1 Introduction

The FrameNet Project (Fillmore & Baker 2010; Ruppenhofer *et al.* 2006) at the International Computer Science Institute is an ongoing effort to produce a lexicon of English that is both human- and machine-readable, based on the theory of Frame Semantics and supported by annotating corpus examples of the lexical items. The work of FrameNet can be thought of as the implementation of a theory that was already well-developed, but, as others have found, the process of annotating actual text has also pushed forward the development of the theory.

2 Frame Semantics

The theory of Frame Semantics has been under construction since the 1970s by Charles Fillmore and colleagues, (Fillmore 1976; Fillmore 1977; Fillmore 1982; Fillmore 1985) as a natural progression from Fillmore's case grammar (Fillmore 1968; Fillmore 1969). Case grammar proposed that much of the semantic content of language can be analyzed in terms of predicators and their arguments (and adjuncts), each of which plays one of a small number of predefined roles in the predication; the set of roles is similar to those used in a variety of semantic theories: agent, patient/theme, source, path and goals, place, time, manner, means/instrument, etc. The mental lexicon would then contain, in addition to a representation of the basic semantics of the word, knowledge about the syntactic patterns in which these roles could appear. But as time went on, it became apparent that there were subtle differences in how the roles applied with different predicators and some, such as *replace* and *resemble*, required roles which did not fit into the usual categories. For example, in *Reagan replaced Carter as President in 1981*, it is a little strange to think of this as simply Reagan as Agent and Carter as Theme; what is important about replace is that Carter is the old entity and Reagan is the new entity in a replacement event. So the theory began to change; increasingly, the original case roles (a.k.a. semantic roles, thematic roles, theta roles) were seen as generalizations over a much larger set of roles which provided more detailed information about the participants in a large variety of situations. Then the question becomes, where to stop? Fillmore acknowledged that at the extreme, "each word has its own frame", but such an approach would make the learning of more general patterns much more difficult, both for children and for machine learning algorithms.

The resolution of this dilemma was found in the concept of semantic frames, which represent linguistically motivated conceptual gestalts. Frames are generalizations over groups of words which describe similar states of affairs and which could be expected to share similar sets of roles, and (to some extent) similar syntactic patterns for them. In the terminology of Frame Semantics, the roles are called frame elements (FEs), and the words which evoke the frame are

Frame	Example
Self-motion	The assailants RAN into the fields ...
Leadership	The nursery is RUN by trained staff ...
Fluidic motion	I remember a tear RUNNING down my cheek ...
Operating a system	While the mob was RUNNING the casinos ...

Table 1: Some of the frames for the lemma *run*

referred to as lexical units (LUs). A lexical unit is thus a "sign", an association between a form and a meaning; the form is a lemma with a given part of speech, the meaning is represented as a semantic frame plus a short dictionary-style definition, which is intended to differentiate this lexical unit from others in the same frame. Each lexical unit is equivalent to a word sense; if a lemma has more than one sense, it will be linked to more than one LU in more than one frame. For example the lemma *run*.v is linked to several frames, some of which are shown in Table 1. Note that the link is with the lemma, not the word forms, so *run, ran*, and *running* are treated alike, *pace* the strict corpus linguists, who correctly point out that the different word forms may have very different distributions in text.

Because of the origin of Frame Semantics in the study of verbs and valence, there was emphasis initially on representing events, but the principle that a conceptual gestalt can be evoked by any member of a set of words also applies to relations, states, and entities; furthermore, the evoking words can be nouns, adjectives, adverbs and other parts of speech, as well as verbs. For example, the **Leadership** frame contains nouns like *leader, tyrant, bishop, headmaster*, and *maharajah*, and verbs like *lead* and *command*, and represents a social relation, a situation in which one individual (or group) has some kind of authority over others. The FEs in the **Leadership** frame include the LEADER and the GOVERNED, as shown in the following examples:

- [$_{\text{Leader}}$ Kurt Helborg] is the CAPTAIN [$_{\text{Governed}}$ of the Reiksguard Knights] ...
- Nobody wanted [$_{\text{Leader}}$ John Major] to LEAD [$_{\text{Governed}}$ the Tory Party] in the first place
- [$_{\text{Leader}}$ Rodrigo] COMMANDED [$_{\text{Governed}}$ the army of his overlord Prince Sancho] ...
- [$_{\text{Governed}}$ Jerusalem's] MAYOR, [$_{\text{Leader}}$ Teddy Kollek] , spent the next 25 years ...

Being wet is a frame expressing a state, which can be evoked by a variety of adjectives, as shown below:

- Their eggs are also laid on MOIST [$_{\text{Item}}$ ground] ...

- [ITEM They] look[1] a bit SOGGY from all the bogs they've fallen into.
- Keep the icing covered with a DAMP [ITEM cloth] at all times

In general, Frame Semantics has somewhat less to say about frames evoked by nouns, because nouns in general have fewer specific syntactic and semantic slots that can be filled. But the principle of Frame Semantics apply to many nouns, i.e. that understanding them requires a knowledge of the underlying conceptual frame. For example, the noun *hypotenuse* presupposes the concept of right triangles, *divorce* depends upon marriage, and *alimony* upon divorce, etc.[2] These are conceptual dependencies, relations between concepts, not implications in individual instances.

An important example in the development of Frame Semantics has been the **Commercial transaction** frame, a concept which requires the FEs BUYER, SELLER, MONEY and GOODS. (The FE GOODS is understood as including services.) The two main verbs in English for these events, *buy* and *sell*, differ mainly in that *buy* profiles the agency of the BUYER, and *sell*, that of the SELLER. The LUs *buy* and *sell* were originally treated as being in the same frame; now this difference in profiling is regarded as sufficient to split off two frames, with the awkward names **Commerce buy** and **Commerce sell**. Those words which do not have any profiling, such as *commerce, merchandise* and *price*.n are in a more general frame now called **Commerce scenario**.

Frame elements can be divided into core FEs and non-core FEs, based on a combination of semantic and syntactic criteria: core FEs, in addition to being conceptually necessary to the definition of the frame, occur in core syntactic positions. Thus in **Commerce sell**, we can have [SELLER Mila] sold [BUYER Vlad] [GOODS a car], with a double object construction, where SELLER, BUYER, and GOODS are all core FEs. In **Commerce buy**, we would have [BUYER Vlad] bought [GOODS a car] [SELLER from Mila], with BUYER and GOODS as core FEs and SELLER as non-core. If we add the non-core MONEY FE, it would be a PP with *for*, such as [MONEY for $200] in both frames. Syntactically, core FEs tend to be arguments and non-core FEs tend to be adjuncts, but the correspondence is not perfect.

Clearly, there are many varieties of commercial transactions; the price may be fixed in advance or arrived at by extensive bargaining, the GOODS may be a piece of land, so that the transfer is made only on paper, etc. But the **Commerce scenario** embodies the idea that these four roles must exist in any commercial transaction in any society, even though not every sentence that talks about a commercial transaction contains fillers for all four. (Barter, giving, and theft are treated as separate frames.)

Another example of one "unperspectivized" scenario which divides into frames which differ in perspective is the domain of employment, where the FEs include

[1] *Look* is a support verb in this sentence allowing the ITEM FE to be realized as an external argument.

[2] FrameNet currently includes LUs for *marriage* and *divorce*, but not *hypotenuse* or *alimony*.

Table 2: Frames and LUs in the Employment domain

Frame	**Lexical units**
Employment scenario	*employer, employee, job.n, position.n, employment, worker, ...*
Employment begin	(none)
Employment continue	(none)
Employment end	(none)
Employee's scenario	(none)
Get a job	*get a job, hire on, sign up (with), enroll in, enlist in*
Being employed	*work.v, employed.a, working.a, employee, wage earner, ...*
Quitting	*quit, walk off (the job), give notice*
Employer's scenario	(none)
Hiring	*hire, take on*
Employing	*employ*
Firing	*fire, sack.v, give the sack, shed.v, pink slip*

EMPLOYER, EMPLOYEE, and POSITION. The employment process is expressed with verbs (and event nouns) that represent a basic three-stage event structure, with a beginning, a steady continuing state, and an end. The language used from the employee's perspective includes *get a job*, *work* and *quit*; the same three stages can be described from the employer's perspective with *hire*, *employ* and *fire* or *lay off*. Table 2 summarizes the Frames and LUs in this domain. The FEs EMPLOYER and EMPLOYEE are core FEs in all the frames, while other FEs, such as POSITION, TASK and FIELD may be core or non-core in different frames, depending on the point of view. There are nine frames which contain LUs, and four which do not (called non-lexical frames), but are needed to represent the structure of the domain. Most of the vocabulary in the domain is in the "bottom" six frames, as shown in Table 2.

FrameNet uses frame-frame relations to represent the relations between these subevents. There are eight types of frame-frame relations in FrameNet as shown in Table 3, but we will not discuss all of them in detail.

Figure 1 on page 38 shows graphically how frame relations are used to represent the employment domain. In the figure, the lexical frames have shaded backgrounds, while the non-lexical frames have white backgrounds. Four kinds of frame relations are displayed: PERSPECTIVE ON relations from **Employment scenario** to **Employee's scenario** and **Employer's scenario**, and from **Employment start, Employment continue** and **Employment end** to the corresponding frames under the two perspectives. The relations from **Employment scenario** to **Employment start, Employment continue** and **Em-**

Table 3: Some of the frame-to-frame relations in FrameNet

Name	Count	Notes
INHERITANCE	704	ISA relation, all parent FEs have corresponding child FEs, child is subtype of parent
PERSPECTIVE ON	107	Child is a subtype of parent, from the point of view of one of the participants
USING	548	Child is **not** subtype of parent, but some FEs correspond to parent FEs; parent provides "conceptual background"
SUBFRAME	123	Child is a subevent of a complex event
PRECEDES	82	Temporal relation between subevents (subframes) of a complex event
CAUSATIVE OF	55	Most of these frames have names like "Cause to X"; causative adds an AGENT FE
INCHOATIVE OF	16	Many frame with names like "Become X", child frame can be an event or state
SEE ALSO	52	Frames that might be confused; no inferences to be drawn.

ployment end are SUBFRAME relations, giving the stages of the event. Similar relations hold between the two "perspectivized" scenarios and the bottom six frames. The **Employment start, continue** and **end** frames are linked by PRECEDES relations, meaning that they must occur in that order; similar relations link the two bottom groups of three frames in each perspective. Finally, **Getting a job** and **Quitting** INHERIT from the high-level frame **Intentionally act**, but **Being employed** does not; getting up to work each morning is an intentional act, but simply being employed is a state, not an action. There are also INHERITANCE relations on the right side of the diagram, from the **Intentionally affect** frame to **Hiring** and **Firing**. These are not only intentional actions, but a subtype that involves affecting another person. (There is also an INHERITANCE relation from **Intentionally act** to **Intentionally affect**, not shown in the diagram.)

