

Survey and Classification of Controlled Natural Languages [DRAFT, 30 October 2012]

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What is here called controlled natural language (CNL) has traditionally been given many different names. Especially during the last four decades, a wide variety of such languages have been designed. They are applied to improve communication among humans, to improve translation, or to provide natural and intuitive representations for formal notations. Despite the apparent differences, it seems sensible to put all these languages under the same umbrella. To bring order to the variety of languages, a general classification scheme is presented here. A comprehensive survey of existing English-based CNLs is given, listing and describing 95 languages from 1930 until today. Classification of these languages reveals that they form a single scattered cloud filling the conceptual space between natural languages like English on the one end and formal languages like propositional logic on the other. The goal of this paper is to provide a common terminology and a common model for CNL, to contribute to the understanding of their general nature, to provide a starting point for researchers interested in the area, and to help developers to make design decisions.

1. Introduction

“Controlled”, “processable”, “simplified”, “technical”, “basic” and “clear” are just a few examples of attributes given to constructed languages of the type to be discussed here. We will call them *controlled natural languages* (CNL) or simply *controlled languages*. Basic English, Caterpillar Technical English, Computer Processable Language, and Attempto Controlled English are some examples; many more will be presented below. This paper investigates the nature of such languages, provides a general classification scheme, and explores existing approaches.

As the variety of attributes suggests, there is no general agreement on the characteristic properties of CNL, making it a very fuzzy term. There are two main reasons for this. First, CNL approaches emerged in different environments (industry, academia and government) of different disciplines (computer science, philosophy, linguistics and engineering) and over many decades (from the 1930s until today). Persons from different backgrounds often used and continue to use different names for the same kind of language. Second, while controlled natural languages seem to share important properties, they also exhibit a very wide variety: some are inherently ambiguous, others are as precise as formal logic; virtually everything can be expressed in some, only very little in others; some look perfectly natural, others look more like programming languages; some are defined by just a handful of grammar rules, others are so complex that no complete grammar exists. This variety makes it difficult to get a clear picture of the fundamental properties of CNL. This paper aims at resolving this problem by giving an overview of existing CNLs and by providing a general classification scheme. Generally, the goals of this work are the following:

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- To establish a common terminology and a common model for CNL
- To give us a better understanding of the nature of CNL
- To provide a starting point for researchers interested in CNL
- To help CNL developers make design decisions

While there are a wide variety of CNLs applied to a wide variety of problem domains, virtually all of them seem to be relevant to the field of computational linguistics. Among other techniques, they involve lexical analyses, grammar and style checking, ambiguity detection, machine translation, and computational semantics.

Unsurprisingly, most CNLs are based on English. For the sake of simplicity, the survey presented in this paper is restricted to these languages and excludes existing controlled languages based on other natural languages. The classification scheme to be presented, however, is general and not restricted to English in any way.

In what follows, the relevant background is discussed (Section 2), a classification scheme is introduced (Section 3), English-based CNLs are listed and classified (Section 4), the results are analyzed (Section 5), and finally the conclusions are discussed (Section 6).

2. Background

Controlled natural language being such a fuzzy term, it is important to clarify its meaning, to establish a common definition, and to understand the differences to related terms. In addition, it is helpful to review previous attempts to classify and characterize CNLs.

2.1 Definition

As mentioned above, there is no generally agreed-upon definition for *controlled natural language* and for closely related terms including *controlled language*, *constrained natural language*, *simplified language* and *controlled English*. The following two quotations illustrate this:

A controlled language (CL) is a restricted version of a natural language which has been engineered to meet a special purpose, most often that of writing technical documentation for non-native speakers of the document language. A typical CL uses a well-defined subset of a language's grammar and lexicon, but adds the terminology needed in a technical domain. (Kittredge 2003)

Controlled natural language is a subset of natural language that can be accurately and efficiently processed by a computer, but is expressive enough to allow natural usage by non-specialists. (Fuchs and Schwitter 1995)

Both descriptions exhibit a strong bias towards one particular type of CNL (these types are discussed in more detail below): the first quotation focuses on technical languages which are designed to improve comprehensibility, whereas the second one only covers languages that can be interpreted by computers. They agree, however, on the fact that a CNL is based on a certain natural language but is more restrictive. It is also generally agreed that CNLs are constructed languages, i.e. languages that did not emerge naturally but have been engineered. The use of the term *subset* is misleading

though, since many CNLs are not proper subsets of the underlying natural language. Many languages have small deviations from natural grammar or semantics. Others make use of unnatural elements like colors and parentheses to increase readability and precision. Some even claim that the programming language COBOL is a controlled natural language (Sowa 2000a). The subset relation in its mathematical sense is clearly too strict to cover a large part of the languages commonly called CNL. While they all clearly share important properties, the specific languages can be quite different in their coverage and nature. It is not surprising that O'Brian (2003), who compared English-based CNLs of different types, comes to the conclusion that no common core language can be identified.

Here, the following definition is proposed:

Definition 1 (long)

A language is called a *controlled natural language* if and only if it has all of the following four properties:

1. It is based on exactly one natural language (its *base language*).
2. The most important difference between it and its base language (but not necessarily the only one) is that it is more restrictive concerning lexicon, syntax, and/or semantics.
3. It preserves most of the natural properties of its base language, so that speakers of the base language can intuitively and correctly understand texts in the controlled natural language, at least to a substantial degree.
4. It is a constructed language, which means that it is explicitly and consciously defined, and *is not* the product of an implicit and natural process (even though it is based on a natural language that *is* the product of an implicit and natural process).

Properties 2 and 3 are deliberately vague, because it is not possible or desirable to draw a strict line there. Properties 1 and 3 refer to the *N* in *CNL*: naturalness. Properties 2 and 4 refer to the *C*: control. We will later be able to be a little more precise concerning property number 3. We can summarize this relatively verbose definition as follows:

Definition 2 (short)

A *controlled natural language* is a constructed language that is based on a certain natural language, being more restrictive concerning lexicon, syntax and/or semantics while preserving most of its natural properties.

The term *language* is used in a sense that is restricted to sequential languages and excludes visual languages like diagrams and the like. This definition includes virtually all languages that have been called CNL, while it excludes natural languages (since they are not constructed), languages like Esperanto (since they are not based on one particular natural language), and common formal languages (since they lack intuitive understandability).

2.2 Related Terms

There are a number of terms that are related to CNL and are easy to confuse: sublanguage, fragments of language, constructed language, style guide, phraseology, and controlled vocabulary.

Sublanguages are languages that naturally arise when “a community of speakers (i.e. ‘experts’) shares some specialized knowledge about a restricted semantic domain” and “the experts communicate about the restricted domain in a recurrent situation, or set of highly similar situations” (Kittredge 2003). As with controlled natural language, a sublanguage is based on exactly one natural language and is more restricted. The crucial difference between the two terms is that sublanguages emerge naturally, whereas CNLs are consciously defined (i.e. “engineered”).

Fragments of language is a term denoting “a collection of sentences forming a naturally delineated subset of [a natural] language” (Pratt-Hartmann and Third 2006). The term is closely related to CNL and the difference seems to be mainly a methodological one: Fragments of language are *identified* rather than *defined*, they are closely kept in the context of the full natural language and related fragments, and their purpose is rather to theoretically study them than to directly use them to solve a particular problem. A CNL can be seen as a fragment of a language “developed for the purpose of supporting some technical activity” (Pratt-Hartmann 2009).

Constructed languages (or *artificial languages* or *planned languages*) are languages that did not emerge naturally but have been consciously defined. In this broad sense, the term includes (but is not limited to) languages like Esperanto, programming languages, and CNL.

Style guides are documents containing instructions on how to write in a certain natural language. Some style guides like “How to write clearly” (European Commission 2011) by the European Commission provide “hints, not rules” and therefore do not describe a new language, but only give advice how to use the given natural language. However, other style guides like the Plain Language Guidelines (PLAIN 2011) are stricter and *do* describe a language that is not identical to the respective full language. The question of whether such a language can be considered a CNL depends on whether the style guide defines a new language or whether it merely describes good practices that have emerged naturally.

Phraseology is a term to denote a “set of expressions used by a particular person or group” (Houghton Mifflin Harcourt 2000). Typically, this term is used when the grammatical structure is simpler than in full natural language. Compared to sublanguages and fragments of languages, phraseologies are not a selection of sentences of a certain natural language but a selection of *phrases*. Phraseologies can be natural or constructed. In the latter case they are usually considered controlled languages.

Controlled vocabularies are collections of standardized terms for certain concepts, mostly from a specific domain. In contrast to CNL, they do not deal with grammatical issues, i.e. how to combine the terms to write complete sentences. Many CNL approaches, especially domain-specific ones, include controlled vocabularies.

2.3 Types and Properties

To bring order to their seemingly chaotic variety, more than 40 properties of CNLs and their environments have been identified (Wyner et al. 2010). Many of these properties, however, are fuzzy and do not allow for a strict categorization. For the survey to be presented in Section 4, we collect nine general and clear-cut properties and give them

letter codes. As it turns out, however, these properties mainly describe the application environment of languages and not so much the languages themselves. For that reason, a classification scheme is introduced in the next section to describe the fundamental nature of CNLs and other languages.

In general, controlled natural languages can be roughly subdivided according to the problem they are supposed to solve (Schwitter 2002): to improve communication among humans, especially speakers with different native languages (we will use the letter code C for these languages); to improve manual, computer-aided, semi-automatic or automatic translation (T); and to provide a natural and intuitive representation for formal notations (F). As we will see, these three types emerged at different points in time: Type C is the oldest, type T emerged later, and type F is a relatively recent phenomenon. While this seems to be a sensible and useful subdivision, a simpler version based on just two types dominates the literature. Huijsen introduced the distinction between “human-oriented” and “computer-oriented” languages (Huijsen 1998). The former roughly corresponds to type C, the latter to the types T and F. However, Huijsen observes that “it is often difficult to qualify a controlled language as either human-oriented or machine-oriented, since often simplification works both ways.” Since these types describe *problems* rather than *languages*, reusing a language in a different problem domain can change its type even if the language itself has not changed at all. Other similar categorizations include the distinction between “naturalistic” (type C and T) and “formalistic” (type F) languages (Pool 2006; Clark et al. 2010) and the distinction between readability and translatability (Reuther 2003).

Another apparent fact is that some languages originated from academia (letter code A), some from industry (I), some from a government or a UN agency (G), and others from a combination of the three. In addition, the distinction between general purpose languages and those for a particular restricted domain is often discussed (Pool 2006). This is related to the distinction of whether the lexicon is open or closed (Adriaens and Schreors 1992). We will use the letter code D to denote languages targeting a specific and narrow domain. A further important difference is the one between written and spoken languages. We will use W to denote languages that are intended to be written, and S for those that are intended to be spoken. However, none of these properties appears to be a fundamental language property: languages that originated in one environment can later be used in another; the lexicon can later be declared open or closed; written languages can be read aloud; and spoken languages can be written down.

