The Racing Mind and the Path of Love: Automatic Extraction of Image Schematic Triggers in Knowledge Graphs Generated from Natural Language

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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. We propose, in this work, a first attempt of image-schematic triggers automatic extraction, starting from knowledge graphs automatically generated from natural language. The methodology proposed here is conceived as a modular addition integrated in the FRED tool, able to generate knowledge graphs from natural language, while it has its foundation in querying ImageSchemaNet, the Image Schematic layer developed on top of FrameNet and integrated in the Framester resource. This methodology allows the extraction of sensorimotor triggers from WordNet, VerbNet, MetaNet, BabelNet and many more.

Keywords

image schemas, knowledge reprentation, cognitive semantics, embodied cognition, frame semantics

1. Introduction

Image schemas (IS) have been proposed within the tradition of embodied cognition as conceptual structures that capture sensorimotor experiences and shape abstract cognition, including commonsense reasoning and semantic structures of natural language (see e.g. [1, 2]). Image schemas are defined as internally structured gestalts [3], that is, composed of spatial primitives (SP) that make up more complex image schemas as unified wholes of meaning [4, 1, 5]. For example, considering the expression "my mind is racing", the "mind" is conceptualized as an entity moving along a path and it activates the well-established SOURCE_PATH_GOAL image schema, which is activated in conceptualizing any kind of movement along a path. This IS, in order to realize its semantics, is (gestaltically) composed by the SOURCE, PATH, and GOAL spatial primitives.

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While their existence in natural language has been studied by means of corpus-based (e.g. [6, 7]) and machine learning methods (e.g. [8, 9, 10]), few approaches to formalize image schemas (e.g. Image Schema Logic [11]) and connect them to existing resources to capture semantics exist.

The notion of image schema profile is used here as in [12] and [13] to describe the collection of IS which are activated by some entity, sentence, situation, or event.

This work proposes a first attempt to build an automatic image schema profile extractor from natural language, and we explain the working pipeline, providing a possible evaluation methodology using as a golden standard the ISCAT repository.

2. Preliminaries

To perform automatic image schema profile extraction we rely on the FRED tool and the ImageSchemaNet ontology, part of the Framester resource.

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 [14] has been most influential as a combination of linguistic descriptions and characterisation of related knowledge structures to describe cognitive phenomena. Words or phrases are associated with frames based on the common scene they evoke. In FrameNet, frames are also explained as *situation types*. In Framester semantics [15] observed/recalled/anticipated/imagined situations are consequently occurrences of frames.

Fillmore explicitly compares frames to other notions, such as experiential gestalt [16], 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 [17, 15] is a linked data hub that provides a formal semantics for frames [15], based on Fillmore's frame semantics [14]. It creates/reengineers linked data versions of linguistic resources, such as WordNet [18], OntoWordNet [19], VerbNet [20], BabelNet [21], etc, jointly with factual knowledge bases (e.g. DBpedia [22], YAGO [23]). Framester also includes ImageSchemaNet [24].

ImageSchemaNet [24] 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.

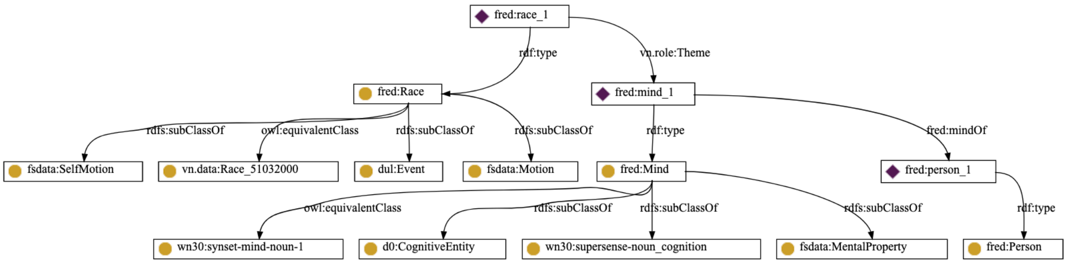

Figure 1: Knowledge graph produced by FRED for *My mind is racing*

Framester can be used to jointly query (via a SPARQL endpoint[1]) all the resources aligned to its formal frame ontology[2]. Framester has been used [25] to formalize the MetaNet resource of conceptual metaphors[3], 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.