Although PERSPECTIVE ON and SUBFRAME relations have been important in the discussion of the employment domain, in FrameNet as a whole, the INHERITANCE relation is the most important, and in fact, several large inheritance hierarchies connect most of the FrameNet frames. FrameNet has always been "language driven", creating frames as needed to encompass the usage data from the corpus, so there was no intention to build a formal ontology. However, as the work has progressed and the frame hierarchies became more complete, it became evident that most of the frames could be grouped under a few top-level frames: **Event** (with its descendants **Intentionally act** and **Intentionally**

Affect), **Relation**, **State**, **Locale**, and **Process** (which is sometimes regarded as a subtype of **Event**). When new frames are added to FrameNet, they are almost always linked to existing frames by Inheritance and other relations.

3 The FrameNet Project

The FrameNet project was conceived of as a continuation of the line of research begun in the DELIS project (Heid 1994; Emele & Heid 1994), combining the traditional "armchair" analysis of verb valences with modern corpus-based study (cf. (Fillmore 1992)). Several figures from DELIS were heavily involved in the establishment of FrameNet, and continued to function as advisors for several years. The annotation methodology of FN directly implements this combination of approaches, in the context of the theory of Frame Semantics outlined above.

FrameNet grew out of Fillmore's work with lexicographer Sue Atkins (Fillmore & Atkins 1992; Fillmore & Atkins 1994). Their goal was to create the "Dictionary of the Future", unfettered by the limitations of paper dictionaries, informed by corpus linguistics , with a richer representation of semantics/syntax of each word than any existing dictionary.

The FrameNet Project got underway thanks to two NSF grants, IRI #9618838, "Tools for Lexicon Building" (PIs Fillmore and Dan Jurafsky) and ITR/HCI #0086132, "FrameNet ++: An On-Line Lexical Semantic Resource and its Application to Speech and Language Technology" (PIs Fillmore, Jurafsky, Srini Narayanan, and Mark Gawron), which funded frame semantic research at ICSI 1997-2000 and 2000-2003, respectively. Since then, funding has come irregularly from various combinations of NSF, DARPA, and industry.

The initial plan was to choose 10 or 12 domains that would be quite different from each other, to test whether Frame Semantics would be suitable for semantic analysis and annotation in each of them; the initial domains were: Health care, Chance, Perception, Communication, Transaction, Time, Space, Body (parts and functions of the body), Motion, Life stages, Social context, Emotion and Cognition. The basic approach was (1) rather than proceeding word by word, finding all meanings of each, proceed "meaning by meaning" (i.e. frame by frame), deciding what LUs are in each frame, and what FEs are needed to represent the event, relation, state, or type of entity and (2) to combine intuitions about what constitutes a conceptual gestalt with corpus searches for patterns of usage.

Because a major product of the research was to be a lexicon with rich information about the valences of the LUs, it was decied that the annotation would also include the **phrase type (PT)** of the annotated constituent and the **grammatical function (GF)** (a.k.a grammatical relation) that it has in relation to the target LU. The plan was to keep the list of GFs and PTs short, so that the choices for annotators would be as simple as possible. That plan succeeded with regard to the GFs, which are limited to seven types: External (subjects of verbs, and external arguments of nouns and adjectives), Object, Dependent (including all complements and indirect objects), Genitive, Appositive, Quantifier, and Head (for example, when the target LU is an adjective, the noun it modifies is marked as Head). For PTs, the list has grown to 29 types, largely as a result of having to annotate full texts, with some very complex sentences (Sec. 3.5.2).

3.1 Data structures and data formats

The data format used in the first few years of FrameNet (Lowe *et al.* 1997; Baker *et al.* 1998) represented all the annotation on the sentence as text with SGML markup, with the frame element (FE), phrase type (PT) and grammatical function (GF) of each labeled constituent entered as attributes on a general "constituent" element <C>, as in this marked-up version of the sentence *I am conscious that it is a difficult and complex subject*, with the target LU *conscious*:

> <S TPOS="81597120">... <C FE="Cog" PT="NP" GF="Ext">I </C> <C TYPE="SuppV" PT="XFE" GF="XFE">am </C> <C TARGET="y"> conscious </C> <C FE="Cont" PT="Sfin" GF="Comp">that it is a complex and difficult subject</C> . </S>

In choosing a data model for the second phase of FrameNet, the FrameNet team was eager to move away from such a representation, for several reasons:

(a) Storing the data as text with markup meant that searching across the data was slow.

(b) There was no way to represent situations in which the one constituent might contain the fillers of more than one FE, as in ... [$_{\text{Affliction}}$ *Ninham 's condition*] *could be TREATED* [$_{\text{Treatment}}$ *by drugs*], where the **Cure** frame is evoked by the word *treated*, and *Ninham's condition* is the filler of the AFFLICTION FE and *Ninham* of the disease FE. In this case, one would need to have one SGML element within another, which causes problems for much of the software for SGML/XML. Therefore, they were seeking a representation in which the two FEs could overlap on the same stretch of text and the FE, PT and GF labels would be on separate "layers", distinct from each other and from the text itself, i.e. standoff markup, which is now standard in most annotation projects.

(c) Making across-the-board changes (such as renaming a frame element) in hundreds of separate SGML files was tedious and error-prone. Thus, we needed a representation in which the labels of the same type would refer to a single definition of the FE, PT or GF.

This last point suggests the answer which was adopted: a relational database. The chief advantage of a relational database is that data which occurs repeatedly is, so far as possible, entered into the database only once. Each use of that value consists of a pointer to that one entry. Of course, this means that the representation is more indirect, and contents of the database are not directly interpretable. But the advantage of having information such as FE names represented only once in the database far outweighs the inconvenience due to the increased complexity.

Suppose, for example, we initially define the **Cure** frame with three core FEs, HEALER, PATIENT and DISEASE; later we decide that the frame should apply to

Patients with medical conditions that are not strictly speaking diseases, such as hypertension. We would like to rename the FE from DISEASE to AFFLICTION and broaden the definition accordingly. With a relational database, we only need to edit the entry in the FrameElement table, substituting AFFLICTION for DISEASE, and all appearances of the FE name, on screen or in reports, would be changed. The other big advantage of using a real database is that off-the-shelf software will provide much faster access, automatic indexing, and query optimization.

The relational database which holds the FrameNet II data has been designed so that its structure, so far as practical, models the conceptual structure of Frame Semantic. But the data we want to store falls into two quite different groups. On the one hand, there are on the order of one thousand frames and ten thousand frame elements (each specific to a given frame). On the other hand there are more than 190,000 annotations of LUs. Each annotation of an LU includes one or more triples of FE, GF and PT labels (one for each annotated FE), so the tables which contain the annotation data are at least an order of magnitude larger than those containing the frames and FEs. It is therefore convenient to consider the part of the database that represents the frames, FEs, lexical units, etc. separately from the part that contains the sentences and their annotation, even though both are implemented in a single MySQL database. We will refer to these as the "lexical database" and the "annotation database" respectively, and will discuss them separately below.

3.1.1 The Lexical Database

The basic units of Frame Semantics are frames and the frame elements that comprise them. In Fig. 2, this situation is represented by the tables Frame and FrameElement, and the one-to-many relation between them, which indicates that each frame element (FE) is defined with regard to exactly one frame, and that frames are typically associated with more than one frame element.[3] Because FEs are defined relative to frames, FEs in different frames may have identical names, without implying any relation between them. In practice, of course, frame elements are given meaningful names, so it is not entirely accidental that more than 70 frames have FEs with the name AGENT. Nevertheless, one cannot conclude anything from this fact alone; if they are all related by a more general concept of agent, this will have to be stated explicitly, by entering FE-to-FE relations in the database, as will be discussed below.

The terminology in this area varies, so it is essential to define our terms at this point. By word form, we mean one of the forms of a word differing by inflection; by lexeme, we mean the uninflected stem of a set of word forms. Typically, each English noun lexeme is associated with two word forms (singular and plural) and each English verb lexeme with four (e.g. *need, needs, needed, needing*), although irregularities increase these numbers slightly. To handle multiword expressions, we posit a higher level of organization, called the lemma,

[3]For simplicity, IDs, pointers and other internal, automatic attributes have been omitted from the diagram.

composed of one or more lexemes. In the left part of Fig. 2, we see the tables relating lemmas, parts of speech, lexemes, and word forms. As the connectors indicate, each lemma has one part of speech, as does each lexeme. Each lexeme is associated with one or more word forms, but each word form is associated with only one lexeme. (This entails some redundancy in the word form table, such as cases in which a noun and a verb have some word forms in common, but is simpler than carefully maintaining the links that would be required for more parsimonious storage.)