Occasionally, fundamental properties of CNLs are identified and discussed, such as expressiveness (Mitamura and Nyberg 1995; Boyd, Zowghi, and Farroukh 2005; Pool 2006), complexity (Mitamura and Nyberg 1995), substantial grammar modifications (Pool 2006), and understandability (Wyner et al. 2010). However, these properties are all very fuzzy and do not allow for strict categorization. What is needed is a principled classification scheme for such fundamental language properties, and such a scheme will be introduced in the next section.

The rules that define a CNL can be proscriptive or prescriptive (Nyberg, Mitamura, and Huijsen 2003), or a combination of the two. Proscriptive rules describe what *is not* allowed, whereas prescriptive rules describe what *is* allowed. Languages defined by proscriptive rules alone must have some starting point in the form of a given (natural) language. Languages with only prescriptive rules, in contrast, typically start from scratch. As we will see, there is a close connection of this distinction to the concept of *simplicity* as introduced in the next section, and for that reason there is no need to introduce another letter code here.

Table 1

Letter codes for properties of CNLs

C	The goal is comprehensibility
T	The goal is translation
F	The goal is formal representation
W	The language is intended to be written
S	The language is intended to be spoken
D	The language is designed for a specific narrow domain
A	The language originated from academia
I	The language originated from industry
G	The language originated from a government

Because of their lack of generality, we do not include here more specific low-level properties like the support for subclauses and free compounding (Adriaens and Schreors 1992), the specific restrictions on grammatical tenses and modal verbs (O'Brien 2003), and the support for interrogative and imperative sentences (Wyner et al. 2010).

Table 1 summarizes the letter codes for CNL properties, which will be used later on. Any two of these properties can overlap, and therefore any combination is possible in theory (with the exception that no language should be neither W nor S).

3. PENS Classification Scheme

In order to compare languages based on their fundamental and inherent properties, a novel classification scheme is introduced here, called *PENS*. This scheme will be used in the survey in conjunction with the nine properties identified above. The four letters of the scheme's name represent four dimensions: Precision, Expressiveness, Naturalness, and Simplicity.¹ The scheme covers all known controlled natural languages and includes natural and formal languages as special cases.

The development of the PENS classification scheme originated from the insight that CNLs can be conceptually located somewhere in the gray area between natural languages on the one end and formal languages on the other. Generally, CNLs are more formal than natural languages but more natural than formal ones. For instance, a natural language like English is very expressive, but complex and imprecise. A formal language like propositional logic, in contrast, is very simple and precise, but at the same time unnatural and inexpressive. CNLs must be somewhere in the middle, but where exactly?

It seems obvious that all four of the above-mentioned dimensions are continuous in nature or at least very fine-grained. In fact, one can argue that each of the dimensions is actually multidimensional and that representing it in one dimension is a rough simplification. Such simplifications are necessary, however, in order to get a precise measure for such vague concepts like *simplicity*.

Intuitively, PENS uses a natural language like English and a formal language like propositional logic as pegs to span a conceptual space in which different kinds of con-

¹ These four dimension have first been sketched as "design principles" in the author's doctoral thesis (Kuhn 2010), where "precision" was called "clearness".

trolled natural languages can be placed. In order to get a general but strict classification scheme, PENS drastically simplifies things, by restricting each of its four dimension to five classes, to be referred to as 1, 2, 3, 4 and 5. These five classes are non-overlapping and consecutively cover the one-dimensional space between the two extremes: English on the one end and propositional logic on the other. For precision and simplicity, English is on the bottom end of the scale in class 1, which we write as P^1 and S^1 . Propositional logic is on the opposite end of the scale in class 5, represented with P^5 and S^5 . For expressiveness and naturalness, the roles are switched: English is at the top end (E^5 and N^5) and propositional logic at the bottom (E^1 and N^1). Combining the four dimensions gives $5^4 = 625$ classes, represented with shorthand like $P^1E^5N^5S^1$ for English and $P^5E^1N^1S^5$ for propositional logic. The difficult and interesting part of this intellectual exercise is where and how to draw the borders between the five classes of each dimension.

3.1 Precision

The precision dimension of the PENS scheme captures the degree to which the meaning of a text in a certain language can be directly retrieved from its textual form, i.e. the sequence of language symbols. Natural language is very imprecise in this sense, because a large amount of context information is needed to grasp at least part of the meaning of typical sentences. Formal logic languages, on the other hand, have maximal precision, because their meaning is strictly defined solely on the basis of the possible sequences of their language symbols. The symbol grounding problem, i.e. the problem of mapping symbols to their counterparts in the real world, is not considered here, because it affects all languages, natural and formal ones. On this precision dimension, languages are divided into the four classes P^1 , P^2 , P^3 , P^4 and P^5 as follows:

Imprecise languages (P^1). Virtually every sentence of these languages is vague to a certain degree. Without taking context into account, most sentences of a certain complexity are ambiguous. The automatic interpretation of such languages is “AI-complete”, i.e. a problem for which no complete solutions are in sight. These languages require a human reader to check whether a given statement is syntactically correct, and include borderline statements on which readers disagree. The same applies to the semantic properties of the language. All natural languages belong to this category.

Less imprecise languages (P^2). For these languages, the degree of ambiguity and vagueness is considerably lower than in natural languages, and their interpretation depends much less on context. They restrict the use and/or the meaning of a wide range of the respective ambiguous, vague or context-dependent constructs. However, they are still too dominant to make automatic interpretation reliable. Such languages are typically not related to a formal (i.e. mathematically precise) underpinning.

Reliably interpretable languages (P^3). The syntax of these languages is heavily restricted, though not necessarily formally defined. The restrictions are strong enough to make automatic interpretation reliable. There is a logical underpinning or at least a formal conceptual scheme, in which the semantics of sentences can be represented. However, the mapping of sentences to their formal representations is itself not formally defined, and is therefore not possible without external background knowledge, heuristics, or user feedback.

Deterministically interpretable languages (P^4). Such languages are fully formal on the syntactic level; that is, they are (or can be) defined by a formal grammar. Each text in such a language can be deterministically parsed to a formal logic representation, or a small set of all possible representations (including all and only the possible ones). Based on the underlying formalism, these representations describe the meaning of the sentences, but they may be underspecified in the sense that they require certain parameters, background axioms, external resources or heuristics to enable sensible deductions.

Languages with fixed semantics (P^5). These languages are fully formal and fully specified on both the syntactic and semantic levels. Each text has exactly one meaning, which can be automatically derived. The circumstances in which inferences hold or do not hold are fully defined. What conclusions follow from a given text in the language (e.g. whether it is consistent and which sentences of the language are a consequence of the text) can be defined with mathematical rigor, and no heuristics or external resources are necessary for this.

3.2 Expressiveness

The dimension of expressiveness describes the range of propositions that a certain language is able to express. A language X is more expressive than a language Y if language X can describe everything that language Y can, but not vice versa. The relation of “being more expressive” does not constitute a total order: for two given languages of nonequal expressiveness, it can be the case (and often is the case) that neither is more expressive than the other. This entails that ranking a general set of languages in a linear order according to their expressiveness cannot be done in a completely objective way. A classification scheme, such as the one presented here, must therefore rely on only a subset of all possible expressiveness features. These expressiveness features should be general and important ones, and at the same time allow for a balanced and clear discrimination between the languages to be classified. The PENS classification scheme employs the following five expressiveness features:

1. universal quantification over individuals (possibly limited)
2. relations of arity greater than 1 (e.g. binary relations)
3. general rule structures (*if-then*-statements with multiple universal quantification that can target all argument positions of relations)
4. negation (strong negation or negation as failure)
5. second-order universal quantification over concepts and relations

There are a number of other important features that could be considered, e.g. support for existential quantification, equality or procedural statements. However, to achieve a simple classification into a sequence of five classes, the features listed above will turn out to be sufficient and lead to a classification that seems consistent with the intuitive understanding of “expressiveness”.

Since this classification system should not only include declarative formal languages but also informal as well as procedural ones, it makes sense to apply a weaker notion of “expressiveness” than what is usually applied to logic languages. We can adopt from the research on programming languages the convention that a certain lan-

guage construct adds expressivity if its removal would require “a global reorganization of the entire program” (Felleisen 1991). If a certain language construct allows us to express something locally which would otherwise require us to reorganize the entire text, then we say that this language construct makes the language more expressive. This means, for example, that a language with second-order features relying on Henkin semantics qualifies for the last criterion of the above list, even though Henkin semantics can be reduced to first-order. A given set of statements written in a language with Henkin-style second-order features cannot generally be reduced to first-order logic without global reorganization, i.e. changing statements that do not actually use second-order features.

Inexpressive languages (E^1). These are languages lacking one or both of the features 1 and 2: They have no universal quantification or no relations of arity greater than 1. Propositional logic belongs to this category.

Languages with low expressiveness (E^2). Such languages have both of the features 1 and 2 (but are not E^3 -languages): universal quantification over individuals and relations of arity greater than 1. Description logics belong to this category.

Languages with medium expressiveness (E^3). These languages have all of the features 1, 2, 3 and 4 (but are not E^4 -languages): general rule structures and negation, in addition to the features of E^2 . First-order logic belongs to this category.

Languages with high expressiveness (E^4). Such languages have all listed features 1, 2, 3, 4 and 5 (but are not E^5 -languages): second-order universal quantification over concepts and relations, in addition to the features of E^3 . Second order predicate calculus belongs to this category.

Languages with maximal expressiveness (E^5). These languages can express anything that can be communicated between two human beings. Such languages cover any statement in any type of logic. Obviously, this includes all features listed above. All natural languages belong to this category.

3.3 Naturalness

The dimension of naturalness describes how close the language is to a natural language, in terms of readability and understandability to speakers of the given natural language.

Unnatural languages (N^1). These are languages that do not look natural, making heavy use of symbol characters, brackets, or unnatural keywords. It might be possible to use natural words or phrases as names for certain entities, but this is neither required nor further defined by the language.

Languages with dominant unnatural elements (N^2). Natural language words or phrases are an integral part of such languages, but are dominated by unnatural elements or unnatural statement structure, or have unnatural semantics. The natural elements do not connect in a natural way to each other, and speakers of the given natural language typically fail to intuitively understand the respective statements.

Languages with dominant natural elements (N^3). In such languages, natural elements are dominant over unnatural ones and the general statement structure corresponds to natural language grammar. Due to the remaining unnatural elements, however, the sentences can not be considered valid natural sentences. Speakers of the given natural language do not recognize the statements as sentences of their language, but are nevertheless able to intuitively understand them to a substantial degree.

