceptual metaphors, namely: EMOTIONS ARE SUBSTANCES, MONEY IS A SUBSTANCE, QUALITIES ARE SUBSTANCES,

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TAXATION IS FORCEFUL REMOVAL OF A SUBSTANCE, TIME IS A SUBSTANCE, and WEALTH IS A SUBSTANCE.

While the presence of image schemas in natural language has been investigated using corpus-based [8, 9] and machine learning methods [10, 11, 12], there are few formal approaches to operationalize image schemas (e.g., Image Schema Logic; [6]) and connect them to existing resources for semantic representation.

Here, the term "image schema profile" is employed as defined in [13] and [14]. It refers to the collection of activated image schemas associated with an entity, sentence, situation, or event.

The approach adopted in this work is derived directly from Fillmore's Frame Semantics. Image Schemas are in fact explicitly defined by Johnson [3] as internally structured gestalts, that are, composed of spatial primitives (SP) that make up more complex image schemas as unified wholes of meaning [4, 1, 5].

Frames are schematizations of recurrent situations, requiring a certain number of necessary elements (namely semantic roles) participating to the situation to occur. Frame Semantics is described more in detail in Section 2.1. ImageSchemaNet is the ontology (formal and explicit representatin of knowledge of a certain domain) for Image Schemas. In the context of ImageSchemaNet each image schema is modeled in OWL2 synstax as a frame with a certain number of roles. Currently ImageSchemaNet covers the following IS:

- Containment: an experience of boundedness, entailing an interior, exterior and a boundary [3].
- Center_Periphery: the experience of objects or events as central, while others are peripheral or even outside [15]. The periphery depends on the center but not vice versa [16].
- Source_Path_Goal: a source or starting point, goal or endpoint, a series of contiguous locations connecting those two, and movement [3].
- Part_Whole: wholes consisting of parts and a configuration of parts [16].
- Support: Contact between two objects in the vertical dimension [17].
- Blockage: obstacles that block or resist our force; a force vector encountering a barrier and then taking any number of directions [3].

This work aims at investigating a less covered specification of the Object image schema, namely Substance.

The formal representation of Substance is important from a theoretical perspective since it is in some way related to the notion of "Mass-Count" introduced in Lakoff & Johnson [18], and it is documented by Hurtienne [19] in the Image Schema Catalogue (ISCAT) repository.

Formalizing knowledge about the concept of Substance would improve commonsense knowledge extraction, allowing possible automatic inferences such as: if there is an entity which triggers Substance, it needs to be spatially located in some sort of Container or at least bounded Surface. Furthermore, automatic detection of substance could provide ways to detect conceptual metaphors mapping multiple domains (such as Emotions, Money, Time, etc.) on the Substance one. Finally, automatic detection Substance could find useful integration in works such as [20], exploring affordances and behavior of liquid entities.

This work preludes some research questions such as:

- Is Substance an image schema *per se*? Or is it a property of *matter* which determines the typology of an Object as being of type “Mass-Count”, and consequently determining its affordances?
- What are the defining properties of Substance? (For example its mereology, including homeomery, homogeneity, arbitrary divisibility, etc.)

This work is a preliminary investigation to provide an answer about the ontological nature of Substance, therefore, in this perspective, it is not interesting nor useful trying to provide a top-down formalization which would not reflect real world occurrences. For this reason this work focuses on populating a knowledge graph of semantic triggers of Substance, namely, real world occurrences, to foster future meaningful clustering and investigations of subtypes and properties restrictions. In the next paragraph we provide details about the adopted approach.

2. Related Works

In this section we provide details about current state of the art about the domain of image schemas. Firstly we mention relevant works in the image schema domain, while in Section 2.1 we describe previous works modeling image schemas from an ontological perspective.
There is no clear agreement on “Substance” as Image Schema or Spatial Primitive.
Studies have been developed about Object by Peña [21], and Langacker [22].

Cienki [23] describes the Object image schema as:

> An object is a material thing which we can see and feel. We may think of an object as a discrete item.

In particular the Object image schema has been the focus of Santibanez work [24], and it is described as:

> The OBJECT image-schema is experientially grounded in our physical and social interaction with our own bodies and with other discrete entities in the world.

More recently, Szwedek [25] defines an Object as:

> [...] An OBJECT schema can be defined as matter, with density as a fundamental property, in some bounded form.

The Substance IS that we examine in this work seems to differ from Cienki and Santibanez’ Object for “being a discrete item”. Consider as example the famous Sorite’s paradox, for which a pile of sand remains a pile of sand if one single grain of sand is taken off, but if we continue grain by grain, there is no clear threshold determining which is the last grain of sand that can be taken away, for that entity to remain a pile of sand. Furthermore, Substance seems to differ also from Szwedek’s Object definition, for its specification of being “in some bounded form.”