The Lexeme Entry table is needed to represent multiword expressions (MWEs), such as verb+particle (*take off*), N-N compounds (*family practitioner*), and longer constructions (*Martin Luther King Day, have bats in one's belfry, an X's paradise*). For the sake of consistency, all lemmas, even those with only one lexeme, are connected to their lexemes via a record in the Lexeme Entry table. In the case of MWEs, the fields in this table indicate not only the order of the lexemes, but also which lexeme is the lexical head, and whether or not the MWE is separable. For example, the lemma *go broke* is comprised of the two lexemes *go* and *broke*; the first is the head and undergoes the usual inflection for the lexeme *go* while the latter is invariant (**went broken*). Therefore, the first lexeme will be associated with the appropriate five word forms (*go, goes, went, gone, going*), while the second lexeme has only one word form, not related (as least in our database) to the lexeme *break* that has the word forms *break, breaks, broke, breaking, broken*. To give another example, there would be two lexical units in quite different frames containing the lexemes *take off*, one separable (*take your sweater off*) and one inseparable (*the plane took off*). In both of these, the lexeme *take* would be marked as the head of the lemma. In the 'wear' sense, the record in the Lexeme Entry table connecting to the lexeme *off* would also have the field called "Break before?" set to "true", to indicate that light NPs can break the lemma into two parts by being inserted before *off* (*took them off*).

3.1.2 Frames, Lemmas and Lexical Units

Lexical Units (LUs) are defined as an association between a lemma and a frame. Since lemmas are units of form and frames represent meaning, lexical units correspond roughly to dictionary senses. Each LU thus has a link to a single frame and a single lemma. Many lemmas are associated with more than one frame, and thus constitute more than one LU; this is how FrameNet represents polysemy. The meaning of the LU is also expressed in words in the Sense Description field of the LexUnit table. Each LU also has its own Name field, in addition to the name of the lemma, because the same lemma can appear twice in the same frame in different senses. A clear example is the noun *possession* which occurs in two different LUs in the **Possession** frame, one referring to the things possessed (*His possessions were destroyed in the fire.*) and the other to the abstract state of possessing something (*The house came into her possession upon her father's death.*) The names of these two LUs are *possession*.n and *possession of goods*.n respectively.

One or more statuses can be associated with each LU. Some of these are intended to be temporary, used for keeping track of the state of work on each lexical unit; others are intended to tell end users of the FrameNet data the final disposition of the lexical unit. Unfortunately, since the statuses are not generated automatically by the annotation software, but have to be set manually by the annotators, they are not always kept up to date.

3.2 Annotation software

When the project began, there was little in the way of freely available annotation software or NLP system frameworks. The FrameNet team experimented for a while with the Alembic annotation software, made available by Mitre Corporation, but found the input and output incompatible with the kinds of data files they wanted to produce. So they wrote their own web-based system which output the SGML in-line annotation files of the sort described above and used this software for several years.

In 2000, when the project shifted from the in-line SGML to the relational database, it was necessary to build a new annotation system, once again, created entirely in-house. Both the new database and the new annotation system were designed and written from the top down with careful planning and a long period of successive refinements to the system before and after it was put into "production" use.

A client-server model was chosen, with a JBOSS application server (`https://www.jboss.org`) that connected to the MySQL database on the back end, and a thin Java application for the client on the front end. This had the advantage of providing transaction integrity–each time an annotator labeled a piece of a sentence, the label was stored immediately in the database, so that if a session were interrupted for any reason, there would be no garbage left in the database. This assurance came at a price, however, as the JBOSS server had to be running all the time as a separate process in addition to the database itself, and the system overall was rather complex for such a simple basic task–sentences and labels were represented as Java objects in the server, caches had to be synchronized between the client and the server, etc. The decision to write the client as a Java application was largely made on the grounds that the clean intuitive graphical user interface (GUI) that was planned could not easily be written in the HTML available at the time. The trade-off for this benefit was that it was not possible to do annotation through a web interface– all annotation had (and still has) to be done on the ICSI network.[4] This has come to seem like more and more of a limitation as collaborative annotation projects have become more common.

The resulting GUI, like the database structure, corresponds closely to the concepts of Frame Semantics. The interface supports the creation of frames, frame elements, and lexical units, each with an editor tailored to that task. In

[4]Although it is possible to use X-window tunneling to log into this system from elsewhere and run the annotation software on ICSI machines, the performance is usually poor under those conditions.

case the lemma is not already in the database, there is also a lemma editor which allows the user to add a new lemma and its wordforms. The annotation window for each sentence displays a table of all the layers associated with each target LU: the text itself, one layer each for FE, GF, and PT and four additional layers which are used less often and will not be discussed here.

The default view of the database in the annotation tool is organized by frames and lexical units, with an alphabetical list of frames on the left and fold-down lists of LUs in each frame. Within each lexical unit there is a list of FEs and another list of "subcorpora", containing example sentences grouped by syntactic patterns and collocations. A few years after the annotation software went into use, we began a new type of annotation, "full-text" annotation (see Sec. 3.5.2), and the software was modified to make this possible. It turned out to be relatively straightforward to change the left window to display a view of the database organized by corpus and successively smaller units of document, paragraph and sentence. Thanks to the flexibility of the database structure, it is possible to see the same annotation on the same sentence either as one of set of examples of a particular lexical unit or as one annotation within all of those for an entire document.

One other change in the GUI that was necessary for full-text annotation was the ability to select a word-form and see a list of the LUs which it (or rather, its lemma) is part of. The annotator then chooses the appropriate LU, and goes into the sentence annotation editor. The users can also select "new LU" and create a new LU on the spot if needed. A few other minor modifications have been made to the annotation software since then. The user can now control which layers are displayed, and there is a new modification that can read a list of known errors and display only those sentences, for manual correction.

3.2.1 Input and Output of Text and Annotations

The import of text to be annotated and the export of text with annotations is handled outside the GUI, by command-line scripts. At the time that the change to the relational database took place, two project-specific XML formats were defined, one for import of text to be annotated and one for export of text with annotations. In later years, the export format was changed to match the import format, so that a file which had been annotated could be re-imported to add more annotation later. In practice, all the imported sentences are contained in the MySQL database, whether they are completely annotated or not, but this ability to import annotated sentence will be important once automatic semantic role labeling reaches the threshold of being helpful to annotators.

Although the XML format is project-specific, it is valid XML with accompanying XML schemas; the annotation is represented in the XML as labels with indexes to the starting and ending character positions in the text. Each sentence is in a separate element and is accompanied by one **annotation set** for each target LU, containing elements for the annotation layers and labels, to the XML also clearly reflects the conceptual structure of Frame Semantics. In collaborating with the team at the American National Corpus (ANC) on FrameNet annotation of ANC texts, they found that it was straightforward to convert the FrameNet XML into their own data exchange format. (Nancy Ide, p.c.)

3.3 Personnel

Since the FrameNet project has been in operation since 1997, there has obviously been a lot of turnover in personnel. There has usually been a group of about three to six people actively working on the project, including both undergraduates and grad students at UC Berkeley, and often post docs. Despite being housed at the International Computer Science Institute this entire time, most of the participants have stronger backgrounds in Linguistics than in Computer Science, but most have had (or developed while with the project) an interest in all aspects of Computational Linguistics. Some undergrads have trained first as annotators and later made important contributions to Frame Semantic Theory.

There have also usually been at least a few visitors present and many of them have been fully engaged in discussions of both Frame Semantic principles and annotation practices and have contributed important insights in the process. The project has received substantial help from a succession of German post docs funded by the German Academic Exchange program (DAAD) for stays of one to two years, including Jan Scheffczyk, Thomas Schmidt, Birte Lönecker, Katrin Erk, Sebastian Padó, Bernd Bohnet and Alexander Ziem. Further help has come from long-term visitors to ICSI who were working on FrameNets in their own languages (discussed in Sec. 3.12); the developers of Frame Semantics have always tried to consider the cross-linguistic applicability of decisions about the theory, but having native speakers of other languages present for some of the discussions has helped enormously.

3.4 Vanguarding

There is a preliminary stage before annotation, which is called **vanguarding**. This task is to decide where and how new LUs and frames are to be added to FrameNet, by a combination of corpus research and thoughtful judgements based on the one's knowledge as a native speaker of English. We refer to staff members engaged in of defining frames and lexical units and setting the parameters for extraction of example sentences as "vanguarders", and those engaged in marking frame elements on sentences as "annotators", even though many staff members do both sorts of work.

Since FrameNet is small compared with WordNet and some other lexical databases, LUs often need to be added to FrameNet. But, as should be clear from the above discussion of frames, FEs and LUs and frame relations, adding an LU to the FrameNet lexical database is sometimes simple and sometimes not, and adding a new frame requires a thorough understanding of the overall structure and organization of the database.

Consider the simplest case, in which a new lemma, one that is not in FrameNet, is to be added, and the lemma is monosemous (has only one word sense). If the new lemma evokes an existing frame, all that has to be done is to create a new lexical unit in that frame: add the lemma to the frame and give it a brief definition, either created from scratch or by consulting an existing lexical resource.

In a slightly more complicated case, if the lemma is already in FrameNet, but the instance under consideration seems to have a different meaning than the LU already in FrameNet, the vanguarder must consider whether the difference is sufficient to require the lemma to be an LU in a different frame from the current one, and, if so, whether any existing frame is suitable.

Finally, if the lemma clearly does not fit in any existing frame, a new frame will have to be created for it. Creating a new frame almost always means finding where it can be attached to the current frame hierarchy and the appropriate frame-frame relation for doing so. Frames are defined according to several interrelated criteria. All the LUs in a frame should be able to appear with the same set of frame elements– the same number of FEs, with the same semantic constraints. All of the LUs should be defined in relation to the same conceptual gestalt, and be more closely related to that frame than any other. Note that this does not mean that they are all synonyms; for example, in the frames **Judgement, Judgement communication**, and **Judgement direct address**, LUs expressing positive evaluations (*praise, eulogize*) and those expressing negative evaluations (*condemn, disparage*) are in the same frame, as they are defined relative to the same type of situation and take the same set of FEs. From a computational point of view, they will also have a similar distribution across contexts.