Languages with natural sentences (N^4). These are languages with sentences that can be considered valid natural sentences. Speakers of the respective natural language recognize statements of the language as sentences of their language and are able to understand their essence without instructions or training. This understanding is not in conflict with the semantics defined for the given language. Minor or infrequent exceptions and unnatural means for clarification (including colors, indentation, brackets, hyphenation, and capitalization) are permitted as long as they do not disturb the natural look and feel, the natural flow of the sentence, and the natural understandability. While single sentences have a natural flow, this does not scale up to complete texts or documents. Complete texts in such languages read very clumsy and repetitive, and lack a natural text flow.

Languages with natural texts (N^5). With these languages, complete texts and documents can be written in a natural style, with a natural text flow, and with natural semantics.

We can now be a little more precise concerning our definition of CNL. Property number 3 of the long version of the definition shown in Section 2.1 says that a CNL “preserves most of the natural properties of its base language, so that speakers of the base language can intuitively and correctly understand texts in the controlled natural language, at least to a substantial degree”. We will interpret this in such a way that it only includes languages of naturalness N^3 and higher. Thus, by this definition, there will be no CNLs with N^1 or N^2 .

3.4 Simplicity

The fourth dimension of PENS could be called *complexity*, but is called *simplicity* to have a dimension of the type “more is better”. It is a measure of how simple or complex it is to describe the language in an exact and comprehensive way, if possible at all. This should not presuppose intuitive knowledge about any natural language, but it should measure the effort needed to implement the language in a computer program. It is therefore not primarily a measure for the effort needed by a human to learn the language, neither does it capture the theoretical complexity of the language (as e.g. the Chomsky hierarchy does).

The PENS scheme applies a very pragmatic and simple indicator for simplicity: the number of pages in natural language needed to describe the language in an exact and comprehensive way. For languages for which no such exact and comprehensive descriptions exist or can be written (that do not presuppose linguistic knowledge on the side of the reader, and given the current state of science), we can distinguish languages with the complexity of natural language from languages with considerably lower complexity.

These “exact and comprehensive descriptions” should define all syntactic and semantic properties of the language using accepted grammar notations to define the syntax and accepted mathematical or logical notations to define the semantics. They

are assumed to use scientific writing style as found in conference papers or technical reports, and should allow a skilled grammar engineer to implement a correct and complete parser within reasonable time. The page count should be based on a one-column format with up to about 700 words per page. It is important to note that the criterion is not the *presence* of such a description but whether it is *possible or not* to write one.

In order to treat languages with fixed vocabularies and those with extensible ones in an equal way, the above mentioned language descriptions do not need to include the vocabularies.

Very complex languages (S^1). These languages have the complexity of natural languages. They cannot be described in an exact and comprehensive manner.

Languages without exhaustive descriptions (S^2). These are languages that are considerably simpler than natural languages, in the sense that a significant part of the complex structures are eliminated or heavily restricted. Still, these languages are too complex to be described in an exact and comprehensive manner. Usually, the definitions of such languages just describe restrictions on top of a given natural language that is taken for granted.

Languages with lengthy descriptions (S^3). Such languages can be defined in an exact and comprehensive manner, but it requires more than 10 pages to do so.

Languages with short descriptions (S^4). These are languages for which an exact and comprehensive description requires more than 1 page but not more than 10 pages.

Languages with very short descriptions (S^5). Such very simple languages can be described in an exact and comprehensive manner on just 1 page or even less.

S^1 and S^2 are considered complex because they rely on a given natural language. Coming back to a distinction briefly introduced in the previous section, such languages are typically defined by *proscriptive* rules, describing what is not allowed compared to the full language. S^3 , S^4 and S^5 , in contrast, typically use *prescriptive* rules that define the language from scratch. For that reason, they are simpler in our sense of the word than languages of the first type that “import” the complexity of full natural language.

Before we move on to actually apply this scheme, it should be stressed that PENS is designed to measure the *nature* of a language, not its *quality* or *usefulness*. In theory, more is better for each of the PENS dimensions; in practice, however, a certain level in any of the dimensions is often good enough for a given application domain, and going beyond that level brings no additional benefit. Query languages, for example, are typically not as expressive as knowledge representation languages, simply because they do not need to be. PENS should be used to *describe* languages, not to *rank* them.

4. Languages

We can now turn to the actual survey. For practical reasons, we restrict ourselves here to English-based languages, leaving out CNLs that are based on other languages, such as Chinese, French, German, Greek, Spanish and Japanese (Pool 2006). In what follows, a comprehensive list of English-based controlled natural languages is given, consisting

of 95 languages listed in alphabetical order. After that, a handful of other languages are introduced for comparison, such as natural English and propositional logic. Each language is classified according to the nine properties with letter codes and the PENS scheme. A best guess is made in the cases where not enough information is available. The descriptions are shorter in the case of similar languages or scarce information.

There are many approaches on user interfaces based on some sort of natural language input, and it could be argued that they all — at least indirectly — define and use a controlled language (because none of them is able to correctly process full natural language). Such approaches, however, are included here only if the restrictions on the language are considered an inherent property of the approach and not a shortcoming of its implementation. In other words, the following listing excludes languages whose restrictions are not design decisions of the general approach but practical concessions, e.g. Warren and Pereira (1982). The same criterion is applied to verbalization approaches, which inevitably define a restricted version of the respective language that could be considered a CNL, e.g. Halpin (2004), Jarrar, Keet, and Dongilli (2006), Lukichev and Wagner (2006). Some languages follow an approach called *conceptual authoring* or WYSI-WYM (Hallett, Scott, and Power 2007) where texts are created by short cycles of language generation and user-triggered modification actions. We include such languages here, because in this case the restrictions on the language are an important aspect of the approach. Finally, it should be mentioned that we leave out fictional languages, such as Newspeak of George Orwell’s *Nineteen Eighty-Four*.

Languages that do not have an official name are introduced by a “generic name in quotation marks”. Unless stated otherwise, quotes and examples are taken from the publications cited in the beginning of each paragraph.

4.1 English-based Controlled Languages

AECMA Simplified English (AECMA-SE) (Gingras 1987) was the predecessor of ASD Simplified Technical English (see below). — P²E⁵N⁵S¹, C W D I

“Airbus Warning Language” (Spaggiari, Beaujard, and Cannesson 2003) is a language for short industrial warnings, focusing on abbreviations and restricting the word order. This is an exemplary statement:

ENG1 REV NOT LOCKED

— P²E¹N³S³, C W D I

ALCOGRAM (Adriaens and Schreors 1992) is a CNL developed at Alcatel. It originated from COGRAM as an “algorithmic variant”, focusing on the use within a computer-aided language learning tool. In contrast to COGRAM, which consists of three components that declaratively define the language, ALCOGRAM is defined based on a four-staged algorithm. Each of these four stages checks certain aspects: preparatory textual control (e.g. “Define technical terms and acronyms in advance”), syntactic control (e.g. “Write one instruction per sentence for single actions”), lexical control (e.g. “Avoid gender-specific language”), and micro control (e.g. “Use words for a number when it is the first word in the sentence”). These are two examples of ALCOGRAM sentences:

Set the switch to the middle. Press the button on your right.

When the test circuit is called, a test tone with the proper transmit level is returned.

— P²E⁵N⁵S¹, C T W D A I

ASD Simplified Technical English (ASD-STE) (ASD 2007) (often abbreviated to *Simplified Technical English* (STE) or just *Simplified English*) is a CNL for the aerospace industry. Originally inspired by ILSAM (Adriaens and Schreors 1992), the language had its origins in 1979, but it was only in 1986 when it was officially presented for the first time, then under the name *AECMA Simplified English*. It received its current name in 2004 when AECMA merged with two other associations to form ASD. The main purpose of the language is to make texts easier to understand, especially for non-native speakers. While AECMA Simplified English was designed to make translation into other languages unnecessary, one of the original goals of ASD-STE was to improve translation. Today, the language is maintained by the Simplified Technical English Maintenance Group. ASD-STE is based on English with restrictions expressed in about 60 general rules. These rules restrict the language on the lexical level (e.g. “Use approved words from the Dictionary only as the part of speech given”), on the syntactic level (e.g. “Do not make noun clusters of more than three nouns”), as well as on the semantic level (e.g. “Keep to the approved meaning of a word in the Dictionary. Do not use the word with any other meaning.”). There is a fixed vocabulary consisting of terms common to the aerospace domain. Additionally, user-defined “Technical Names” and “Technical Verbs” can be introduced. This is an exemplary excerpt of a text in ASD-STE:

These safety precautions are the minimum necessary for work in a fuel tank. But the local regulations can make other safety precautions necessary.

Even though its restrictions make ASD-STE considerably more precise than full English, it does not allow for automatic and reliable interpretation. — $P^2E^5N^5S^1, C T W D I$

Attempto Controlled English (ACE) (Fuchs, Kaljurand, and Kuhn 2008) is a CNL with an automatic and unambiguous translation into first-order logic. ACE was first presented in 1996 as a language for software specifications. Later, the focus shifted towards knowledge representation and the Semantic Web. The language has been extended over the years in various ways. The most notable features of ACE include complex noun phrases, plurals, anaphoric references, subordinated clauses, modality, and questions. These are two exemplary ACE sentences:

Every planet that does not orbit the Sun is an extrasolar planet.

A customer owns a card that is invalid or that is damaged.

ACE sentences are deterministically mapped to discourse representation structures, a notational variant of first-order logic. These expressions, however, are underspecified in the sense that many deductions require further background axioms that are not fixed by the ACE definition. This makes it possible to use ACE in different areas like ontology editors, rule systems, and general reasoners with semantics that are not fully compatible. ACE is, with a few minor exceptions, fully natural on the sentence level, but longer texts do not have a natural text flow. — $P^4E^3N^4S^3, F W A$

Avaya Controlled English (Avaya 2004) is a language for technical publications in the telecommunication and computing industry. Its use should reduce translation costs and should make texts easier to understand for human readers. It puts restrictions on the lexicon (e.g. “Do not use *abort*”), grammar (e.g. “Use active voice”), semantics (e.g. “Use *may* only to grant permission”), and style (e.g. “Put command names in bold monospaced type”). An open list of about 250 words defines preferred terminology for the given computer and telephony domain, and clarifies usage and meaning of these words. These are two examples of sentences:

This procedure describes how to connect a dual ACD link to the server.

If the primary server fails, you can use the secondary server.

— P²E⁵N⁵S¹, C T W D I

Basic English (Ogden 1932) is a language presented in 1930 that should improve communication among people around the globe. It is the first reported instance of a controlled version of English, at least the first one that received broader recognition. It influenced Caterpillar Fundamental English, which became itself a very influential language. Basic English was designed as a common basis for communication in politics, economy and science. It restricts the grammar and makes use of only 850 English root words. The restrictions are arguably most drastic in the case of verbs. Only 18 verbs are supported: put, take, give, get, come, go, make, keep, let, do, be, seem, have, may, will, say, see, and send. These verbs can be combined with prepositions to form more specific relations like “put in” to express “insert”. Other verbs can be expressed with the help of nouns, like “give a move” instead of using “move” as a verb. The usage of the given words and their variants is described by informal grammar rules, e.g. “Collective nouns may be formed from adjectives when used with *the*”. These are two examples of sentences in Basic:

The camera man who made an attempt to take a moving picture of the society women, before they got their hats off, did not get off the ship till he was questioned by the police.