2.2. FRED Tool

FRED [26] is a hybrid knowledge extraction system to generate knowledge graphs directly from natural language text input. It is built with a pipeline that includes both statistical and rule-based components, aimed at producing 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.

3. Automatic Image Schema Profile Extraction

The workflow to extract IS and SP from natural language is composed as follows: the first step is to take a sentence and pass it to FRED tool to generate a knowledge graph from text. Let's take as example "*My mind is racing*", which relates to the cognitive metaphor "THE BODY IS A MACHINE" and shows the activation of SOURCE_PATH_GOAL. Figure 1 shows the knowledge graph automatically generated as output by FRED[4].

The second step consists in taking all the subjects, predicates, and objects of all triples, namely all nodes and arches in the graph, to systematically interrogate the Framester repository, in particular the ImageSchemaNet graph, via SPARQL queries, to check if there is an activation of some Image Schema or Spatial Primitive[5]. The ImageSchemaNet graph contains more than 40k triples which take as subject entities from resources in the Framester hub (FrameNet, VerbNet,

[1]http://etna.istc.cnr.it/framester2/sparql
[2]The Framester Schema is available at: https://w3id.org/framester/schema/
[3]The MetaNet schema in Framester's OWL is at https://w3id.org/framester/metanet/schema/.
[4]This graph can be reproduced using the *My mind is racing* sentence as input for the FRED online demo, available here: http://wit.istc.cnr.it/stlab-tools/fred/demo/ and ticking the "Align concepts to Framester" option.
[5]Some useful explorative queries are available at https://github.com/StenDoipanni/ISAAC/tree/main/ImageSchemaNet

Table 1
PATH-family subset accuracy

ISCAT	Processed	Extracted	SOURCE_PATH_GOAL	SOURCE	PATH	GOAL
390	383	262	187	0	65	8

WordNet etc.) and declare the activation of some IS or SP. ImageSchemaNet knowledge graph generation is shown in [24].

Finally, for each occurrence of activation retrieved, a triple is added to the original graph declaring the activation. In the above-mentioned example, shown in Figure 3, IS activators retrieved in the ImageSchemaNet graph are: the frames `fsdata:SelfMotion` and `fsdata:Motion`, and the VerbNet verb `vn.data:Race_51032000`, resulting in three occurrences of SOURCE_PATH_GOAL activation.

4. Evaluation

We propose here an evaluation setting and some preliminary results, even though the evaluation process poses some problems, as exposed in the following sections.

4.1. Evaluation Setting

The evaluation setting uses the ISCAT dataset[6] [27], and both above mentioned FRED tool as state-of-the-art for frame detection from natural language and ImageSchemaNet ontology. ISCAT is a repository of sentences manually annotated with one image schema per sentence. All examples are taken from a large variety of original sources, mainly from literature (e.g. [28, 3]), but also from some online sources (e.g. MetaNet, newspaper articles), which are listed in the cleaned version of the repository[7]. Please be reminded that multiple image schemas might be correct for a single sentence, and no inconsistency or incompatibility could come from co-location of different image schemas in the same sentence, even if each sentence in the ISCAT dataset is manually annotated with only one.

4.2. Evaluation Results

Table 1 shows some first results, in particular the column "ISCAT" is the amount of sentences in the ISCAT repository which were labeled as activating SOURCE_PATH_GOAL. Column "Processed" shows the actual number of sentences for which FRED successfully generated a knowledge graph. The 7 missing entries produced blank files, probably due to the brevity of the sentences, and were for this reason left apart. Column "Extracted" shows the number of actual sentences for which our method individuated the activation of at least one of the six IS covered by ImageSchemaNet ontology. Finally, columns "SOURCE_PATH_GOAL", "SOURCE",

[6]Image Schema Database procured by Jörn Hurtienne
[7]Available here https://github.com/dgromann/ImageSchemaRepository

Table 2
CONTAINMENT coactivation in PATH-family subset

CONTAINMENT	CONTAINER	INSIDE
61	44	0

Table 3
PART_WHOLE coactivation in PATH-family subset

PART_WHOLE	PART	WHOLE
56	0	0

Table 4
CENTER_PERIPHERY coactivation in PATH-family subset

CENTER_PERIPHERY	CENTER	PERIPHERY
48	0	5

Table 5
BLOCKAGE coactivation in PATH-family subset

BLOCKAGE	BLOCKER	BLOCKED
16	0	0

"PATH", and "GOAL" show the number of occurrences in which it was retrieved the activation of SOURCE_PATH_GOAL or one of its spatial primitives.