3.5 The Annotation Process

FrameNet annotation is basically entirely manual. The only exception is that when the annotator assigns an FE label to a string of text, a small "grammar" method within the annotation software fills in the corresponding GF and PT layers based on a set of rules that look a the POS labels on the text. These grammar rules are usually right, but it is the annotator's responsibility to correct any mistakes in the automatic labels.

Annotation is usually performed either in lexicographic mode or in "full-text" mode. In lexicographic mode, the annotator is working on one lemma in one frame at a time, and the objective is to document the range of syntactic patterns in which a given lemma is used. In full-text annotation, the annotator is working with an entire text, and attempting to annotate each frame-evoking expression, indicating the frame and annotating the fillers of the frame elements. There are usually multiple frame-evoking expressions per sentence, and quite different frames. Each of these modes is explained in more detail below.

3.5.1 Lexicographic annotation

Lexicographic annotation begins after the LU has been added to the database, when the annotator selects example sentences from a corpus. There are actually two different systems for performing this selection, depending on the type of word being searched for and the annotator's preferences. In the Rule-based System, researchers begin by creating a set of rules based on their knowledge of the valence alternations characteristic of the lexical unit. These rules are written inside the annotation software, in simple syntactic patterns which are later translated into the query language used by the search engine. For example, the examples for *staff*.v in the frame **Working a post** were created using two rules "T NP" and "T PP", meaning that the search engine[5] will search the selected corpus for 20 sentences in which some form of the verb *staff* is followed by an NP and also 20 more in which it is followed by a PP, rather than an NP, these being the two patterns which the annotator expected to find, based on a combination of corpus search and intuitive knowledge of the English lexicon. The program will automatically also search for 50 sentences which don't match either of these rules; the annotator will carefully examine these to find any unforeseen syntactic contexts in which this LU can appear.

The rules are saved to a text file, and an external script is run which searches the corpus, writes an input file with the extracted sentences in a project-specific XML format, and imports from that file into the database, forming "subcorpora" listed under the LU in the annotation software, one for each rule executed.

The annotator then looks through the sentences, tries to find a few clear examples of each alternation, and annotates them. For the LU *staff*.v, two of the annotated sentences are:

- T NP: ... [$_{\text{Agent}}$ soldiers] STAFFED [$_{\text{Post}}$ two distribution points for free fuel to residents].
- T PP: But since "[$_{\text{Post}}$ family response units] " STAFFED [$_{\text{Agent}}$ by female officers] were established in some police stations in 2006, ...

This annotation method is optimal for producing a lexicon that human beings can read and understand; since the output is produced in XML, it can also be directly used in a variety of NLP software. However, the frequency distribution of the resulting annotations are is nothing like the distribution they would have in running text. The annotators are instructed to find sentences which are understandable in isolation; this means avoiding examples where the FEs are filled mainly with pronouns (*They staffed it for a month* would tell you nothing about the meaning of *staff*) and examples where the target LU is heavily embedded in a complex sentence. Passive examples are not often annotated, since the passive patterns are generally predictable from active examples.

3.5.2 Full text annotation

In full text annotation, a text is chosen, and the goal is to annotate every frame-evoking expression (both single words and multi-word expressions) that occurs in it. Since FrameNet is concentrating on the core vocabulary of English, the ideal text should not be too specialized; it should be something that most

[5]FrameNet is currently using the command-line tool cqpcl from the IMS Corpus Workbench project, see `http://cwb.sourceforge.net`.

people could read and understand without difficulty. It should also be freely redistributable, since FrameNet has a policy of distributing the text and the annotation together. This requirement greatly limits the available texts; for the most part FrameNet has annotated either texts from the Open American National Corpus (Ide *et al.* 2002) (including a good deal of material from Berlitz travel guides) or government documents of one sort or another, such as web pages from the Nuclear Threat Initiative website (`http://www.nti.org`). The input text is converted to the FrameNet input XML format and POS tagged if it is not already; this process also requires that sentence boundaries and paragraphs be marked, if they are not already, which can be done semi-automatically. The imported document is attached to a corpus name, and a hierarchical structure, of paragraphs and sentences is created in the database.

This does not mean that the FrameNet team undertakes to annotate every word, even in full-text annotation mode. The vast majority of the annotation is on so called "content words", i.e. nouns, verbs, some adjectives and a few adverbs. As will be discussed in Sec. 3.9, FrameNet does not plan to annotate most common nouns that name simple entities, such as *rock, bird* and *kettle*; the problem of recognizing proper nouns (called "named entities" in NLP) is also left for others to resolve. Although FrameNet is trying to add most prepositions to the lexicon, this work is not far enough along to annotate prepositions in full text at this time.[6] The importation process marks the text so that the nouns, verbs, adjective and adverbs are distinguished from the other parts of speech, both to facilitate annotation, and to help in the calculation of the coverage of the text as the annotation progresses.

The full text annotator goes through the document in order; for each frame-evoking expression, he or she can open a drop down menu of existing LUs. This menu is created by a lookup from word form to lexeme to lemma to LU(s). If one of the existing LUs is appropriate for the current example, the annotator selects it, which marks the word as a target and opens an annotation window like that used for lexicographic annotation, with the correct FEs for the frame. If none of the LUs seems appropriate, the annotator can choose "Create new frame", the frame editor will open, and he or she can begin defining the new frame and its FEs, working just like a regular vanguarder. The newly defined frame is available immediately to annotate the sentence, but it is also necessary to think about what other LUs belong in that frame as part of the frame creation process, and to specify its relation to other existing frames.

As more LUs are annotated in a sentence, the many layers attached to it become somewhat hard to view in the annotation tool. The annotation of each LU is not a problem, but it is difficult to get a sense of the way the annotations go together in the software. The web-based display of full text, however, does a good job of showing the overall structure of a multiply annotated sentence. The top part of the window shows the text, with frame-evoking words underlined. Clicking on one of them adds a copy of the sentence to the lower

[6]There is also some question as to whether most users of Framenet data would consider annotations which specify the senses of prepositions useful, although this seems to be necessary for reasoning about texts in depth.

part of the window with the annotations for that LU displayed. This functionality is very difficult to explain in print, but there are many examples on the FrameNet public website; some clear examples can be seen by visiting the full text index (`https://framenet.icsi.berkeley.edu/fndrupal/index.php?q=fulltextIndex`) and choosing American National Corpus Texts/Berlitz History of Greece.

3.6 Development of Frame Semantic Theory Stemming from Annotation

Frame relations: One of the most surprising parts of the work on FrameNet has been the extent to which Fillmore's early theoretical work provides answers to many of the questions that arise in the process of adding frames and doing annotation. From very early on, Frame Semantics presupposed a hierarchy of frames, with some frames as subtypes of others, which means that, in turn, many of the frame elements of the child frame are equivalent to, or proper subtypes of, the frame elements of the parent frame. In the course of the project, these principles were made more precise, and a total of eight types of frame-to-frame relation were defined, including the idea that some frames were related by Perspective on relations, and that this would be tied to differences in the profiling of similar sets of FEs as discussed in Sec. 2.

The addition of these types of frame relations and their accompanying FE relations have made possible the partial representation of complex events, such the stages of a criminal process, including the frames **Arrest, Arraignment, Trial**, and **Sentencing**, with Subframe and Precedes relations between them, as shown in Fig. 4, where the straight, blue dashed arrows represent the Subframe relation, and the curved, black arrows represent the Precedes relation, giving the temporal order of the stages.

This ability to model complex events as a set of frames linked together by Subframe and Precedes relations is still limited, however; there is no way to indicate, for example, that one event is repeated many times and that repetition constitutes another type of event, possibly in a different frame; examples are the relation between *step*.v and *walk*.v, *talk*.v (or *speak*.v) and *chatter*.v or *verbose*.a. There is also no way in FrameNet to represent situations in which an event may have different successor events, or an event only becomes possible if certain resources are available, or an event can be interrupted and resumed, such as the Trial phase of the criminal process, which can be (and often are) postponed or adjourned, and then resumed. Representing such connections requires a richer representation; to this end, the FrameNet team have begun working with the X-net formalism (Narayanan 1999; Sinha & Narayanan 2005), which can represent all these phenomena.

Null instantiation: Relatively early in the development of FN, the staff came to the realization that it would not be sufficient to annotate only the FEs that appear in the sentence—at least in some cases, it would be necessary to annotate FEs which do **not** appear in it. Because the basic concept of a frame is that all instances of it have the same number and type (broadly speaking) of roles (FEs), this is considered to be true even in cases where one or more of the FEs is not expressed. Aside from the virtue of general consistency, this also allows many uses traditionally counted as "intransitive" to be included in the basic transitive frame. For example, the sentence *Perhaps she should have paid by check*, is an instance of the **Commerce pay** frame in which we can be sure that *she* is the BUYER but we have no information about what goods (or services) were bought, or from whom, or for how much. In FrameNet terminology, the FEs GOODS, SELLER and MONEY are all "null instantiated". In this case, we assume that the hearer would have to know what GOODS were being purchased; we call such cases Definite Null Instantiation (DNI). For this to be a commercial transaction, we assume that some SELLER and some MONEY were also involved, but since it is not clear that the hearer must know what they are, they are annotated as Indefinite Null Instantiation (INI). In cases where a grammatical construction allows the omission of an FE, such as omission of the agent subject with passives, we mark Constructional Null Instantiation (CNI).

In the above example, *by check* is also annotated as the FE MEANS in the **Commerce pay** frame. Clearly, if money is to be transferred, it has to be in the form of cash, check, use of a credit card, etc., but the means of payment is not central to the frame to the same degree as are the BUYER, SELLER, GOODS, and MONEY. As discussed above (Sec. 2), these four FEs are classified as "core" FEs of the **Commerce pay** frame; when they are not expressed, this is indicated by NI annotations. Other FEs in the frame which occur frequently but are not considered core FEs include MEANS (*in cash*), Manner (*promptly*), Time (*yesterday*), and Frequency (*every Friday*); these are called Peripheral frame elements. They may be logically entailed (every payment must occur at some place and time) but they are not as conceptually central to the frame definition or as syntactically privileged as the core FEs.