It was his view that in another hundred years Britain will be a second-rate power.

Many variations exist that use larger word sets, e.g. the Simple English version of Wikipedia² claims to use Basic English, but in fact uses a much less restricted language. Basic English is still used today and promoted by a dedicated Basic-English Institute.³ Many texts have been written in this language, including textbooks, novels, and large parts of the bible. — P²E⁵N⁵S¹, C W

BioQuery-CNL (Erdem and Yeniterzi 2009) is a language for biomedical queries. It serves as an interface language for a query engine based on answer set programming. BioQuery-CNL was initially designed as a subset of ACE with some small modifications handled in a preprocessing step. The ACE parser was used for processing the language. In later versions, however, the language has diverged from ACE and evolved into an independent language with its own parser. This is an exemplary query:

What are the genes that are targeted by all the drugs that belong to the category Hmg-coa reductase?

— P⁵E²N⁴S⁴, F W D A

Boeing Technical English (Wojcik, Holmback, and Hoard 1998) is an extension of AECMA Simplified English to improve readability and consistency of documents, with the specific goal to broaden the scope beyond the aviation domain. — P²E⁵N⁵S¹, C W I

Bull Global English (Smart Communications Inc. 1994) (or *Bull Controlled English*) is a language developed at Groupe Bull, a French computer company. It was probably influenced by SMART Plain English. Bull Global English can be summarized by the following ten rules (Karkaletsis and Spyropoulos 1997), which have a considerable overlap with the rules of Caterpillar Fundamental English:

² <http://simple.wikipedia.org>

³ <http://www.basic-english.org>

- | | |
|------------------------------------|--|
| 1. Make positive statements. | 6. Use active voice and parallel construction. |
| 2. Keep sentence length 21 words. | 7. Avoid conditional tenses. |
| 3. Avoid false nomenclature. | 8. Avoid abbreviations and colloquialisms. |
| 4. One thought per sentence. | 9. Use correct punctuation. |
| 5. Use simple sentence structures. | 10. Use standardised nomenclature. |

— P²E⁵N⁵S¹, C T W D I

CAA Phraseology (CAA 2011) is a language for air traffic control introduced by the Civil Aviation Authority (CAA) in the 1980s or possibly earlier. To a large extent, it is indistinguishable from other such phraseologies like the ones by FAA and ICAO (see below); they only differ in details (Robertson 1987). — P²E¹N³S², C S D G

Caterpillar Fundamental English (CFE) (Verbeke 1973) was an influential controlled language developed at Caterpillar. It was officially introduced in 1971, was based on Basic English (Smart 2003), and has been reported to be the earliest industry-based CNL (Wojcik and Hoard 1997). The need for a controlled language emerged because of the increasing sophistication of Caterpillar's products and the need to communicate with non-English speaking service personnel in different countries (Verbeke 1973): "To summarize the problem: There are more than 20'000 publications that must be understood by thousands of people speaking more than 50 different languages." The idea of CFE was "to eliminate the need to translate service manuals" (Kamprath et al. 1998). A trained, non-English speaking mechanic familiar with Caterpillar's products should be able to understand the language after completing a course on CFE consisting of 30 lessons. The vocabulary of the language is restricted to around 800 to 1000 words (Crabbe 2009), with only one meaning defined for each of them (e.g. *right* only as the opposite of *left*). Still, many of the words "had broad semantic scope and it was assumed that they would be disambiguated in context by the human reader" (Kamprath et al. 1998). The literature on CFE does not reveal the specific grammatical restrictions, only the following ten rules that summarize them (Crabbe 2009):

- | | |
|--|---|
| 1. Make positive statements. | 6. Avoid complicated past and future tenses. |
| 2. Avoid long and complicated sentences. | 7. Avoid conditional tenses. |
| 3. Avoid too many subjects in one sentence. | 8. Avoid abbreviations, contractions, and colloquialisms. |
| 4. Avoid too many successive adjectives and nouns. | 9. Use punctuation correctly. |
| 5. Use uniform sentence structures. | 10. Use consistent nomenclature. |

These are two examples of CFE sentences:

The maximum endplay is .005 inch.

Lift heavy objects with a lifting beam only.

CFE was discontinued by Caterpillar in 1982, because (among other reasons) "the basic guidelines of CFE were not enforceable in the English documents produced" (Kamprath et al. 1998). As a result, Caterpillar Technical English (see below) was developed following a different approach: The restrictions on the language should be enforceable, and should reduce translation costs instead of trying to eliminate the need for translations altogether. — P²E⁵N⁵S¹, C W D I

Caterpillar Technical English (CTE) (Hayes, Maxwell, and Schmandt 1996; Kamprath et al. 1998) is the second CNL developed at Caterpillar. Its development started in 1991, i.e. almost a decade after the discontinuation of CFE. Apart from improving consistency and reducing ambiguity of technical documentation, the goal of CTE was to improve translation quality and reduce translation costs with the help of machine translation. This is an example of a CTE text:

This category indicates that an alternator is malfunctioning. If the indicator comes on, drive the machine to a convenient stopping place. Investigate the cause and determine the solution.

In contrast to CFE, texts in CTE are supposed to be translated before given to personnel in non-English speaking countries. As a further difference, CTE was designed to be an “enforceable controlled English” that comes with an authoring tool that enforces the compliance with the restrictions. The CTE lexicon consists of about 70'000 terms with a “narrow semantic scope” (compared to CFE’s less than 1000 terms with a broader semantic scope). The syntax is restricted too, including restrictions on the use of conjunctions, pronouns, and subordinate clauses. CTE comes with a language checker that allows for interactive disambiguation on the lexical level, enriches the technical texts with SGML annotations, and uses the syntax analyzer of the KANT system (see KANT Controlled English below). — P²E⁵N⁵S¹, C T W D I

Clear And Simple English (CASE) (Pym 1990) was a controlled English introduced in the 1980s at the J.I. Case Company, a manufacturer of construction and agricultural equipment. It descended from CFE. — P²E⁵N⁵S¹, C W D I

ClearTalk (Skuce 2003) is a CNL for the Semantic Web first presented in the 1990s. Its creator claims that documents in ClearTalk can be “almost automatically” translated into a formal logic notation and into other natural languages. It “offers a flexible degree of formality” that lets an author choose to “leave or remove ambiguity”. It has been used to encode more than 25'000 facts in different technical domains. ClearTalk is heavily restricted on the syntactic level (e.g. basic sentences have the general form *subject predicate complement modifier-phrases*) as well as on the semantic one (e.g. the determiner ‘a’ at subject position represents universal quantification). These restrictions are expressed in a large number of rules. Two examples of sentences are shown here:

Any adverb that modifies a verb must be adjacent to (that verb or another adverb).

Mary hopes that [- Bill loves her -].

ClearTalk can itself be described in ClearTalk; the first example is from this self-description. Different forms of parentheses are used to disambiguate different kinds of scopes, which mitigates the natural look-and-feel. — P³E³N⁴S³, F W A

“CLEF Query Language” (Hallett, Scott, and Power 2007) is a language used within a system called *CLEF* (Clinical E-Science Framework), which should help clinicians, medical researchers and hospital administrators to query electronic health records. The language was influenced by the Drafter language. Basic queries are composed of three elements: the set of relevant patients, the received treatments, and the outcomes. This is an example:

For all patients with cancer of the pancreas, what is the percentage alive at five years for those who had a course of gemcitabine?

Complex queries can have multiple elements of the same type. The system employs a conceptual authoring approach: Users cannot directly edit the CNL text, but they can only trigger modifications starting from a small stub sentence. The queries are then translated in several steps to SQL and given to a database engine. — P⁵E¹N⁴S³, F W D A

COGRAM (Adriaens and Schreors 1992) was a controlled language developed in the late 1980s for the telecommunication domain (at Alcatel). It was developed as a response to the finding that the existing controlled languages AECMA Simplified English, Ericsson English, and IBM’s controlled English were “incomplete and defective in many ways”. COGRAM consists of a vocabulary of approximately 5000 words plus another

1000 technical terms, and a grammar with about 150 rules. These rules fall into three categories: “Do not use ...”, “use only ...”, and “avoid (try not to use) ...”. Grammar rules of the last type can be seen as style-guides that do not restrict the language. The language definition is divided into three components: lexical (e.g. “Use short infinitives of regular action verbs”), syntactic (e.g. “Do not use a participle to introduce an adverbial clause.”), and stylistic (e.g. “Expound major topics, restrict minor topics”). The definition of COGRAM has been found to be “not the most motivating of texts for technical writers to use in the writing process”, which lead to the development of ALCOGRAM. — P²E⁵N⁵S¹, C T W D A I

Common Logic Controlled English (CLCE) (Sowa 2004) is a language that can be translated into first-order logic with equality in the form of the Conceptual Graph Interchange Format (CGIF). It is defined by a grammar in Backus-Naur form “that allows every ambiguity to be resolved when a sentence is parsed”. Some of the most important syntax restrictions are: no plural nouns, only present tense, and variables instead of pronouns. For an unambiguous mapping to logic, a number of interpretation rules are applied and parentheses are used to determine the structure of deeply nested sentences. Sentences in this language should be similar to those found in software documentation and textbooks of mathematics, for example:

If some person x is the mother of a person y , then the person y is a child of the person x .

Declare give as verb (agent gives recipient theme) (agent gives theme to recipient)
(theme is given recipient by agent) (theme is given to recipient by agent) (recipient is given theme by agent).

Imperative sentences, as the second example, are used to import or declare words. Names, nouns, verbs, adjectives, adverbs, and prepositions can be declared in this way. — P⁵E³N⁴S³, F W A

Computer Processable English (CPE) (Pulman 1996; Sukkarieh and Pulman 1999) is a controlled language that can be “completely syntactically and semantically analysed”. An early version of the language used KIF (Knowledge Interchange Format) as its logic formalism, whereas McLogic was used later on. The language comes with a bidirectional grammar implemented as a Prolog unification grammar. Two examples are shown here:

Every animal X eats some animal that is smaller than X .

Every registered user who has borrowed less than ten copies can borrow every available copy.