The Substance IS has been documented by Hurtienne [19], and it is reported in the Image Schema Catalogue (ISCAT)[1].

[1] An updated and upgraded version is available as Image Schema Repository here:https://github.com/dgromann/ImageSchemaRepository

Therefore, in this work our focus is on the notion of “Substance” as specification of Object lacking the restriction of some bounded form. We propose to model the Substance IS as a semantic frame (described in Section 2.1) subclass of the Object class in ImageSchemaNet.

2.1. Framester, ImageSchemaNet and the Frame Semantics Approach

Frames in a most general notion are (cognitive) representations of typical features of a situation. Fillmore’s frame semantics [26] has been most influential in conjugating linguistic descriptions and characterisation of related knowledge structures to describe cognitive phenomena. Words, multi-words expressions, and phrases are associated with frames based on the common scene they evoke. A resource formalizing this theory is FrameNet [27], in which frames are explained as *situation types*.

Fillmore explicitly compares frames to other notions, such as experiential gestalts [28], stating that frames can refer to a unified framework of knowledge or a coherent schematization of experience. Thus, widely acknowledged frames provide a theoretically well-founded and practically validated basis for commonsense knowledge patterns.

Framester [29, 30] is a linked data hub that provides a formal semantics for frames [30], based on Fillmore’s frame semantics [26]. In Framester semantics [30] observed/recalled/anticipated/imagined situations are occurrences of frames. It creates/reengineers linked data versions of linguistic resources, such as WordNet [31], OntoWordNet [32], VerbNet [33], BabelNet [34], jointly with factual knowledge bases (e.g. DBpedia [35], YAGO [36]). Framester also includes MetaNet[2] [37] a cognitive metaphors layer of knowledge, ImageSchemaNet [7] the image schemas ontology.

ImageSchemaNet is a formal and re-usable representation of image schemas as Semantic Web technology in form of an ontological layer. It presents a formal representation of image schemas as a new layer of the Framester hub. Since a major flaw in current image schema theory was the lack of agreement about the lexical coverage of image schemas, ImageSchemaNet introduces an image-schematic layer linking IS and SP to FrameNet frames and frame elements, WordNet synsets (sets of contextual synonyms) and word supersenses, VerbNet verbs, etc., thereby creating a formal, lexicalized integration of cognitive semantics, enactive theories, and frame semantics. Currently, ImageSchemaNet provides lexical coverage and formalization for the following six image schemas: Source_Path_Goal, Containment, Center_Periphery, Part_Whole, Support, and Blockage.

Framester can be used to jointly query (via a SPARQL endpoint[3]) all the resources aligned to its formal frame ontology[4]. Framester has been used [37] to formalize the MetaNet resource of conceptual metaphors[5], based on FrameNet frames as metaphor sources and targets (frame-based), as well as to uncover semantic puzzles emerging from a logical treatment of frame-based metaphors.

[2]The MetaNet schema in Framester’s OWL is at https://w3id.org/framester/metanet/schema/.
[3]http://etna.istc.cnr.it/framester2/sparql
[4]The Framester Schema is available at: https://w3id.org/framester/schema/
[5]The MetaNet schema in Framester’s OWL is at https://w3id.org/framester/metanet/schema/.