FE relations within frames: To make matters a little more complicated, FrameNet recognizes certain relations among the FEs within a frame. In **Commerce pay**, for example, the MONEY may be expressed either as a single sum (*paid $60 for the dress*) or as a rate (*pay $50 a month for a gym membership*). MONEY and RATE are both core FEs of this frame, but they are also marked as being in a "core set" together; this indicates that they are alternative ways of expressing similar notions. FrameNet keeps both of them as core FEs, but if one appears in a sentence, the other in not marked as null instantiated, since the sentence is effectively complete if either appears.

Extrathematic FEs: It is also important to recognize that some aspects of FN annotation do not correspond directly to Frame Semantic theory; some are shortcuts, or promisory notes for future work. For example, in addition to the core and peripheral frame elements mentioned above, annotators sometimes encounter elements of the sentence they are working on which are, properly speaking, licensed by another frame. For example, many intentional actions have intended beneficiaries, as in *Raúl baked a cake for Alicia*, where *baked* evokes the **Cooking creation** frame, with *Raúl* as the COOK and *cake* as the PRODUCED FOOD. *Alicia* is not, strictly speaking, part of that process, but it is clear from the sentence that she is the intended recipient of the cake. One could annotate the sentence again in the **Conferring benefit** frame, marking *Raúl* as the BENEFACTOR, *for Alicia* as the *Beneficiary*, and *a cake* as the BENEFICIAL SITUATION, which would formally represent the entire situation. FrameNet practice, however, has been to add some of the most frequent non-core frame element to the main frame of the sentence to allow this relation to be annotated without bringing in another frame. Such FEs are called **extrathematic** FEs, because they do not actually represent a thematic role of the predicator. In this example, the **Cooking creation** frame has an extrathematic FE RECIPIENT, which can be used to annotate *for Alicia*.

Agentive nouns as LUs: Another departure from orthodox Frame Semantics is that FrameNet includes some agentive nouns in frames denoting events. Frames for events properly include event nouns as well as verbs; the **Cooking creation** frame could include the nouns *baking*, *cooking*, and *preparation* along with the verbs *bake, cook* and *prepare* since they are regular alternatives for describing the same situation, e.g. *It took Eva 30 minutes to prepare the salad* vs. *Eva's preparation of the salad took 30 minutes*.The noun *cook* does not denote an event, so strictly speaking it should be in a different frame for entities, specifically, for people filling the agentive role in the **Cooking creation** frame, along with *chef* and perhaps *preparer*. Instead *cook*.n has been included in the **Cooking creation** frame, so that a phrase like *pastry cook* evokes that frame, with *pastry* filling the PRODUCED FOOD role. Such nouns are marked with a semantic type "Agentive noun" to indicate this special status. (FrameNet semantic types will be discussed in Sec. 3.9).

3.7 Quality control and Data integrity checking

Because the FrameNet team has been relatively small but work has continued over a long time, and because the annotation process is relatively expensive, it has been difficult to set up the usual studies of inter-annotator agreement. Which measure(s) of agreement to use for FE annotation is also a question, since the possible labels are different for each frame. Nevertheless, a study of inter-annotator agreement was performed in 2005, with a modification of Cohen's kappa statistic (Siegel 1956) to allow for variable numbers of responses per item. The average kappa across all pairs of annotators was 0.65, and two pairs of the more experienced annotators had kappas of 0.82 and 0.86; these levels of agreement are generally considered adequate and very good, respectively.

Likewise, because the annotation team has usually been small and the development of frames is relatively complex, FrameNet has an annotation process that, in some cases, involves a great deal of consultation and discussion until a consensus is reached on how to handle specific annotation problems, rather than a formal system of multiple annotation and adjudication. The addition of an LU to a frame can lead to the addition of new frames and conversely: when an LU is added to a frame, the process of annotating examples of the new LU often demonstrates that the LU is polysemous, which sometimes means that a new frame is needed for the other sense(s). The addition of a new frame means a careful search for all the lemmas that have LUs in that frame, some of which may be polysemous, and so on. Being sure that the new frames are connected to the existing hierarchy by the correct frame-to-frame relations requires a good knowledge of the overall structure of the graph. In the worst case, the creation of a new frame requires that an existing frame be split, with some of its LUs being moved to the new frame. There is software specifically to enable this process, but it is still difficult, and to be avoided unless necessary, in part because it is confusing for users of the FrameNet data when the divisions of frames change from one data release to the next.[7]

Since the annotators mark spans of text and choose labels manually, with few constraints built into the annotation tools, errors inevitably occur in the process. In addition to manual procedures, FrameNet has developed a variety of software to ensure the integrity, consistency, and completeness of the data. As discussed in Sec. 3.1, the lexical database and the annotation database are quite different, so they require different types of integrity checking. The lexical database needs to be consistent with the principles of Frame Semantics, the definitions need to be clear, and they need to include examples. A visiting post doc. on the German DAAD program, Jan Scheffczyk, created what is essentially an expert system by reading the FrameNet documentations and interviewing FrameNet staff members about what is required and what is desirable w.r.t. the lexical database. He then wrote a Haskell program that checks every item against a set of rules developed from this process. The rules range from theoretical requirements, such as “Every frame must have at least one frame element” and “Every frame element must be attached to exactly one frame”, to desiderata that are not strictly required, such as “There should be at least one annotated example of each FE in each frame” and “Each frame definition should contain one example sentence”. The rules are ranked according to the seriousness of the violation, and the system can be run against the database to produce a human-readable report, listing violations of the rules in decreasing order of severity. Since the lexical database is relatively small and it is crucial that it be theoretically sound, the FrameNet team reviews these kinds of violations regularly and fixes them.

A different approach is needed for checking the annotation database. The size of the annotation database makes checking for all possible problems in one pass impractical, and the variety of language structures encountered and annotated make it hard to develop rules for what has to be included in a properly annotated sentence. Instead, the team has written a suit of scripts that run over the annotation database and check for low-level errors according to basic consistency criteria: every annotation set that contains an FE layer should have all the other standard layers (GF, PT, Target, etc.), for each FE label there should be coterminous labels on the GF and PT layers, for each sentence with an FE label, there should be a target annotated in the same frame, there can only be one instance of an FE in an annotation set[8], etc. These checking programs can be run automatically, and the results reported in a way that facilitates

[7] See Petruck *et al.* (2004) for more detailed discussion.

[8] There is one exception to this: the Path FE can be instantiated more than once in **Motion**-related frames.

POS	WordNet	FrameNet
Noun	146,312	5,177
Verb	25,047	4,879
Adjective	30,002	2,270
Adverb	5,580	(other) 387
Totals	206,941	12,713

Table 4: WordNet vs. FrameNet: numbers of word senses

correcting the errors.

3.8 Relationship to WordNet

WordNet (Fellbaum 1998), `http://wordnet.princeton.edu` is the largest human-curated lexicon of English, and is thus the natural standard against which other lexica are compared. If we look at the number of word senses of each part of speech in the two resources, shown in Table 4, it is clear that WordNet is in a different league from FrameNet.

The structures of the two resources are also completely different. WordNet is divided into synonym sets ("synsets"), comprised of a number of words of these same part of speech which are partially interchangeable in certain circumstances. Each synset is accompanied by a "gloss", a definition which is supposed to cover all of the words in the set, and (usually) a few example sentences. Thus, a word sense in WordNet is an association between a lemma and a synset.

The synsets are organized into hierarchies, with various types of relations between them, such as hypernymy and hyponymy (equivalent to subtype, ISA), part-whole relations, and entailment, with one hierarchy for each part of speech (nouns, verbs, adjectives, and adverbs). There is also a limited amount of linking between these hierarchies based on morphological relatedness, such as between verbs and corresponding event nouns. WordNet is associated with a 360k-word sense-tagged corpus, and a version of WordNet is available in which every noun or verb in every gloss is marked for which WordNet sense it has, a sort of "transitive closure" of WordNet, called the Princeton WordNet Gloss Corpus (`http://wordnet.princeton.edu/glosstag.shtml`).

In the early development of FrameNet, it was expected that many FrameNet frames could be created by simply taking one synset and inserting all the lemmas as the LUs of the frame. This strategy did not work out as had been hoped; it is in fact quite rare for the LUs in a frame and the lemmas in a synset to correspond exactly. Some synsets are narrower than frames, such as the **Judgement communication** frame which contains both *praise* and *denigrate*, antonyms which fall into separate synsets for that reason. On the other hand, consider the following WN synset:

> order, tell, enjoin, say (give instructions to or direct somebody to do

something with authority) "I said to him to go home"; "She ordered him to do the shopping"; "The mother told the child to get dressed"

FrameNet has a **Request** frame which has *order* and *tell* among its LUs, but not *say*; *enjoin* is not in Framenet, but *say* appears in four frames, none of which imply giving instructions. There probably should be a sense of *say* in the **Request** frame, but it seems only to occur with a *for*... *to* complement (*Mom said for you to come home*); the example *I said to him to go home* is unlikely to occur, given the availability of *I told him to go home*. It is not clear why *command*.v is in the FrameNet frame but not in the WordNet synset.

What seems more productive, and in fact has provoked a lot of research, is to align FrameNet LUs with WN word senses. Many alignment methods have been proposed: Burchardt *et al.* (2005) wrote an interactive script for users to find the correct FN frame for ambiguous lemmas by choosing WN senses. Chow & Webster (2006) produced an WN-FN alignment by linking both with SUMO. Tonelli & Pianta (2009) aligned the resources by mapping between FN frame definitions and WN synset glosses. Ferrández *et al.* (2010) used the structure of the two resources, based on comparing bags of words, but over neighborhoods of frames and synsets. Bryl *et al.* (2012) "enrich FrameNet by mapping the lexical fillers of semantic roles to WordNet using a Wikipedia-based detour". Finally, the UBY project (Gurevych *et al.* 2012) links FrameNet, WordNet, and a number of other lexical resources into a common database.