The mapping to logic seems to be deterministic, even though the available literature is not explicit about this. — P⁵E²N⁴S³, F W A

Computer Processable Language (CPL) (Clark et al. 2005) is a controlled variant of English developed at Boeing. It is very different from earlier CNL approaches where Boeing was involved in, like ASD-STE and Boeing Technical English. CPL is much more restricted than these earlier approaches and sacrifices to some degree expressiveness and naturalness for the sake of automated reasoning support. Basic CPL sentences are restricted to the pattern “subject + verb + complements + adjuncts”. There are further restrictions on the syntax, e.g. that definite references have to be used instead of pronouns. Statements involving universal quantification are constructed from seven templates like “If sentence1 then typically sentence2”, where “sentence1” and “sentence2” are basic CPL sentences of the structure introduced above and where “typically” is a reliability degree: one of “(almost) always”, “usually”, “sometimes” and “never”. These are two examples of CPL:

IF a person is carrying an entity that is inside a room THEN (almost) always the person is in the room.

AFTER a person closes a barrier, (almost) always the barrier is shut.

A parser translates CPL sentences into a frame-based language with well-defined semantics. In contrast to most other logic-based CNL approaches with custom-built parsers, the parsing process of CPL involves different external tools and resources. An existing parser for unrestricted English is used to generate an intermediary logical form. Then, WordNet and other resources are used to make a “best guess”. The resulting logical representation is then paraphrased and shown to the user for verification or correction. — P³E³N⁴S², F W I

Controlled Automotive Service Language (CASL) (Means and Godden 1996; Means, Chapman, and Liu 2000) is a controlled language for writing service manuals and bulletins at General Motors developed in the 1990s. The goals were to improve translatability, as well as consistency and readability. The approach moved from an “author-centric model” towards a “hybrid model” that included the role of an editor, before it went to full production in 2000 (Godden 2000). The CASL restrictions are defined by 62 rules, including restrictions on sentence structure, word order, vocabulary, and punctuation. This is an exemplary sentence:

Several diseases result from asbestos exposure, with latency periods of 10 to 40 years or longer.

Writers are supported by a software tool called *CASLChecker*. — P²E⁵N⁵S¹, C T W D I

“Controlled English at Clark” (Adriaens and Schreors 1992) was a language used at the Clark Material Handling Company. It was developed around the late 1980s and was influenced by SMART Plain English. — P²E⁵N⁵S¹, C W D I

“Controlled English at Douglas” (Kleinman 1982) was a language developed in 1979 by the McDonnell Douglas aerospace company for their technical manuals. It was based on a dictionary of about 2000 words (most of them verbs), favoring short and simple words and aiming at a single word per meaning and a single meaning per word. In addition to the words of the dictionary, “nomenclature words” can be introduced. The goal was to improve readability, translatability and standardization. It was probably influenced by CFE and had itself an influence on AECMA SE. — P²E⁵N⁵S¹, C T W D I

“Controlled English at IBM” (Adriaens and Schreors 1992) was a language developed and used at IBM in the late 1980s. It was influenced by ILSAM and might have influenced EasyEnglish, which was also developed at IBM several years later. It relied on a closed list of words, and writers were assisted by different instruction programs. — P²E⁵N⁵S¹, C W D I

“Controlled English at Rockwell” (Adriaens and Schreors 1992) was a language used at the company Rockwell International. It was developed around the late 1980s and was influenced by SMART Plain English. — P²E⁵N⁵S¹, C W D I

Controlled English to Logic Translation (CELT) (Pease and Li 2010) is a controlled natural language presented in 2003. It is a domain-independent language inspired by ACE. In contrast to ACE, it uses existing linguistic and ontological resources, concretely the SUMO ontology and WordNet. These are two exemplary sentences:

Dickens writes *Oliver Twist* in 1837.

Every boy likes fudge.

The syntax structure of CELT sentences is deterministically parsed. Heuristics are applied only afterwards to map the words to SUMO and WordNet. The language is implemented as a unification grammar in Prolog. — $P^4E^2N^4S^3, F W I$

Controlled Language for Crisis Management (CLCM) (Temnikova 2010, 2011) is a language for writing instructions about how to deal with crisis situations. The language is defined by about eighty simplification rules. These simplification rules include restrictions on text structure (e.g. “Write a title for every specific situation”), formatting (“Separate with a new line each block of instructions”), lexicon (e.g. “avoid technical terms”), syntax (e.g. “Avoid passive voice”), semantics (e.g. “Use only literal meaning”), and pragmatics (e.g. “Remove unimportant information”). — $P^2E^5N^5S^1, C T W D A$

Controlled Language for Inference Purposes (CLIP) (Sukkarieh 2003) is a language based on the logic notation *McLogic*. The language was influenced by CPE. It is “semantically-driven”, meaning that it was designed around the given logic formalism and not vice versa. Two examples are shown here:

Every student who laughs succeeds
Smith and Jones sign five contracts

— $P^5E^2N^4S^3, F W A$

Controlled Language for Ontology Editing (CLOnE) (Funk et al. 2007) (previously called *CLIE controlled language*) is a CNL designed as a front-end language for OWL, covering only a small subset of it. It is defined by ten basic sentence patterns. It adds procedural semantics on top of OWL to introduce and remove entities and axioms. These are two examples of CLOnE sentences:

Persons are authors of documents.
Forget everything.

— $P^5E^2N^4S^4, F W A$

Controlled Language Optimized for Uniform Translation (CLOUT) (Muegge 2007) is a CNL to improve machine translation. It puts restrictions on the vocabulary and prohibits structures like passive voice and pronouns. — $P^2E^5N^5S^1, T W I$

Controlled Language of Mathematics (CLM) (Humayoun and Raffalli 2010) is a language for expressing mathematical texts, as found in textbooks. The language is similar to Naproche CNL and ForTheL. The grammar of CLM is implemented in GF (Grammatical Framework) and allows for deterministic translation into first-order logic. The goal is to automatically verify mathematical proofs. — $P^5E^3N^4S^3, F W D A$

Coral’s Controlled English (Kuhn and Hoefler 2012) is a controlled language for expressing formal queries to annotated text corpora. It is influenced by ACE, but is much less expressive, simpler and more domain-specific. It is embedded into a query interface called Coral to enable users with no particular background in computer science to effectively use large corpora of annotated texts. This is an exemplary query:

Find all passages where a noun phrase contains a verb phrase; the verb phrase precedes a prepositional phrase; the prepositional phrase contains a verb “see”;

Such queries are deterministically mapped to AQL, an existing formal query language. The language is defined by 51 simple grammar rules. — $P^5E^1N^4S^4, F W D A$

Diebold Controlled English (DCE) (Hayes, Maxwell, and Schmandt 1996; Moore 2000) is a controlled language developed at Diebold with the goal to make translation faster and less expensive by assisting human translators with specific translation tools. It

was inspired by CTE, but has less strict restrictions on lexicon and grammar, making the approach more flexible. The approach consists of three main components: a lexical database, a set of grammar rules, and a checking tool. — $P^2E^5N^5S^1$, C T W D I

DL-English (Thorne and Calvanese 2010) is a Description Logic based controlled language presented together with other similar languages to study and compare their computational complexity. It is similar to Lite Natural Language by the same research group. — $P^5E^2N^4S^4$, F W A

“Drafter Language” (Power and Scott 1998) is a CNL used in a system called *Drafter-II*. The language is used for instructions to word processors and diary managers. This is a very simple example of an incomplete instruction:

Schedule the appointment by applying *this method*.

Employing a conceptual authoring approach, such incomplete statements are gradually completed by the user. Internally, the statements are mapped to Prolog expressions and then executed. — $P^4E^1N^4S^3$, F W D A

E-Prime (or *E'*) (Bourland 1965) is a restricted version of English with the only restriction being that the verb “to be” is forbidden to use. This includes all inflectional forms like “are”, “was” and “being”, regardless of whether used as auxiliary or main verb. The language was presented in 1965 but the idea goes back to the late 1940s. The motivation for the use of E-Prime is the belief that “dangers and inadequacies [...] can result from the careless, unthinking, automatic use of the verb ‘to be’”. E-Prime is claimed by its proponents to enhance clarity. The statement “We do this because it is right” would not be allowed, but one would have to rephrase it in a way that does not include “to be”, for example:

We do this thing because we sincerely desire to minimize the discrepancies between our actions and our stated “ideals”.

In the area of natural language processing, however, the verb “to be” is *not* considered one of the most difficult problems, which is good evidence that E-Prime is not considerably more precise than full English in the PENS sense of the word *precise*. — $P^1E^5N^5S^1$, C W A

E2V (Pratt-Hartmann 2003) is a controlled language that was introduced in 2001 and that corresponds to the language \mathcal{E}_3 studied in later work (Pratt-Hartmann 2004). The ultimate goal is “to provide useable tools for natural language system specification”. E2V deterministically maps to the two-variable fragment of first-order logic. Because of this, satisfiability of E2V sentences and texts is decidable and computation is NEXP-TIME complete. Two examples of E2V sentences are shown here:

Some artist does not despise every beekeeper.

Every artist who employs a carpenter despises every beekeeper who admires him.

The language is defined by 15 simple grammar rules plus nine predefined lexical rules for general words like “every” and “does not”. A separate, user-defined lexicon contains the domain-specific words like “artist” and “admires”. — $P^5E^2N^4S^4$, F W A

EasyEnglish (by IBM) (Bernth 1997) (not to be confused with Wycliffe Associates’ EasyEnglish) is a language developed at IBM. It might have been influenced by an earlier controlled English at IBM (Adriaens and Schreors 1992). The main goal of EasyEnglish was to improve machine translation. The approach is based on a sophisticated grammar checker that returns suggestions and warnings. Apart from detecting

common grammar errors, the system can enforce the use of a certain controlled vocabulary and can spot ambiguities. For such ambiguities, the system can propose alternatives, but it is ultimately up to the user whether to follow the system's suggestions or not. The problems encountered in a given document are quantified in the form of a *clarity index*, which must be above a certain threshold value. The fact that the restrictions of the language are not enforced but just suggested does not make the language more precise or simpler than full natural English. EasyEnglish has been extended later to check not only on the sentence level but also on the document level, and this has been implemented in a tool called EasyEnglishAnalyzer (Bernth 2006). — P¹E⁵N⁵S¹, C T W I

EasyEnglish (by Wycliffe Associates) (Betts 2003) (not to be confused with IBM's EasyEnglish) is a controlled language used for transcribing biblical texts. The original goal was to improve the translation process into other languages, but EasyEnglish is also directly used by readers with limited knowledge of English. The language is restricted with respect to lexicon, syntax and semantics. There are two levels: level A makes use of about 1200 words, whereas level B has a larger lexicon of about 2800 words. The meaning of these words is restricted. For example, "fair" can only mean "unbiased", and "to see" cannot be used in the sense "to meet". It is possible to use words that are not on the list, but these words have to be explained in separate EasyEnglish sentences. The following is an excerpt of a text in EasyEnglish ("moore" is not in the lexicon and has to be explained):

The Highlands of Scotland consist of lakes, mountains and moors. The moors are flat empty lands where no trees grow. This land is wonderful and magnificent because it is so empty.