Tables 2, 3, 4, 5, and 6 show the number of occurrences of coactivation of one of the other IS in the subset of sentences that in the ISCAT repository were originally labeled as activating only SOURCE_PATH_GOAL.

4.3. Evaluation Discussion

Although the results are promising, a precise evaluation criterion is still lacking, mainly due to the fact that our method, as previously shown by tables, is strongly inclined to detect many image schemas per sentence, while the golden standard considers only one activation per sentence. This tendency is better explained in Figure 2 that shows an excerpt of the knowledge graph[8] generated for the sentence "*Our relationship hit rock bottom and we were stuck there without moving forwards or backwards*" and enriched with IS and SP activation.

In this highly metaphoric example, our methodology retrieves the activation of BLOCKAGE by some Framester frames, namely `fs:CauseImpact`, `fs:HitTarget` and `fs:Impact`, and by the WordNet synset `wn:synset-hit-verb-2`; locative references like the `fs:Placing` frame and the `wn:supersense-noun-location` activate CONTAINMENT and the CONTAINER spatial primitive,

[8]The full graph is available in Appendix A in Figure A.

Table 6
SUPPORT coactivation in PATH-family subset

SUPPORT	SUPPORTER	SUPPORTED
17	0	0

while the aspect of movement is captured by `fs:SelfMotion`, `fs:Travel`, `fs:BodyMovement` and `fs:Motion` frames, as well as by the VerbNet entity `vn:Move_11020000`. Interestingly the WordNet synset `wn:synset-bottom-noun-1` activates both PART_WHOLE and CENTER_PERIPHERY. This double activation could be explained considering the gestaltic nature of image schemas: to conceive the "bottom" of some entity is necessary to conceive the whole entity and then to focus on some part, and if the considered entity is some kind of container, then its "bottom", as well as its top border, could be seen as the periphery of the area occupied by the container. A final positive aspect of this frame-based approach is that, due to the graph structure of the output, the image schema profile extraction is fully explainable and it is possible to navigate through the graph from the activation occurrence to the trigger entity, back to the lexical unit in the original sentence.

5. Conclusion and Future Works

We proposed here a first version of an automated frame-based image schema profile extractor which operates in an explainable way, enriching knowledge graphs with an image schematic lexical layer. Actual ongoing improvements of this approach include extending image schematic coverage, including also other IS left aside in the current version of the ImageSchemaNet ontology. Furthermore, we are working on frame role-labeling mechanism to enhance IS and SP matching to natural language statements. Future developments could include, on the side of the evaluation golden standard, a further manual revision of the proposed image schematic labeling approach. On the technical side, we are considering the integration of more recent neural frame labeling approaches, in order to allow the reuse of image schemas detector for other knowledge layers e.g. emotionality, moral values, etc. expressed in natural language grounded in embodied cognition.

Appendix

A. The Path of Love

Here you find the graph produced by FRED for a sample sentence automatically enriched with image schemas and spatial primitives activation, expressed in Turtle syntax. The locus of activation is in this way clear and explainable via linking the IS or SP activation directly to the lexical unit from natural language text.