3.9 The Limits of FrameNet

The theory of Frame semantics aims to cover a lot of ground, and FrameNet has been able to implement much of the theory. One obvious limitation is its size, since it only includes a small part of the English lexicon; in principle, given more time and more funding, FrameNet could expand and become more adequate in this regard. Some of the other limitations, however, are due to decisions made by the FrameNet team as to what is to be covered and what is left to others to work on. This section will discuss eight such limitations:

1. Most common nouns
2. Technical terms
3. Proper Nouns (a.k.a Named Entities)
4. Lexical relations
5. Negation and Conditionals
6. Using frames as definitions of possible fillers/semantic types
7. Metaphor
8. Implications as frame relations

Common nouns: For the most part, FrameNet does not deal with common nouns because they simply do not evoke a rich frame structure, or take FEs related to a usefully specific frame. FrameNet does contain some examples of common nouns in frames such as **Accoutrements** (*anklet.n, armband.n, armlet.n, badge.n, balaclava.n, bandanna.n, bangle.n, belt.n, beret.n, biretta.n, boater.n, bonnet.n, bowler.n, bracelet.n, brooch.n, cap.n*, ...) and **Natural features** (*archipelago.n, atoll.n, bar.n, bay.n, bayou.n, beach.n, beck.n, berg.n, brook.n, burn.n, butte.n, canyon.n, cascade.n, cataract.n, cave.n, cavern.n, cay.n, channel.n, cirque.n, cliff.n, clough.n, coastal.a, continent.n, continental.a*,, ...). These frames have FEs that resemble the qualia structures discussed in Pustejovsky 1995; for example **Natural features**, in addition to the core FE LOCALE, which is denoted by the noun itself, has non-core FEs such as CONSTITUENT PARTS, FORMATIONAL CAUSE, which resemble Pustejovsky's formal, constituative, and agentive qualia, respectively. They are included in Framenet in part because, besides these FEs, they have other useful frame-specific FEs: for example the **Natural Features** frame also includes non-core FEs CONTAINER POSSESSOR, NAME and RELATIVE LOCATION, as in *... into the* [$_{\text{NAME}}$ *Altai*] [$_{\text{LOCALE}}$ *MOUNTAINS*] [$_{\text{CONTAINER POSSESSOR}}$ *of Mongolia*].

The other common nouns in FrameNet are usually those denoting events and relations, such as *marriage* and *kinship*, or agentive nouns in event frames, such as *leader* and *lecturer*; in general, these frames also contain verbs and adjectives, such as *wed*.v, *head*.v and *teach*.v. Furthermore, common nouns are the largest part of WordNet and other machine-readable dictionaries; those noun hierarchies seem adequate for most NLP purposes, and their coverage is much larger than FrameNet can hope to equal using present methodology.

Lexical relations: Although FrameNet is a lexicon, it does not contain any relations between LUs, except those implicit from frame relations, which are sometimes too general. For example, the frame **Cause to be wet**, with LUs *dampen.v, douse.v, drench.v, humidify.v, hydrate.v, moisten.v, moisturize.v, saturate.v, soak.v, sop.v, souse.v,* and *wet.v*, has a **Causative of** relation to the frame **Being wet**, containing *clammy.a, damp.a, dewy.a, drenched.a, humid.a, moist.a, moistened.a, saturated.a, soaked.a, soaking.a, sodden.a, soggy.a, sopping.a, sweaty.a, waterlogged.a, wet.a*. Obviously, performing one of the actions from the first frame produces the states described in the second frame, but not every pairing is felicitous: *The rain drenched us and left us sopping/soaked/?moist/*humid/*hydrated*. If FrameNet included lexical relations, there would be a way to represent the specific facts relating certain pairs or sets of words: *moisten/dampen* → *moist/damp*, *humidify* → *humid*, etc. Of course, WordNet and other on-line resources contain large numbers of lexical relations; although they may not cover all the pairs in the corresponding FrameNet frames, it was decided that FrameNet would not attempt to duplicate this information.

Technical terms and Proper Nouns: FrameNet has taken as its mandate to cover the "core" lexicon of English, comprised of words in common use, whose definitions are established by their usage. As has been known since Zipf (1949[1965]), the number of senses per word increases with the frequency of occurrence, so the most frequent words are likely to be the most polysemous and therefore both the most important and the most challenging for NLP. In general, the FrameNet team have assumed that technical vocabulary, whose definitions are established by domain experts, will be handled in terminologies collected for each domain, from major resources such as the Medical Subject Headings of the U.S. National Library of Medicine (`https://www.nlm.nih.gov/mesh/meshhome.html`) and the Department of Defense Dictionary of Military Terms (`http://www.dtic.mil/doctrine/dod_dictionary/`), to smaller, more specialized resources such as the Digital Dictionary of Buddhism (`http://www.buddhism-dict.net/ddb`) and the Encyclopedia of Insects (`http://www.sciencedirect.com/science/book/9780123741448`). Of course, some of these terms are not solely technical: for example, legal dictionaries have definitions of *contract*.n and *fine*.n/v but there is also a lay understanding of these concepts that partially overlaps; likewise, military lexica give definitions of *group*.n and *force*.n that are narrower versions of much more general and common terms. The common uses of these lemmas are certainly within FrameNet's sphere.

For similar reasons, FrameNet does not annotate proper nouns, also known in NLP as named entities.[9] FrameNet cannot and has no reason to compete with the on-line resources for these domains, such as Wikipedia, lists of male and female personal names, and gazetteers. When doing full-text annotation, named entity recognition (NER) has already taken place, and we treat the NER labels on nouns as a sort of automatic frame labeling, where the "frames" are concepts such as a geographical place, a human being, etc. Some of these labels could be treated as additions to or subtypes of FrameNet frames such as **Locale by use** (LUs *campus, canal, factory, pub, settlement*) and **Natural features** (*bay, canyon, brook, peninsula*).

Negation and Conditionals: FrameNet does not have representations for negation and conditional sentences. Regarding negation, FrameNet does not include the words *no* and *not*; the words *never*.adv and *seldom*.adv are LUs in the **Frequency** frame, but there is no recognition of their status as negatives. The general approach which the FrameNet team has proposed would be to treat negative expressions as parts of constructs licensed by constructions which have a "negation" frame as their meaning pole, and license negative polarity items over some scope in the sentence. Defining that scope is a notoriously difficult problem which FN does not deal with currently; in general, we would look for a combination of syntactic and semantic factors to define the scope, rather than purely syntactic means. We are just beginning to work on the related problem of conditional sentences, which also involves setting up two or more mental spaces, as in other cognitive linguists' treatments, such as Dancygier & Sweetser 2005. and Sweetser 2006. FrameNet does not include the word *if*, but does include both LUs and annotation for a number of modal verbs and other types of nouns and adjective which can be used to express conditionality, incuding the following:

[9] We leave aside, for purposes of this discussion, the "extended" type of NER, which recognizes categories of common nouns, such as types of weapons or vehicles.

Frame	: **LUs**
Possibility:	*can, could, might, may*
Capability:	*able*.a, *ability*.n, *can*.v, *potential*.n/a, ...
Likelihood:	*likely*.a, *might*.v, *may*.v, *must*.v, *possible*.a, ...

Metaphor: Since a metaphor is a mapping from a source domain to a target, it might seem that the logical way to represent this would be a frame-to-frame relation. In practice, however, it is rare for all of the LUs in one frame to have a corresponding metaphorical use in another frame, so a frame relation may not be the right way to model this phenomenon. What FrameNet does instead, is to annotate metaphorical uses of a lemma in one frame or the other. The decision as to whether to annotate in the source or the target frame is basically lexicographic, depending on whether the metaphor is more "productive" or more lexicalized. There are a number of criteria involved in this judgement, including the extent to which a group of near-synonyms are mapped from frame to frame, the mapping of FEs from frame to frame, and the extent to which speakers are supposed to be conscious of the source domain while interpreting the lemma in the target domain. When a metaphorical use is lexicalized, it is treated like any other LU in the target frame, and there is no reference to the source frame. When annotated in the source frame, the annotator is supposed to mark the annotation set with a "metaphor" label, but there is no reference to the target frame. Some examples of sentences that have been marked in this way are:

Filling.*pack*.v	: His lectures were above all popular because he packed them with information.
Emptying.*purge*.v:	To purge themselves of earthly desires–that was all they were worried about.
Placing.*place*.v	: Which is why I'm placing Marshal Tolonen in charge.
Motion.*slide*.v	: ...make sure [the economy] doesn't slide into recession again.

For further explanation of this policy, see Ruppenhofer *et al.* 2006. The FrameNet project is currently working in close collaboration with the MetaNet project at ICSI `http://metanet.icsi.berkeley.edu`, and it is possible that a more complete representation of metaphors will be available in FrameNet soon.

Inference: FrameNet does not have a frame relation that directly supports inference, although this has been proposed for some time. In fact, certain kinds of inference are possible from the usual FrameNet annotation. For example, in addition to the FEs named CAUSE in many frames, causes of events are often inferrable from the annotation of the FE REASON, e.g. in the **Firing** frame, in the sentence When [$_{\text{EMPLOYER}}$ he] FIRES [$_{\text{EMPLOYEE}}$ Craig Norman] [$_{\text{REASON}}$ for incompetent management], ..., one can infer that Craig Norman was (or at least was believed to be) an incompetent manager and that this was the cause of his being fired. In the **Cause temperature change** frame, one finds both the FEs CAUSE and RESULT, so that in the sentence [$_{\text{CAUSE}}$ The Sun] itself is destructive, HEATING [$_{\text{ITEM}}$ the rocks] [$_{\text{TIME}}$ by day] [$_{\text{RESULT}}$ so they expand], ..., we are given both the cause and the result of the heating; this situation is common in all the frames with a causal relation (i.e. **Causative of**) to another frame.