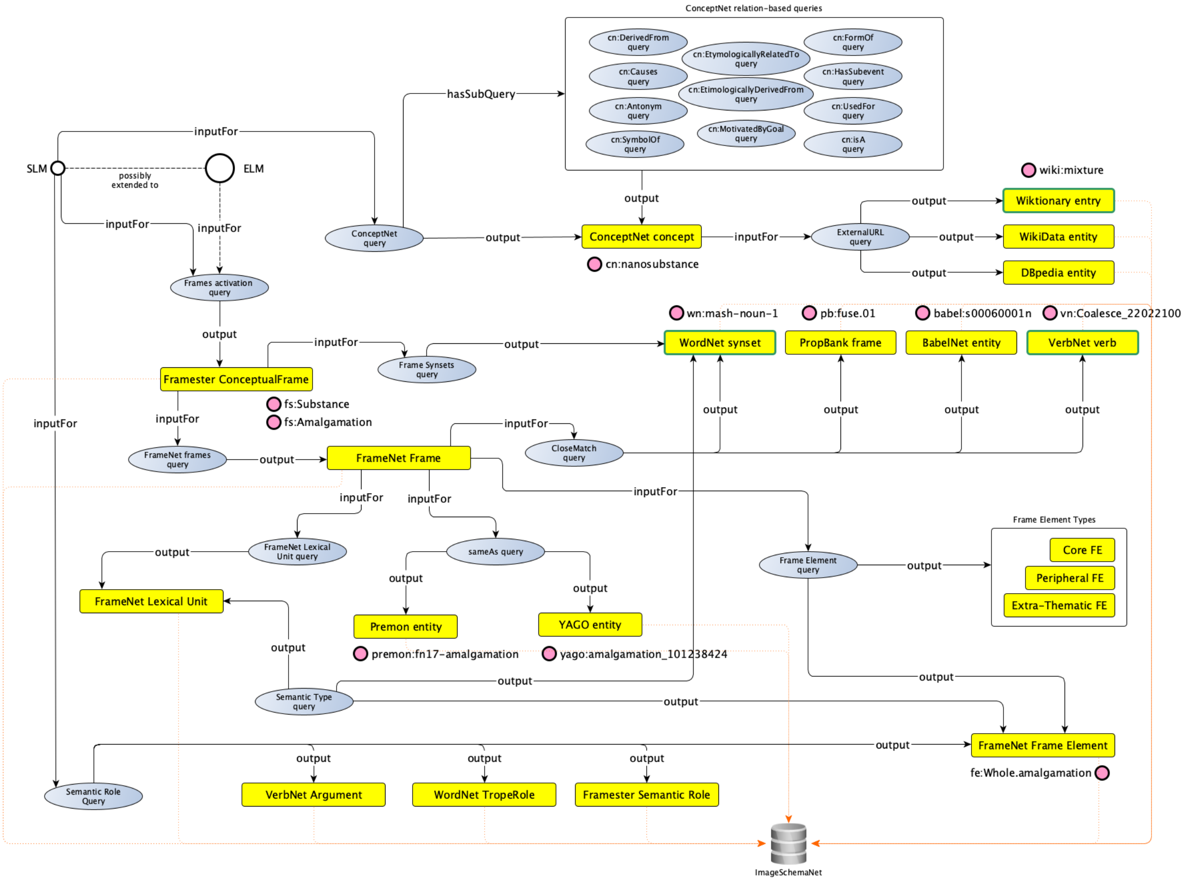

Figure 1: ImageSchemaNet graph population workflow reusing entities from the semantic web resources aligned in the Framester hub.

3. Substance Knowledge Graph

Proposing SUBSTANCE as a specification of OBJECT in ImageSchemaNet requires some steps to populate the knowledge graph of semantic triggers, as described in the following. Adopting the frame semantics approach as mentioned above means that every lexical unit referring to a portion of reality that can only be understood having in mind some notion of "substance" will be a trigger for the SUBSTANCE image schema. We proceed describing the knowledge graph population step by step, as shown in Figure 1. All the yellow rectangles are classes of entities, coming from multiple semantic web resources, while blue ovals are SPARQL queries, provided as additional material.[6]

Manual Lexical Units Selection The initial step in the process involves a manual selection of a limited set of lexical units that are directly related to the conceptual frame being constructed, in this case: Substance. We call this set "Starting Lexical Material" (SLM). The SLM set is

[6]The SPARQL queries are available here: https://github.com/StenDoipanni/QUOKKA

selected manually considering the SUBSTANCE examples in the ISCAT repository, and then further expanded using the WordNet resource, which can be accessed through its online user interface[7]. This expansion aims to leverage the relationships of hyponymy and synonymy among terms. By manually selecting an initial set of lexical units and expanding it using WordNet, we can lay the foundation for building a robust conceptual frame for the desired domain.
All the following steps are performed via SPARQL queries to the Framester endpoint.[8]

ConceptNet-driven triggering Some ConceptNet relations are used to gather knowlegde, as shown in Figure 1. By leveraging these ConceptNet relations, we can explore the interconnectedness between lexical units and concepts, expanding the initial set of terms and enriching the conceptual frame construction process. In Figure 1 it is shown as a lexical unit like "substance" leads to a more specific entity in ConceptNet, such as `cn:nanosubstance`.

WikiData lexical triggering The WikiData lexical triggering step relies on the entities obtained from the ConceptNet-driven triggering process. The Starting Lexical Material (SLM) set serves as the input variable to retrieve all corresponding WikiData entries. In Figure 1 the individual shown is `wiki:mixture`.

DBpedia factual triggering In parallel with the WikiData lexical triggering step, it is possible to retrieve entities aligned with the DBpedia resource, which provides factual grounding for the domain knowledge base.