There is a strict sentence length limit of 20 words, and paragraphs may not contain more than 150 words. Sentence structure is kept simple by allowing not more than two finite clauses and not more than two prepositional phrases per sentence. Furthermore, deep nesting and passives are restricted. In addition, texts should adhere to logical simplicity: "EasyEnglish writers are encouraged to identify the basic idea units in a complex sentence or paragraph and arrange them in logical order". — P²E⁵N⁵S¹, C T W D

Ericsson English (EE) (Adriaens and Schreors 1992) was a language used at Ericsson, developed in the early 1980s and influenced by ILSAM. The language is built on a closed list of acceptable words, but other words can be introduced if accompanied by a definition in EE. — P²E⁵N⁵S¹, C W D I

FAA Air Traffic Control Phraseology (FAA 2010) is a controlled language defined by the Federal Aviation Administration (FAA) and used for the communication in air traffic coordination, going back to at least the early 1980s but probably earlier. There are other very similar languages for air traffic control like the ICAO and CAA phraseologies. Together, they are sometimes called "AirSpeak" (Robertson 1987). The FAA Phraseology is defined by more than 300 fixed sentence patterns like "(ACID), IN THE EVENT OF MISSED APPROACH (issue traffic). TAXIING AIRCRAFT/VEHICLE LEFT/RIGHT OF RUNWAY". An example of a statement following this pattern is shown here:

United 623, in the event of missed approach, taxiing aircraft right of runway.

In addition to these explicit patterns, there are many more implicit patterns defined in prose form, e.g. "Issue advisory information on [...] bird activity. Include position, species or size of birds, if known, course of flight, and altitude". The following statement is an example that corresponds to this implicit pattern:

Flock of geese, one o'clock, seven miles, northbound, last reported at four thousand.

Vocabulary and semantics are restricted too, e.g. “Use the word *gain* and/or *loss* when describing to pilots the effects of wind shear on airspeed”. Phraseology statements can be mixed with statements in full English in cases where no pattern exists to express the desired message. — $P^2E^1N^3S^2, C S D G$

First Order English (Pool 2006) is a controlled natural language that maps to first-order logic. No detailed description of this language is available. — $P^5E^3N^4S^3, F W A$

Formalized-English (FE) (Martin 2002) is a CNL for knowledge representation. It is based on Conceptual Graphs and the Knowledge Interchange Format (KIF), and focuses on expressiveness. It covers a wide range of features including general universal quantification, negation, contexts (statements about statements), lambda abstractions, possibility, collections, intervals, and higher-order statements (reducible to first-order logic). Two examples of statements in FE are shown here (the second one is higher-order):

At least 93% of [bird with chrc a good health] can be agent of a flight.

If ‘a binaryRelationType *rt has for chrc the transitivity’ then ‘if ‘^x has for *rt ^y that has for *rt ^z’ then ‘^x has for *rt ^z’ ‘.

FE looks natural for simple statements, but becomes quite unnatural for more complex ones. This is due to unnatural use of parentheses, quotation marks, variables, and keywords like “chrc”. The language is defined by about 50 rules in a parser generator language. — $P^5E^4N^3S^3, F W A$

ForTheL (Vershinin and Paskevich 2000) is a CNL for mathematical texts similar to Naproche CNL and CLM. The name stands for “Formal Theory Language”. Statements in this language can be automatically translated into first-order logic with equality. The following is an exemplary text:

Lemma 1. Each set has a subset.

Proof. 0 is a subset of all sets. QED.

— $P^5E^3N^4S^3, F W D A$

Gellish English (van Renssen 2003) is a controlled language designed as a common data language for industry. Basically, it consists of simple subject-predicate-object structures with predefined relations in the form of fixed phrases like “is a specialization of” and “is valid in the context of”. These are two examples:

collection C each of which elements is a specialization of animal

the Eiffel tower has aspect h1

h1 is classified as a height

h1 is qualified as 300 m

Gellish builds upon a fixed upper ontology with a large number of predefined concepts and relation types. Gellish texts can be transformed into relational database tables, which provides the logical foundation of the language. The semantics of the language, however, is not fully formalized. Gellish has limited support for quantification, but not for general rule structures. — $P^4E^2N^4S^3, F W A I$

General Motors Global English (Means, Chapman, and Liu 2000) (or just *Global English*) is a controlled language developed at General Motors. The goal was to improve comprehension for non-native speakers and translatability. It is defined by 15 rules based on four principles: “be brief”, “be clear”, “be direct”, and “be culturally alert”. These rules include a limit on the sentence length and grammatical restrictions such as the exclusion of passive voice. The language evolved from a reduced set of 12 of

the 62 rules of the CASL language, which was developed at General Motors several years earlier. In contrast to CASL, Global English does not come with a software tool for checking the compliance with the restrictions. — $P^2E^5N^5S^1$, C T W D I

“GINO’s Guided English” (Bernstein and Kaufmann 2006) is a language used in GINO, a system to query and edit ontologies. The language was influenced by Ginseng and supports the same kinds of queries. In addition, GINO has some limited support for procedural statements to introduce new entities, for instance:

There is a subclass of class water area named lake.

Query statements are mapped to SPARQL and procedural statements map to OWL axioms to be added or modified. Queries can exhibit structural ambiguity, in which case the system evaluates all possible interpretations and shows the user the union of answers. The grammar that describes the language consists of 120 grammar rules. — $P^4E^2N^4S^3$, F W A

“Ginseng’s Guided English” (Bernstein et al. 2006) is a CNL used in a system called Ginseng, which is a query interface to access knowledge bases in the form of OWL ontologies. The vocabulary for the language is loaded from the respective ontologies. These are two examples of queries:

What are the capitals of states that border Nevada?

Is there a city that is the highest point of a state?

The grammar consists of 120 static grammar rules plus additional dynamic rules generated from the ontologies. — $P^5E^1N^4S^3$, F W A

Hyster Easy Language Program (HELP) (Smart 2003) is a controlled English developed in the 1980s for maintenance manuals for lift trucks. It is based on SMART Plain English and thus indirectly on CFE (Pym 1990). — $P^2E^5N^5S^1$, C W D I

ICAO Phraseology (Eurocontrol 2009) is phraseology for air traffic control defined by the International Civil Aviation Organisation (ICAO). It is very similar to the phraseologies by FAA and CAA. — $P^2E^1N^3S^2$, C S D G

“ICONOCLAST Language” (Power 1999) is a CNL to write patient information leaflets. It is similar to the Drafter Language. A formal logic representation is used in the background, employing a conceptual authoring approach. This is a simple example:

If you develop a rash, you should consult your doctor.

— $P^4E^3N^5S^3$, F W D A

iHelp Controlled English (iCE)⁴ is a language developed by iHelp Ltd, a documentation consultancy company. iCE consists of “a set of flexible rules and vocabularies for companies wishing to standardise and improve their information”. — $P^2E^5N^5S^1$, C T W I

iLastic Controlled English (iLastic 2012) is a language to allow non-developers to write intuitive and natural scripts that automatically retrieve, transform and combine data from the web, databases, files, and other resources. This is an exemplary statement:

delete all files under the tmp folder if the space of the disk is lower than 1024.

⁴ <http://www.lindy-hop.co.uk/iHelp/ice/>

— $P^5E^3N^4S^3$, F W I

International Language of Service and Maintenance (ILSAM) (Pym 1990) is an influential language similar to Caterpillar Fundamental English, from which it was derived in the 1970s. — $P^2E^5N^5S^1$, C W D I

ITA Controlled English (ITA CE) (Mott 2010) is a controlled language defined by the International Technology Alliance, a US/UK military research program. It is inspired by CLCE, but is less strict in terms of precision: it has an “informal meaning and a semi-formal mapping to predicate logic”. The following are two examples of statements of different types:

if (the person X has the person Y as brother) and (the person Z has the person X as father) then (the person Z has the person Y as uncle) .

“the plan has failed” because “there was a misunderstanding”.

The first example shows a “logical rule”; the second example is a “rationale” statement. Parentheses and variables are used to disambiguate. Around 90 grammar rules define the language. — $P^3E^3N^4S^3$, F W I

KANT Controlled English (KCE) (Mitamura and Nyberg 1995) is a controlled natural language for machine translation used within the KANT translation system. The language was first presented under this name in 1995, but it had at that point already been studied and used for several years. The focus is on technical documents, and KCE was the basis for the development of Caterpillar Technical English. Lexicon, grammar, and semantics are restricted. In addition, ambiguities are resolved interactively by augmenting the input sentences with SGML tags. In the sentence “Secure the gear with twelve rivets”, for example, the attachment of the preposition “with twelve rivets” is ambiguous. In KCE, this ambiguity can be resolved by augmenting the sentence with an SGML tag of the following form:

Secure the gear with <attach head=‘secure’ modi=‘with’> twelve rivets.

For the classification of the language, the question arises whether the SGML tags are part of the language or just a method to keep track of decisions concerning ambiguities. The SGML tags positively contribute to the precision of the language but heavily impede its naturalness. Since such markup tags are usually hidden and since KCE texts are initially written without tags, which are only afterwards added, we consider them a part of the KANT methodology but not of the controlled language itself. — $P^2E^5N^5S^1$, T W A

Kodak International Service Language (KISL) is a CNL developed at Kodak in the early 1980s. Some see it as a decendent of CFE (Spaggiari, Beaujard, and Cannesson 2003). — $P^2E^5N^5S^1$, C W D I

Lite Natural Language (Bernardi, Calvanese, and Thorne 2007) is a CNL based on the language E2V and its variants. It has a deterministic mapping to DL-Lite, which is a logical formalism optimized for good computational properties and is equivalent to a subset of OWL. — $P^5E^2N^4S^4$, F W A

“Massachusetts Legislative Drafting Language” (Massachusetts Senate 2003) is a restricted language for legal texts defined by the Massachusetts Senate. The purpose of the language is “to promote uniformity in drafting style, and to make the resulting statutes clear, simple and easy to understand and use”. It is defined by about 100 rules that restrict syntax (e.g. “Use the present tense and the indicative mood.”), semantics (e.g. “Do not use ‘deem’ for ‘consider’.”), and document structure (“Use short sections or subsections.”). In addition, there are close to 90 words and phrases that must not be

used, with suggested replacements for each of them (e.g. “hide” instead of “conceal”, and “rest” instead of “remainder”). — $P^2E^5N^5S^1$, C W D G

“MILE Query Language” (Piwek et al. 2000) is a query language to access maritime rules and regulations. It follows the conceptual authoring approach in a very similar way as the Drafter and CLEF languages. — $P^4E^1N^4S^3$, F W D A

Multinational Customized English (MCE) (Ruffino 1982) is a controlled language developed at Xerox to improve the quality of machine-assisted translation. It was based on ILSAM (Adriaens and Schreors 1992). It uses a restricted domain-specific vocabulary and “a set of writing rules which encourage a clear, concise English and a minimization of ambiguities”. — $P^2E^5N^5S^1$, T W D I

Nortel Standard English (NSE) (Smart 2006) is a language developed at Nortel, a telecommunications equipment manufacturer. The development started in 1995 with the help of SMART Communications, so it was probably influenced by SMART Plain English. — $P^2E^5N^5S^1$, C W D I

Naproche CNL (Cramer et al. 2010) is a controlled language for mathematical texts similar to CLM and ForTheL. Texts in Naproche CNL can be deterministically mapped to first-order logic and then automatically checked for logical correctness. The following is an excerpt of a proof written in this language:

Axiom 3: For every $x, x' \neq 1$.