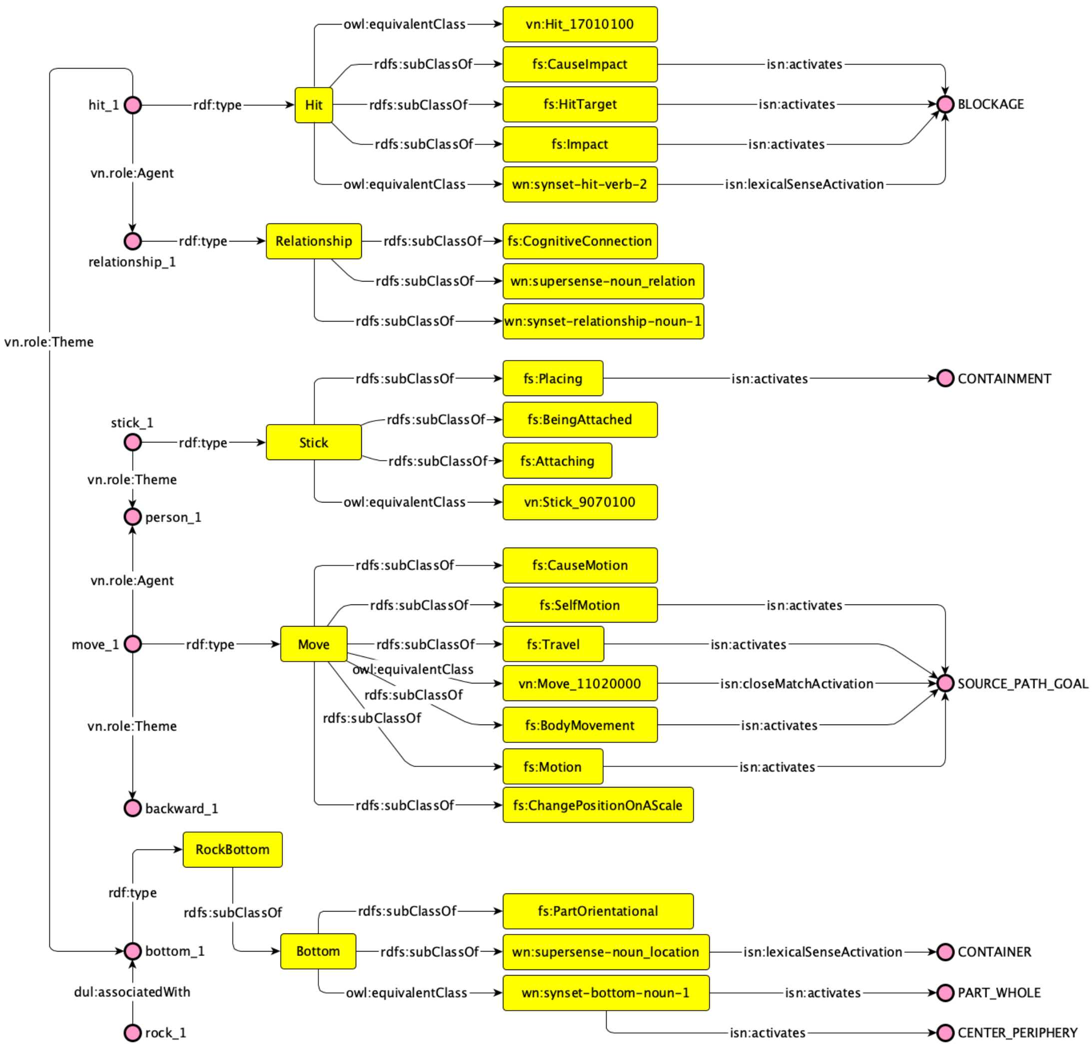

Figure 2: An excerpt of the knowledge graph produced by FRED and enriched with Image Schema and Spatial Primitive activation retrieved by querying ImageSchemaNet for *Our relationship hit rock bottom and we were stuck there without moving forwards or backwards.* The full graph is available in Appendix A in Figure A.