Frame-driven triggering In a separate branch, as depicted in Figure 1, the selected lexical units from the Starting Lexical Material (SLM) set are examined to determine if they serve as lexical triggers for existing FrameNet frames. This step aims to leverage pre-existing frames that may partially overlap with the desired domain or provide more specific or general situational schematization. In this case are shown and declared as triggers for SUBSTANCE the `fs:Substance` and `fs:Amalgamation` frames.

Frame element-driven triggering This step pertains to a scenario for which certain aspects of SUBSTANCE may already be addressed by existing frames, enabling the adoption of the established structure of formalized semantic roles, where frame element activation revolves around the activation of semantic roles associated with the occurrence of a certain situation, i.e., a Frame occurrence, within the specified domain.

FrameNet Lexical Units triggering This step naturally follows from the preceding paragraphs and the adoption of a frame structure. By accessing the online user interface of the FrameNet resource[9], it becomes apparent that certain lexical units are identified as evoking

[7]WordNet online resource is available here: https://wordnet-rdf.princeton.edu/
[8]The Framester endpoint is available here: http://etna.istc.cnr.it/framester2/sparql
[9]The FrameNet online user interface can be found at https://framenet.icsi.berkeley.edu/fndrupal/about

specific frames. To fully comprehend the semantics of these lexical units, a common understanding of the system of semantic relations and the contexts in which they convey their meanings is required. The purpose of this SPARQL query is to incorporate the FrameNet lexical units as triggers for the frame being constructed. These lexical units are declared in FrameNet as triggers for frames that exhibit either total or partial overlap with the intended domain.

WordNet lexical triggering The activation of lexical material plays a significant role in semantic detection, and it is accomplished by automatically reintroducing the results of the Frame activation query into the workflow. This refers to the frames that were previously manually selected. The rationale behind this step is that if an entity evokes a FrameNet frame that is related to the frame being modeled, then that entity should also be activated in relation to the frame itself.

Close Match triggering In addition to WordNet synsets, entities from various semantic web resources are aligned with frames in the Framester hub. This alignment is established at the meta-level using the `skos:closeMatch` object property. It declares that a concept identified by a specific URI in one resource has a close match with another concept identified by a different URI in another resource. Although the two entities remain distinct, they point to the same or similar aspect of reality.

Here, we specify the entities aligned with the `skos:closeMatch` relation from several resources, how they interlink with each other, and the specific SPARQL query for each resource:

- **WordNet synsets**: These are sets of contextual synonyms. As explained in the previous paragraph, if two lexical units can be used as synonyms in the same context, it can be inferred that the considered context is possibly a subframe of the frame being modeled. Therefore, declaring the entire synset as a trigger for a frame results in a significant increase in coverage, including all the senses of the terms that can be used in similar situations. Some frames that schematize events or actions may have a `skos:closeMatch` relation to verbs or nouns that point to those events or actions. The query to retrieve WordNet synsets subsumed by a frame is the one mentioned in the previous paragraph, while the general query to retrieve those aligned via `skos:closeMatch` is mentioned at the end of this paragraph.
- **VerbNet verbs**: Verbs from the VerbNet resource can be retrieved through the alignment between WordNet "word senses" and VerbNet "key senses", as well as through the close match alignment with frames. The verb `Coalesce_22022100` is shown as example in Figure 1.
- **PropBank frames**: Frames from the PropBank resource are aligned with FrameNet frames through the `skos` relation. By providing the URIs of the FrameNet frames as input for the "PropBank triggering" SPARQL query, entities from the PropBank resource can be collected. The example shown is the `pb:fuse.01` frame.
- **BabelNet entities**: A further multilingual coverage is provided through the alignment of BabelNet with Framester frames. The updated online version of BabelNet (5.2) may differ in size and coverage compared to the version in the Framester resource (3.7). Nonetheless, it

is possible to retrieve entities from over 270 languages through the `skos:closeMatch` alignment.

- **Premon entries**: Premon entries are an extension of the lemon model by the W3C Ontology - Lexica Community Group.

YAGO Ontology triggering The WordNet lexical grounding is utilized once again to retrieve entities from the YAGO (Yet Another Great Ontology) resource. In this case, the alignment is achieved through the `owl:sameAs` property towards WordNet synsets.

Semantic role-driven triggering While potential roles participating in a specific frame are extracted from FrameNet frame elements (as described in the "Frame element-driven triggering" paragraph), according to Framester semantics, they are not the only sources for structural elements that can serve as roles in a frame occurrence.