Axiom 4: If $x' = y'$, then $x = y$.

Theorem 1: If $x \neq y$ then $x' \neq y'$.

Proof: Assume that $x \neq y$ and $x' = y'$. Then by axiom 4, $x = y$. Qed.

According to its authors, most texts of mathematical textbooks “can be rewritten in the Naproche CNL in such a way that they resemble the original text”. — $P^5E^3N^4S^3$, F W D A

NCR Fundamental English (NCR 1978) is a CNL developed at NCR Corporation. The language was used for the technical manuals of the company in order to make them “easier to read and use by NCR employees and customers around the world”. These are two examples of sentences:

While repairing the unit, the field engineer also performs normal maintenance if it is needed.

No maintenance can be performed until the maintenance lock has been activated.

The language consists of three parts: nomenclature, glossary, and vocabulary. Every word of the language belongs to exactly one of these categories. The nomenclature is an open set of different kinds of named individual entities, such names of products, tools, routines, as well as named modes and conditions. The glossary is another open set of words for technical concepts, like “audit trail”, that cannot be replaced by a phrase or brief clause using the words of the vocabulary. The vocabulary, finally, is the most interesting part. It consists of a fixed set of 1350 words (verbs, nouns, adverbs, adjectives, pronouns, prepositions, articles, and conjunctions) plus 650 abbreviations. The content of the vocabulary ranges from fundamental words like “a”, “not” and “in” to domain-specific terms like “testware”, “calibrate” and “taxable”. The meaning of these words is restricted. Each word comes with a definition in full English. The noun “medium”, for instance, is defined as “a method of payment” and must not be used in any other sense. The grammar is not explicitly restricted. — $P^2E^5N^5S^1$, C W D I

Océ Controlled English (Cucchiari 2002) is a controlled language developed at Océ, a Dutch company in the printing and copying business. Océ Controlled English is

combined with traditional machine translation techniques to improve the translation quality of the company’s documentation in 17 different languages. One of the important properties of the language is that it leads to more concise texts. For example, instead of “In several windows, an icon shows the current status/activity of a printer. See the list below for a description of each status.” one would write:

These icons show the status or activity of the copier.

The language is implemented with the help of the MAXit Checker by SMART Communications. — $P^2E^5N^5S^1, T W D I$

OWL ACE (Kaljurand and Fuchs 2006) is a controlled language for the ontology language OWL. Syntactically, it is a subset of ACE. Semantically, it is tailored towards the expressiveness of OWL and is more specific than ACE with its underspecified semantics, particularly in the case of plurals. Thus, OWL ACE is more precise but less expressive than ACE. — $P^5E^2N^4S^3, F W A$

“OWLPath’s Guided English” (Valencia-García et al. 2011) is a query language for a tool called *OWLPath*, with which ontologies can be queried. Statements in this language start with the phrase “view any”. These are two examples:

View any COMMODITY has_quoted_price in BMF.

View any COMPANY whose STOCK_PRICE.lastTrade is_greater_than \$30 and is_included_in Dow_Jones in 2009-04-24.

These statements are translated into the SPARQL query language. Even though their structure roughly follows English grammar, they cannot be considered valid English sentences. — $P^5E^2N^3S^4, F W A$

OWL Simplified English (Power 2012) is a controlled language for the Semantic Web. In contrast to most other approaches, there is no real lexicon, neither built-in nor user-defined. Only a very small number of function words are predefined, and users have to list the verbs they intend to use. All other word categories are inferred based on syntactic clues such as capitalization and adjacent words. This is an example (assuming that “governed” and “lives” are listed as verbs):

London is capital of a country that is governed by a man that lives in Downing Street.

— $P^5E^2N^4S^4, F W A$

“PathOnt CNL” (Kim et al. 2005; Namgoong and Kim 2007) is a controlled language developed for a tool called *PathOnt*. The tool is multilingual, supporting English and Korean. Statements in this language are deterministically mapped to RDF triples. These are two exemplary sentences:

Nam is a student supervised by a professor named Kim.

A received specimen fixed in formalin is a soft tissue mass.

The language seems to cover only simple existential statements. — $P^5E^1N^4S^4, F W A$

PENG (Schwitter 2002) is a controlled language whose name stands for “Processable English”. It is a rich but unambiguous language that can be automatically translated via discourse representation structures into first-order logic with equality. It is inspired by ACE and has a strong focus on predictive editing. These are two examples:

Every animal A eats all plants or eats all animals B that are smaller than A and that eat some plants.

While the fox sleeps, the cat chases a bird.

— $P^5E^3N^4S^3, FWA$

PENG-D (Schwitter and Tilbrook 2004) is a language derived from PENG, the main difference being that PENG-D builds upon RDF and OWL instead of discourse representation structures. — $P^5E^3N^4S^3, FWA$

PENG Light (Schwitter 2008) is another language derived from PENG. It maps to the TPTP notation for first-order logic. — $P^5E^3N^4S^3, FWA$

Perkins Approved Clear English (PACE) (Pym 1990) is a controlled language developed at Perkins, a diesel engine manufacturer and now a subsidiary of Caterpillar. The language was introduced in 1980 and was based on ILSAM. The goal was to improve machine-assisted translation. In order to avoid the use of synonyms, PACE comes with a dictionary which has been gradually extended and counted 2500 entries in 1990, such as “passage (n): A drilling along which a fluid moves”. PACE is summarized in “Ten Rules of Simplified Writing”:

- | | |
|--|--|
| 1. keep sentences short | 6. avoid elliptical constructions |
| 2. omit redundant words | 7. do not omit conjunctions or relatives |
| 3. order the parts of the sentence logically | 8. adhere to the PACE dictionary |
| 4. do not change constructions in mid sentence | 9. avoid strings of nouns |
| 5. take care with the logic of ‘and’ and ‘or’ | 10. do not use ‘ing’ unless the word appears thus in the PACE dictionary |

The aim of the first five rules is to make the text short and simple, while the last five rules have the somewhat opposing objective to make the text more explicit. This is an example consisting of two PACE sentences:

Loosen the pivot fasteners of the dynamo or of the alternator. Loosen also the fasteners of the adjustment link.

— $P^2E^5N^5S^1, CTWDI$

PERMIS Controlled Natural Language (Inglesant et al. 2008) is a language for expressing access control policies for grid computing environments. It is based on CLonE with specific extensions for authorization policies:

Staff can print on HP Laserjet 1.

I trust David to say who managers are.

Such statements are mapped to different formal target notations. Each statement follows one of only nine statement patterns. — $P^5E^2N^4S^4, FWD A$

“PILLS Language” (Bouayad-Agha, Power, and Belz 2002) is a language for medical information documents used in a system called *PILLS*. It follows a similar editing approach as the ICONOCLAST language, which was developed a couple of years earlier by the same research group. With the PILLS approach, different types of documents can be automatically generated from a master document and translated into different languages. — $P^4E^1N^5S^3, TFD A$

Plain Language (or *Plain English*) (SEC 1998; PLAIN 2011) is an initiative by the US government and other organizations. It had its origins in the 1970s with the goal to make official documents easier to understand and less bureaucratic. “Use pronouns to speak directly to readers” and “Avoid double negatives and exceptions to exceptions” are two exemplary rules. Unlike other such “style guides”, many of the guideline rules are strict and, with the Plain Writing Act of 2010, US governmental agencies are obliged to comply with them. With the focus being on human understandability and acceptance,

documents in Plain Language do not seem to be considerably more precise or simpler from a computational point of view, compared to full English. — $P^1E^5N^5S^1$, C W G

PoliceSpeak (Johnson 2000) is a language developed to improve police communications of English and French officers at the Channel Tunnel. The goal was to “make police communications more concise, more predictable, more stable and less ambiguous”. The project was launched in 1988 and the language was ready in 1992. It has a similar goal and application area as SEASPEAK and the different air traffic control phraseologies. — $P^2E^1N^3S^2$, C S D G

“PROSPER Controlled English” (Grover et al. 2000) is a language for the specification and verification of hardware designs, developed in the late 1990s. The language is based on a restricted version of a general English grammar. Sentences of the language can be automatically mapped to a certain type of temporal logic. This is an exemplary sentence:

If *sigi* is high and then is low on the next cycle, then *sigo* is low and after one cycle becomes high and then after one more cycle becomes low.

Since ambiguity is not completely eliminated, the mapping to logic is not deterministic. However, ambiguous sentences can be automatically spotted and reported to the user. — $P^3E^3N^4S^3$, F W D A

Pseudo Natural Language (PNL) (Marchiori 2004) is a language designed as a user-friendly language for the Semantic Web. It builds upon RDF and first-order logic, and uses Prolog to calculate inferences. These are two exemplary sentences:

JOHN represents the person “John Smith” from the company “http://www.example.com/staff”.

if IMPLY has as ARGUMENTS X and Y in this order, then X LOGICAL-IMPLY Y.

Upper-case words like “JOHN” act as variables that can be instantiated with concrete definitions involving URIs. PNL is unambiguous and has well-defined semantics. The sentences look quite natural, though the capitalization mitigates the natural flow. The language looks simple at first sight, but rather complex rules have to be applied in order to resolve ambiguous syntax trees. — $P^5E^3N^4S^3$, F W A

“Quelo Controlled English” (Franconi et al. 2011) is a language introduced in 2010 and used in a query interface called *Quelo*. This is an exemplary query:

I am looking for something. It should be equipped with an automatic transmission system and sold by a car dealer. The car dealer should sell a fleet car.

Following a conceptual authoring approach, users cannot directly edit the sentences, but they can trigger modification actions on the underlying formal representation. — $P^4E^1N^4S^4$, F W A

Rabbit (Hart, Johnson, and Dolbear 2008) is a controlled language for OWL. It has been developed and used by Ordnance Survey, Great Britain’s national mapping agency. Rabbit is designed for a specific scenario, in which it is used for the communication between domain experts and ontology engineers to create ontologies. Three types of statements are supported: declarations, axioms, and import statements. These are examples of the first and second type:

Sheep is a concept, plural Sheep.

Every River flows into exactly one of River, Lake or Sea.