There has been a lively interest in using FrameNet for text-based reasoning, e.g. Scheffczyk *et al.* 2010, and it has been tested on the Textual Entailment task (Burchardt *et al.* 2009), where it produced a small but measurable improvement in results. Interestingly, the major problem with using FrameNet for inference in the RTE task was not the limited coverage of FrameNet, but parsing errors. A number of people have tried to derive an axiomatic system from FrameNet, notably (Ovchinnikova *et al.* 2011), who suggested adding formal representations of implications to FrameNet.

Frames as semantic types:

FrameNet has a small hierarchy of semantic types which can be marked on Frames, FEs and LUs. As with most parts of FrameNet, we postulate only what seems necessary to explain the linguistic facts. We will discuss here only those semantic types which are most relevant to understanding FN annotation.

The true "ontological" semantic types in FrameNet are similar to nodes in other ontologies, but limited to those which are linguistically important; for example, most agent FEs (not only those called "Agent", but all those descended from the AGENT FE in the high-level frame **Intentionally act**) have the semantic type SENTIENT. Some of the ontological semantic types such as POSITIVE JUDGEMENT and NEGATIVE JUDGEMENT add information to LUs, often crosscutting the frame hierarchy; this pair is used to separate the LUs in the frames **Judgement, Judgement communication** and **Judgement direct address** into those with positive or negative affect.

There are two semantic types used only on frames: NON-LEXICAL FRAME, which marks frames which have no LUs, and NON-PERSPECTIVALIZED FRAME, which marks frames which do not have a clear perspective on a scenario and therefore may have a collection of FEs that are not consistent. The non-lexical frames are postulated as needed to fill gaps in the frame hierarchy, as with **Employee's scenario** and **Employer's scenario**; the non-perspectivalized frames are broad frames with a variety of lexical units, which do not have a consistent point of view.

Finally, there are semantic types used only on LUs, such as TRANSPARENT NOUN, used to mark nouns such as those in boldface in these sentences:

1. A **number** of students were already sitting in the classroom.

2. This **type** of ski is not suitable for cross-country skiing.

3. A **flock** of geese were feeding by the lake.

Although these nouns do add to the semantics of the sentence, they are "transparent" to the selectional preferences of the predicator: the students are sitting, not the number, the ski is unsuitable, not the type, the geese were feeding, not the flock. The semantic type AGENTIVE NOUN was already discussed above.

One extension of FrameNet that is clearly needed would be a straightforward way to indicate that the fillers of an FE in frame A should be members of frame B (or members of frames descended from B). This would enable very precise, extensional definition of what the semantics of the fillers of a particular role are. FrameNet has hitherto avoided this alternative, because of the possibility of a recursive loop in the graph, but it is otherwise attractive on theoretical grounds.

3.10 Extensions and Applications

3.10.1 Automatic Semantic Role Labeling (ASRL)

One of the frequent questions to FrameNet staff is "Why don't you just use machine learning to do the frame discrimination and role (FE) labeling automatically?" Indeed, this is something like the holy grail of the semantic role approach, but it has proved rather elusive, although it has been improving steadily.

The idea began with the seminal papers by Dan Gildea and Dan Jurafsky (Gildea & Jurafsky 2000; Gildea & Jurafsky 2002); in order to make the FE labeling task tractable, they assumed that the sentences were frame disambiguated. Over the next several years there were a number of studies on ASRL for both PropBank (See 3.12.2) and FrameNet annotation using a great variety of machine learning techniques. At least three of these ASRL systems were made freely available by their creators: The first was called SHALMANESER (Erk & Padó 2006), created by Katrin Erk and Sebastian Padó, who were working together on the SALSA Project at Saarbrücken. The second was by Richard Johansson and Pierre Nugues, who worked both on English and Swedish (Johansson & Nugues 2006; Johansson & Nugues 2007).

The third is called SEMAPHOR, created by Dipanjan Das and other members of Noah A. Smith's lab at CMU, which is, as far as we know, the current state of the art (Das *et al.* 2010; Das & Smith 2011; Das *et al.* 2013). Their latest system handles unseen predicates, in a kind of semi-supervised lexicon expansion in part by using WN relations combined with latent variables; this is continuing work by Das, Nathan Schneider, Desai Chen and other members of the lab.

There is a chicken-and-egg problem here: even though there are almost 200,000 annotation sets in the FrameNet data, there are only about 20 annotations per LU, not enough to train accurate automatic annotation. Because the automatic annotation is not accurate enough, it is not helpful to incorporate it into the manual annotation process, since correcting the incorrect items takes as long or longer than annotating them from scratch, at least for experienced annotators. (Palmer *et al.* 2010)

3.10.2 "Crowd sourcing" FrameNet Annotation

Another frequent question to FrameNet staff is "Why don't you crowdsource the annotation process'?", with the assumption that it can be made faster, cheaper and just as accurate, as has been demonstrated for a number of other linguistic data collection tasks. FrameNet staff have run some preliminary experiments in this direction, and are in the midst of further testing in collaboration with colleagues at Google. Thus far, it seems that the decision as to which frame applies to a particular instance of an ambiguous lemma ("frame discrimination") is a task which can effectively be crowdsourced. It is not yet clear how or whether marking the FEs can also be crowdsourced; tests so far show that untrained workers have difficulty finding the correct boundaries of the fillers.

3.11 Users and data releases

The FrameNet data has gone through five releases over the years, and has been downloaded by thousands of users around the world; the largest concentrations of downloads are in the U.S., China, India, Germany and the U.K. Each request to download includes some statement about the intended use, and theseare incredibly varied. Some recent examples are: as a resource for dialog understanding, for sentiment analysis of blogs, for classification of legal documents, for teaching lexical semantics, and as an example of an ontology for a computer science term project. A list of users (at least those willing to have their names displayed) and their intended uses is posted on the FrameNet website.

In addition to those who request copies of the data release through the FrameNet website, some of the FrameNet annotation is being released as part of the MASC subcorpus of the ANC, described [CROSS REF elsewhere in this volume]. A Python API has also been developed for the FN data, which is being released as part of the current version of the Natural Language Toolkit (Loper & Bird 2002, `http://www.nltk.org`).

3.12 FrameNets in Other Languages

On encountering the FrameNet project, speakers of other languages often say that they would like to create a similar resource for their language. In many cases, as they learn more about the time and effort required, they give up on this idea, but a number of projects for FrameNet-like lexical resources for other languages have been or are being developed. Table 3.12 on the next page gives the names and URLs of some of these efforts; all of those listed in this table have received substantial funding, primarily from their national or provincial governments.

Several groups in Italy have undertaken work on FrameNet-like resources using a variety of methods. A group of researchers at University of Trento and the Fondazione Bruno Kessler have worked on topics including FrameNet ASRL (Giuglea & Moschitti 2006; Coppola *et al.* 2009; Coppola & Moschitti 2010), adding LUs automatically from WordNet synsets (Tonelli & Pianta 2009) (cf. Sec. 3.8), creating FNs in other languages by projection (Tonelli 2010), and crowdsourcing FN annotation (Fossati *et al.* 2013). At University of Pisa, Alessandro Lenci and colleagues have worked on combining distributional semantic information with manual corpus analysis to build an Italian Framenet

Language	Website
Spanish FN (Subirats 2009)	`http://sfn.uab.es`
German (SALSA) (Erk *et al.* 2003)	`www.coli.uni-saarland.de/projects/salsa`
Japanese FN (Ohara 2012)	`http://fn.st.hc.keio.ac.jp`
Chinese FN	115.24.12.8:8080/cfn
Swedish FN++ (Borin *et al.* 2010)	`http://spraakbanken.gu.se/eng/swefn`
FN Brasil	`http://www.framenetbr.ufjf.br`
French FN	`https://sites.google.com/site/anrasfalda`

Table 5: Some FrameNets in other languages

(Lenci *et al.* 2010). At University of Rome Tor Vergata, there is research on creating an Italian FrameNet by cross-lingual alignment of FameNet annotation (Annesi & Basili 2010).

There have also been efforts to build FrameNet-style lexical resources for Polish (`http://www.ramki.uw.edu.pl/en/`), Slovenian (Može 2009), Hebrew (`http://www.icsi.berkeley.edu/pubs/ai/HFN.pdf`), Bulgarian (Koeva 2010), and other languages, but these do not seem to be as far along as those listed above. A new initiative for Arabic has just begun in the UAE.

The general experience of most of these projects has been that the frames created for English by the ICSI team are also applicable to other languages, i.e., the frame definition and the set of FEs created for a frame in English are at least adequate to represent a similar conceptual gestalt shared by speakers of the target language, so the appropriate target language LUs can be added to the frame in the target language. Of course, some frames will be more similar across cultures than others: as noted in Sec. 2, we expect that the basic **Commerce scenario**, with the FEs BUYER, SELLER, MONEY and GOODS, will be the same across all languages and cultures; conversely, we expect that frames for domains such as religious beliefs, legal systems, and literary styles will differ substantially across languages and cultures.

There are basically two approaches to creating a new FrameNet in another language, manual and automatic. In the manual approach, vanguarders define frames and add LUs for them and annotators manually annotate either full texts or lexicographic examples, as in the work at ICSI; such an approach has been followed in Spanish FN, Japanese FN, FrameNet Brasil, and (in part) in the SALSA project for German. In the automatic approach, a lexicon and annotated texts in the target language are produced either by machine translation from the English FN data or by alignment of bilingual dictionaries (e.g. Chen & Fung (2004),) and bilingual corpora (Padó 2007; Annesi & Basili 2010). The Swedish FrameNet++ project is the best current example of this approach; they are working with a large, pre-existing Swedish lexical database and aligning the LUs and grouping into frames largely automatically. For further discussion of the theory of cross-linguistic frame transfer, see Lönneker-Rodman & Baker (2009); Boas (2009) has articles about the experiences of several of the FrameNet projects mentioned here.