Our relationship hit rock bottom and we were stuck there without moving forwards or backwards.

```
@prefix framestercore: <https://w3id.org/framester/data/framestercore/> .
@prefix ns0: <http://www.ontologydesignpatterns.org/ont/is/isnet.owl#> .
@prefix ns1: <http://www.ontologydesignpatterns.org/ont/dul/DUL.owl#> .
@prefix ns2: <http://www.ontologydesignpatterns.org/ont/is/isaac_vanilla.owl#> .
@prefix ns3: <http://www.ontologydesignpatterns.org/ont/boxer/boxing.owl#> .
@prefix ns4: <http://www.ontologydesignpatterns.org/ont/vn/abox/role/> .
@prefix ns5: <http://www.ontologydesignpatterns.org/ont/fred/domain.owl#> .
```

```
@prefix ns6: <http://www.ontologydesignpatterns.org/ont/fred/quantifiers.owl#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix vndata: <https://w3id.org/framester/vn/vn31/data/> .
@prefix wn30instances: <https://w3id.org/framester/wn/wn30/instances/> .

ns5:hit_1 a ns5:Hit ;
  ns4:Agent ns5:relationship_1 ;
  ns4:Theme ns5:bottom_1 .

ns5:move_2 a ns5:Move ;
  ns3:hasTruthValue ns3:False ;
  ns5:union ns5:move_1 ;
  ns4:Agent ns5:person_1 ;
  ns4:Theme ns5:forward_1 .

ns5:rock_1 a ns5:Rock ;
  ns1:associatedWith ns5:bottom_1 .

ns5:stick_1 a ns5:Stick ;
  ns1:hasQuality ns5:There ;
  ns4:Theme ns5:person_1 .

ns5:Bottom rdfs:subClassOf <http://www.ontologydesignpatterns.org/ont/d0.owl#Location>,
  framestercore:PartOrientational,
  wn30instances:supersense-noun_location ;
  owl:equivalentClass wn30instances:synset-bottom-noun-1 .

ns5:Hit rdfs:subClassOf ns1:Event,
  framestercore:CauseHarm,
  framestercore:CauseImpact,
  framestercore:ExperienceBodilyHarm,
  framestercore:HitTarget,
  framestercore:Impact ;
  owl:equivalentClass vndata:Hit_17010100,
  wn30instances:synset-hit-verb-2 .

ns5:Relationship rdfs:subClassOf ns1:Description,
  framestercore:CognitiveConnection,
  wn30instances:supersense-noun_relation ;
  owl:equivalentClass wn30instances:synset-relationship-noun-1 .

ns5:RockBottom ns1:associatedWith ns5:Rock ;
  rdfs:subClassOf ns5:Bottom .
```

```
ns5:Stick rdfs:subClassOf ns1:Event,
  framestercore:Attaching,
  framestercore:BeingAttached,
  framestercore:CauseMotion,
  framestercore:InchoativeAttaching,
  framestercore:Placing ;
  owl:equivalentClass vndata:Stick_9070100 .

ns5:backward_1 a ns5:Backward ;
  ns6:hasQuantifier ns6:multiple .

ns5:forward_1 a ns5:Forward ;
  ns6:hasQuantifier ns6:multiple .

ns5:move_1 a ns5:Move ;
  ns3:hasTruthValue ns3:False ;
  ns4:Agent ns5:person_1 ;
  ns4:Theme ns5:backward_1 .

ns5:relationship_1 a ns5:Relationship ;
  ns5:relationshipOf ns5:person_1 .

ns5:Move rdfs:subClassOf ns1:Event,
  framestercore:BodyMovement,
  framestercore:CauseChangeOfPositionOnAScale,
  framestercore:CauseMotion,
  framestercore:ChangePositionOnAScale,
  framestercore:Motion,
  framestercore:SelfMotion,
  framestercore:Travel ;
  owl:equivalentClass vndata:Move_11020000 .

ns5:Rock rdfs:subClassOf ns1:PhysicalObject,
  framestercore:CauseHarm,
  wn30instances:supersense-noun_object ;
  owl:equivalentClass wn30instances:synset-rock-noun-1 .
ns5:bottom_1 a ns5:RockBottom .
ns5:person_1 a ns5:Person .

framestercore:BodyMovement ns0:activates ns2:SOURCE_PATH_GOAL .
framestercore:CauseImpact ns0:activates ns2:BLOCKAGE .
framestercore:HitTarget ns0:activates ns2:BLOCKAGE .
framestercore:Impact ns0:activates ns2:BLOCKAGE .
```

```
framestercore:Motion ns0:activates ns2:SOURCE_PATH_GOAL .
framestercore:Placing ns0:activates ns2:CONTAINMENT .
framestercore:SelfMotion ns0:activates ns2:SOURCE_PATH_GOAL .
framestercore:Travel ns0:activates ns2:SOURCE_PATH_GOAL .
vndata:Move_11020000 ns0:closeMatchActivation ns2:SOURCE_PATH_GOAL .
wn30instances:supersense-noun_location ns0:lexicalSenseActivation ns2:CONTAINER .
wn30instances:synset-bottom-noun-1 ns0:lexicalSenseActivation ns2:CENTER_PERIPHERY,
  ns2:PART_WHOLE .
wn30instances:synset-hit-verb-2 ns0:lexicalSenseActivation ns2:BLOCKAGE .
```