In Framester, triggering assertions from FrameNet frame elements are extended to include multiple sources of semantic roles: VerbNet arguments, PropBank roles, and WordNet tropes.

Semantic type-driven triggering A dimension that complements the previously mentioned aspects is the semantic type of an entity.

The final knowledge graph, which consists of several thousands of semantic triggers, from the above mentioned semantic web resources, is available on the ImageSchemaNet GitHub repository. A summary table with details about semantic web resources reused and the exact number of entities per resource triggering the Substance IS is available as additional material on the ImageSchemaNet GitHub.[10].

In the next section we show how, thanks to the knowledge retrieval and frame building workflow shown in Figure 1, it is possible to perform automatic detection from natural language of the Substance image schema.

4. Automatic Substance Detection

Following the methodology described in [38], we are able to perform automatic image schema detection from a sentence via reusing the FRED tool.

FRED [39] could be defined as a "situation analyzer". It is a hybrid knowledge extraction system to generate knowledge graphs directly from natural language. It is built with a pipeline that includes both statistical and rule-based components, and produces as output RDF and OWL knowledge graphs, with embedded entity linking, word-sense disambiguation, and frame/semantic role detection, aligning entities in the produced graph directly to entities from Framester resource.

Consider the sentence "I feel a mixture of anger and emotion" taken from Stefanowitsch's example [40]. The example is taken from the ISCAT repository, and refers to the MetaNet cognitive metaphor `EMOTIONS ARE SUBSTANCES`. We give the sentence as input to the FRED tool which generates the graph shown in Figure 1.

[10]The ImageSchemaNet repository is available here: https://github.com/StenDoipanni/ISAAC/tree/main/ImageSchemaNet

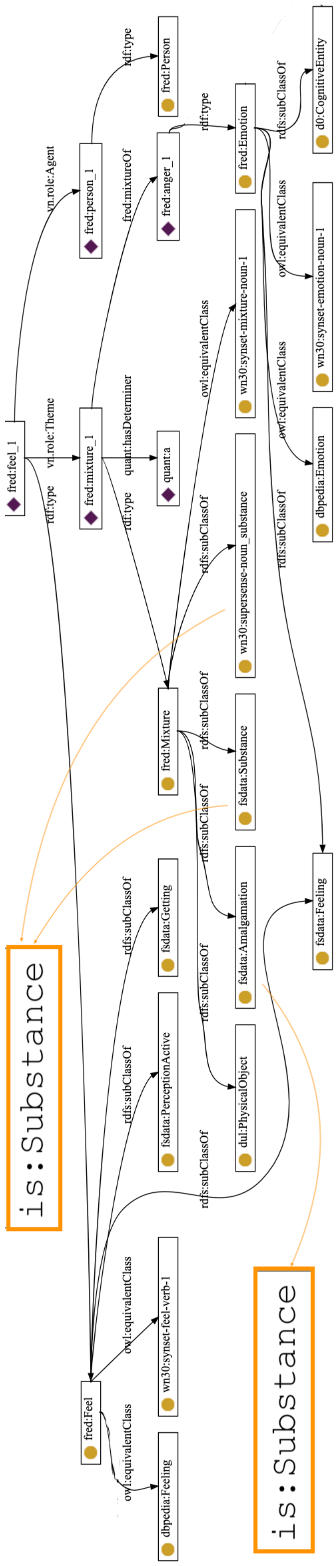

Figure 2: FRED graph automatically generated from the sentence “I feel a mixture of anger and emotion”.

As shown in figure, there is a main “feeling” event, which takes as VerbNet role Theme the “mixture” lexical unit. This unit evokes the `fs:Substance` and `fs:Amalgamation` frames, which in turn trigger the Substance image schema.

Furthermore, the lexical unit “mixture” is disambiguated on `wn:mixture-noun-1`, and the FRED tool disambiguates the lexical units referring to the “Emotions” domain to the `wn:anger-noun-1` and `wn:emotion-noun-1` WordNet synset as well as on the DBpedia enitities `db:Anger` and `db:Emotion`.

5. Conclusions

We started from sparse definition for a less investigated image schema, in particular adopting a bottom-up approach, considering the examples in the Image Schema Catalogue repository, to generate a formal representation of the concept of Substance, introducing it in the already existing ImageSchemaNet ontology.

Substance is modeled as subclass of Object, and we populated the knowledge graph of semantic triggers reusing multiple semantic web resources from the Framester hub.

We finally performed a automatic image schema detection for Substance generating a knowledge graph from natural language with the FRED tool.

Future works include a refinement of the detection process, in order to consider the domains involved, and possibly detect specific cognitive metaphors.

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