3.12.1 FrameNets for Specific domains

Several projects for frame semantic analysis of specific domains deserve mention here.

Kictionary: FrameNet visitor Thomas Schmidt from Germany created and launched the Kicktionary, a domain-specific trilingual (English, German, and French) lexical resource of the language of soccer. Kictionary is based on Frame Semantics and uses WordNet style semantic relations as an additional layer of structure. The lexicon contains around 2,000 lexical units organized in 104 frames and 16 scenarios. Each LU is illustrated by a number of examples from a multilingual corpus of soccer match reports. The Kictionary is available on the web at `http://www.kicktionary.de`[10]

Legal Domain FrameNets: Two recent projects have worked on describing the frame semantics of the legal domain, one for Italian (Venturi *et al.* 2009), and one for Portuguese (Bertoldi & Oliveira Chishman 2012); both used the English FrameNet **Criminal process** frame as a starting point, modified and expanded it for the target language (and legal system) and manually annotated some sample text in the legal domain to test the usability of the frames described.

FN for soccer and other sports and tourism: The FrameNet Brasil project is being funded in part by the federal government to build a frame-semantic trilingual on-line dictionary in the domains of sports in general and more specifically soccer, as well as tourism, as part of the preparations for the Soccer World Cup in 2014 and the Olympics in 2015.

3.12.2 PropBank

The Proposition Bank (usually abbreviated to "PropBank"), is in many ways the closest annotation scheme to FrameNet in spirit, as it contains both a lexicon which defines a set of semantic roles and a substantial body of annotation exemplifying those roles in natural text from corpora. PropBank began with annotating only verbs, but has expanded to include morphologically related nouns and adjectives. The PropBank paradigm has also been extended to other languages, with PropBanks for Korean, Arabic, and Hindi (in progress).

The most fundamental difference between PB and FN is that PB does not have the notion of semantic frames. Instead, it has a two-level structure: At the basic level it uses a a set of 14 very general semantic role labels with names chosen to be theory-neutral, Arg0, Arg1, Arg2 up to Arg5, and more general modifiers, called ArgM, which can add information such as location, extent, cause,

[10]Not to be confused with the Sneaker Kicktionary app. for iPhone, a promotional site for sneakers.

manner, direction, temporal information, and other adverbials. The ArgM labels are defined in the same way across the entire lexicon; the Arg0-Arg5 labels have a further mapping to specific definitions for each lexical item, which thus constitute a much larger set of "second-level" labels.

For example, Table 6 compares PropBank and FrameNet annotations for the sentence *The internal investigation also criticized MiniScribe's auditors, Coopers & Lybrand, for allegedly ignoring numerous red flags*.

Table 6: Comparison of PropBank and FrameNet Annotation

Text	**PB Arg label**	**PB Specific Label**	**FN Frame Element**
The internal investigation	Arg0	critic	Communicator
also	ArgM-dis	–	(not annotated)
criticized	Rel	–	Target
MiniScribe's auditors, Coopers & Lybrand,	Arg1	entity being criticized	Evaluee
for allegedly ignoring numerous red flags	Arg2	on what grounds?	Reason

FrameNet has this sense of *criticize* in the **Judgement Communication** frame, which contains more than 80 lexical units, including verbs like *acclaim, belittle, commend, denigrate, denounce, disparage,* and *praise* and nouns such as *praise, commendation, acclaim, denunciation*, as well as the noun *critic* and the adjective *critical*; all of them use the same set of FE names (COMMUNICATOR, EVALUEE, REASON, MEDIUM, etc.) most of which are related to similar roles in one of two higher-level frames, Judgement and Communication. On the other hand, in PropBank, even though all of these verbs are in the same VerbNet class[11], and they all use the same pattern of Arg0-Arg2 labels on the first level, the specific labels differ by verb, as seen in Table 7.

In general, the Arg0 label is roughly equivalent to Dowty's (1991) "Proto-Agent" and Arg1 to Dowty's "Proto-Patient", but the definitions of Arg2–Arg5 are not consistent across domains. (See Palmer *et al.* 2005 for a much more detailed discussion of the relation between the two resources.)

[11] PropBank is partially based on VerbNet, and the VerbNet classes provide semantic categorization something like FrameNet frames. All of these words are in the VerbNet class 33, Judgement.

Table 7: Differing PropBank labels for Judgement verbs

Verb	Arg0	Arg1	Arg2
criticize	critic	entity being criticized	on what grounds?
disparage	talker, agent	victim	–
denigrate	speaker	subject	grounds, reason
acclaim	acclaimer	acclaimed	cause, acclaimed for what?
commend	entity giving praise	entity being praised	praised for what?

4 Conclusion

The FrameNet Project is an ongoing. long-term effort at lexicon building in which annotation plays an important role. Although widely used, the complexity of the annotation scheme has made it difficult to scale up; it is essential that it be extended and connected with other lexical and annotation resources if it is to realize its full potential.

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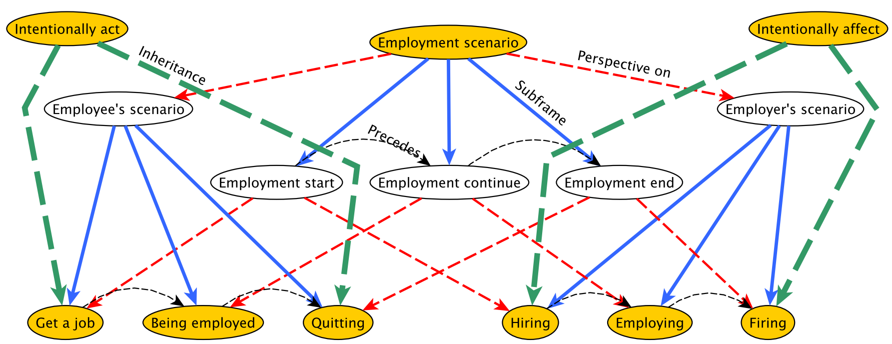

Figure 1: Frames and Frame Relations in the Employment domain

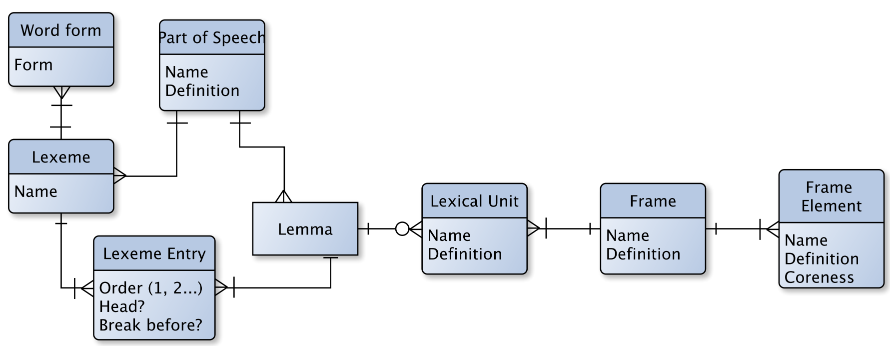

Figure 2: Principle Tables in the Lexical Database

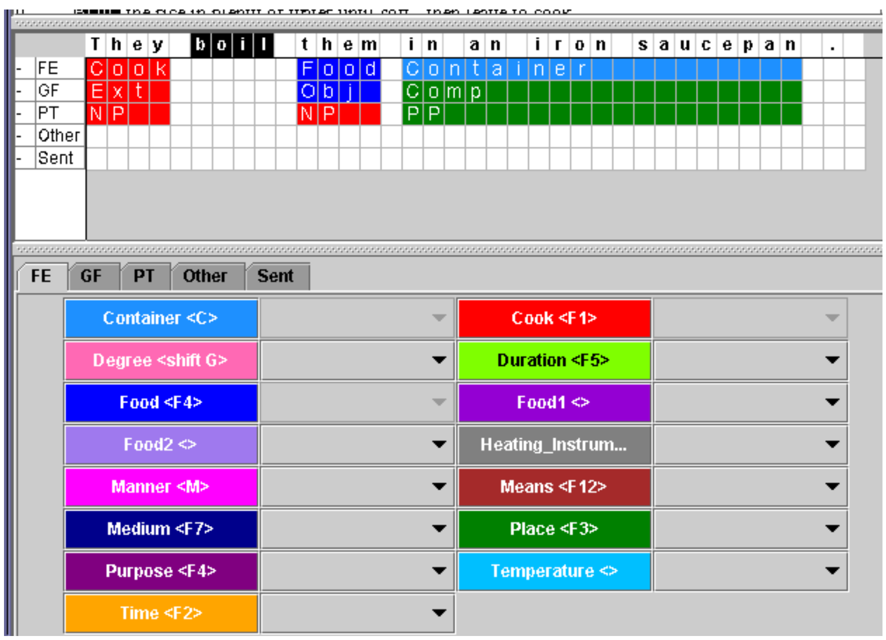

Figure 3: Text, Annotation Layers, and FE choices for Apply heat.boil.v

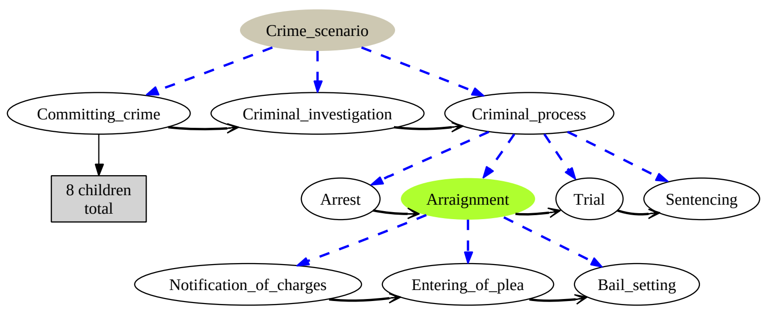

Figure 4: Frames and Subframes related to Crime