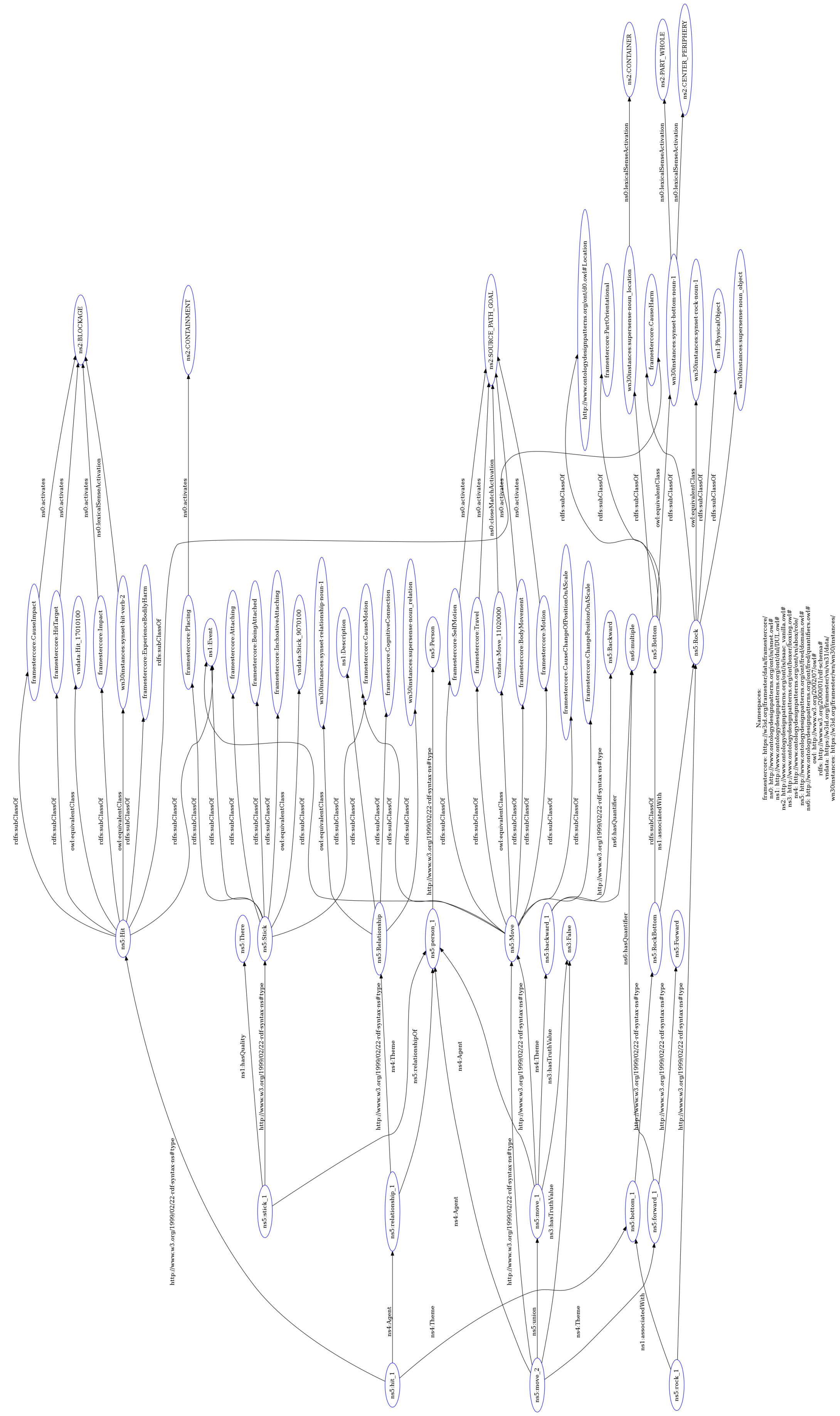

Figure 3: Knowledge graph produced by FRED and enriched with Image Schema and Spatial Primitives activation from ImageSchemaNet for the sentence:
Our relationship hit rock bottom and we were stuck there without moving forwards or backwards
(Visualization realized with Linked Data Finland RDF Grapher service available here: https://www.ldf.fi/service/rdf-grapher).

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