The language is quite simple, being defined by a small number of sentence patterns and some modifications thereof. — $P^5E^2N^4S^4$, F W G

Restricted Natural Language Statements (RNLS) (Breaux and Antón 2005; Breaux, Antón, and Doyle 2008) is a language for policy statements and software engineering goals introduced in 2004. The following are two exemplary RNLS statements:

RNLS #1: The customer will select access codes.

RNLS #2: The provider will recommend (RNLS #1) to the customer.

The second sentence refers to the first one using its identifier “RNLS #1”. There is a mapping between RNLS and Description Logic, but it is not clear whether this mapping is automated. — $P^3E^2N^4S^3$, F W D A

RuleSpeak (Ross 2003; OMG 2008) is a CNL for business rules. The language was developed starting from 1985 and it was first presented in 1994. It is very similar to SBVR Structured English, which emerged later. Each RuleSpeak rule belongs to one of eleven “functional categories” like “computation rule”, “inference rule” or “process trigger”. For each of these categories specific templates are defined. Computation rules, for example, contain the phrase “must be computed as” or simply “=”. The first of the following two examples is such a computation rule:

A product’s cost must be computed as the sum of the cost of all its components.

An order may be accepted only if all of the following are true:

- It includes at least one item.
- It indicates the customer who is placing it.

Sometimes the color codes of SBVR Structured English are adopted to emphasize the different types of the sentence constituents. As SBVR Structured English, RuleSpeak is linked to the SBVR (Semantics of Business Vocabulary and Business Rules) standard, which provides formal semantics based on second-order logic with Henkin semantics. However, the mapping from RuleSpeak texts to the logical representation is only defined in an informal way. The strict templates considerably simplify the language, but there is no formal grammar that would fully define the language. — $P^3E^4N^4S^2$, C F W I

SBVR Structured English (OMG 2008) is a second CNL for business rules. It is part of the SBVR standard, and was probably influenced by RuleSpeak. The vocabulary is extensible and consists of three types of sentence constituents: terms (i.e. concepts), names (i.e. individuals), verbs (i.e. relations), and keywords (e.g. fixed phrases, quantifiers, and determiners). Each of these has its own color and style, as the following examples show:

A rental must be guaranteed by a credit card before a car is assigned to the rental.

Rentals by Booking Mode contains the categories 'advance rental' and 'walk-in rental'.

As RuleSpeak, it has a mapping to second-order logic with Henkin semantics. The second of the above examples makes use of the second-order features. Some keyword have a precise meaning, such as “or” meaning inclusive logical disjunction (unless followed by “but not both”). Other keywords, however, are less precise, like the determiner “a” being defined as “universal or existential quantification, depending on context based on English rules”. As with RuleSpeak, there is no formal grammar of the language, and its definition depends to some degree on the linguistic understanding of a human reader. — $P^3E^4N^4S^2$, C F W I

SEASPEAK (Strevens and Johnson 1983) is an “International Maritime English” designed for clear communication among ships and harbors. Its development started in 1981. It is a controlled phraseology very similar to PoliceSpeak and the different air traffic control phraseologies. — $P^2E^1N^3S^2$, C S D G

SMART Controlled English (Smart 2006) is a “more advanced version” of ASD Simplified Technical English, developed by the company SMART Communications. It was probably influenced by SMART Plain English, and has been applied to different areas. This is an excerpt of a document in SMART Controlled English:

When the Quaternary Pump starts operation, the plunger moves inside the chamber. This movement lets the computer calculate and store a position called “Top Dead Center” (TDC).

The language is implemented in a tool called *MAXit Checker*, which is able to spot violations with the restrictions of the language. — $P^2E^5N^5S^1, C T W I$

SMART Plain English (sometimes called *Plain English Program (PEP)*) is a controlled language developed and used at SMART Communications since the mid 1980s.⁵ It is based on CFE and was the basis for HELP and the controlled languages at Clark and Rockwell (Adriaens and Schreors 1992). As for SMART Controlled English, the tool *MAXit Checker* can be used to create compliant documents. — $P^2E^5N^5S^1, C W I$

“Sowa’s syllogisms” (Sowa 2000b) are simple logic languages based on the syllogisms originally introduced by Aristotle around 350 BC (Aristotle ca. 350 B.C.). Sowa was probably the first to bring Aristotle’s syllogisms into the context of CNL, claiming that they are the first reported instance of a controlled natural language. Because this survey is restricted to English, Sowa’s version of the syllogisms is listed here instead of Aristotle’s original version in ancient Greek. The complete language can be described by just four simple sentence patterns:

Every A is a B. Some A is a B. No A is a B. Some A is not a B.

A and B can be any English common nouns like “cat” and “animal”. This language is very similar to the language \mathcal{E}_0 presented and studied by Pratt-Hartmann (Pratt-Hartmann 2004), who used some additional patterns:

Every A is not a B. No A is not a B. P is a B. P is not a B.

Here, P can be any English proper name like “Socrates”. We will use the term “Sowa’s syllogisms” in a sense that includes such similar approaches. The semantics is equally easy to define. The first four patterns shown above can be mapped to first-order logic like this (and similarly for the other patterns):

$\forall x(A(x) \rightarrow B(x)) \quad \exists x(A(x) \wedge B(x)) \quad \neg \exists x(A(x) \wedge B(x)) \quad \neg \forall x(A(x) \rightarrow B(x))$

— $P^5E^1N^4S^5, F W A$

Special English (Voice of America 2009) is a simplified English developed and used by the Voice of America (VOA), the official external broadcast institution of the US government. The language has been used since 1959 and is still used today for news on radio, television and the web. This makes it the second oldest English-based CNL (after Basic English) and the only one that has been in use for such a long period by the same organization. At the time of its creation, Special English was probably influenced by Basic English. The vocabulary is restricted to about 1500 words, which have changed over time. Sentences should be short and should be spoken at a slower speed. There are no explicit restrictions on grammar or semantics. — $P^1E^5N^5S^1, C W S G$

SQUALL (Ferré 2012) is a controlled natural language in the area of the Semantic Web to query and update RDF graphs. Sentences in this language are translated into the query

⁵ <http://www.smartny.com/plainEnglish.htm>

language SPARQL, whereby structural ambiguity is resolved based on a few syntactic rules. This is an example:

for every publication ?X, ?X has an author ?A and ?A cite-s ?X

The language is defined by about 50 simple grammar rules. — $P^5E^2N^4S^4$, F W A

Standard Language (SLANG) (Rychtyckyj 2002, 2005) is a language developed at Ford Motor Company around 1990. It was used to write process sheets containing build instructions for vehicle assembly plants. With SLANG, engineers can write instructions that are clear and concise and at the same time machine-readable. Based on these instructions, the system can, among other things, automatically generate a list of required elements. In addition, the restricted nature of the language is exploited to translate such instructions with the help of machine translation for their use in assembly plants in different countries. All SLANG sentences are in imperative mood and follow a certain general pattern starting with a main verb and followed by a noun phrase. In addition, there are restrictions on vocabulary and semantics. These are two exemplary sentences:

OBTAIN ENGINE BLOCK HEATER ASSEMBLY FROM STOCK

APPLY GREASE TO RUBBER O-RING AND CORE OPENING

A parser is used to check for compliance with the restrictions. — $P^3E^1N^4S^2$, C F W D I

Sun Proof (Wells Akis and Sisson 2002) is a controlled language introduced at Sun for their technical documentation. The initial development of the language lasted from 1999 until 2002. The general objective was to write texts that are “easier to understand and to translate for humans as well as machines” but with a clear focus on translatability. Sun Proof is restricted by three sets of guidelines: style guidelines, grammar rules, and terminology. One of the most important rules is the limitation of the sentence length to 25 words. Other rules include semantic restrictions like using “may” only for granting permission. This is an exemplary sentence:

This chapter provides an overview of the standardized solutions that are required to make the transition from IPv4 to IPv6.

— $P^2E^5N^5S^1$, C T W D I

Sydney OWL Syntax (SOS) (Cregan, Schwitter, and Meyer 2007) is a controlled language introduced in the context of the Semantic Web. It is based on PENG and provides a bidirectional and complete mapping to the ontology language OWL. These are two exemplary sentences:

The class adult is fully defined as any person that has at least 20 as an age.

If X has Y as a father then Y is the only father of X.

— $P^5E^2N^4S^4$, F W A

Template Based Natural Language Specification (TBNLS) (Esser and Struss 2007) is a CNL approach for functional tests of control software for passenger vehicles. The language is defined by 15 templates that provide a mapping to propositional logic with temporal relations. This is an exemplary sentence:

If Button B_4 is down P_1 occurs, then Lamp L_3 is red P_2 hold immediately, until 10 seconds T_1 elapsed.

P_1 and P_2 represent the propositional variables for the respective boxes, and T_1 is a time variable. — $P^5E^2N^4S^4$, F W D A I

ucsCNL (Barros et al. 2011) is a controlled natural language for use case specifications in the area of automated software testing. The language is intended to be unambiguous

and is defined by a small number of simple grammar rules. There are imperative sentences to describe user actions, as well as declarative statements to describe the system state before and after user actions:

After creating a message with 100 characters, go to the drafts folder

The imported media file is a music file

— $P^5E^2N^4S^4$, F W D A

4.2 Languages for comparison

For the analysis to be described in the next section, we will use the following languages for comparison, which are *not* CNLs according to our definition:

English is our representative of a natural language. — $P^1E^5N^5S^1$, C W S

Propositional logic is a very basic logic language. — $P^5E^1N^1S^5$, F W A

First-order logic can be considered an extension of propositional logic. It is more expressive, but also more complex. — $P^5E^3N^1S^4$, F W A

COBOL is one of the oldest programming languages, which some call a controlled natural language (Sowa 2000a). This is an exemplary COBOL statement:

```
PERFORM LoopBody WITH TEST BEFORE
  VARYING LoopCount FROM 1 BY 2
  UNTIL LoopCount GREATER THAN 5.
```

While COBOL uses natural phrases where other programming languages use symbols or short keywords, the statement structure does not really follow natural grammar. For that reason, we do not consider it a CNL. — $P^5E^2N^2S^3$, F W A I G

Manchester OWL syntax (Horridge et al. 2006) is a user-friendly syntax for the ontology language OWL. This is an exemplary expression:

Pizza and not (hasTopping some FishTopping) and not (hasTopping some MeatTopping)

Instead of logical symbols, natural words like “not” and “some” are used. The general structure, however, resembles formal and not natural languages, which is why we do not consider it a CNL. — $P^5E^2N^2S^4$, F W A

Naturally, there are many more languages that could be used for comparison, but the above languages seem to be a good sample.

5. Analysis

The data collected in the previous section allows for different kinds of aggregations and analyses. In particular, the classes and properties of the observed languages and the timeline of their evolution are interesting.

5.1 Classes and Properties

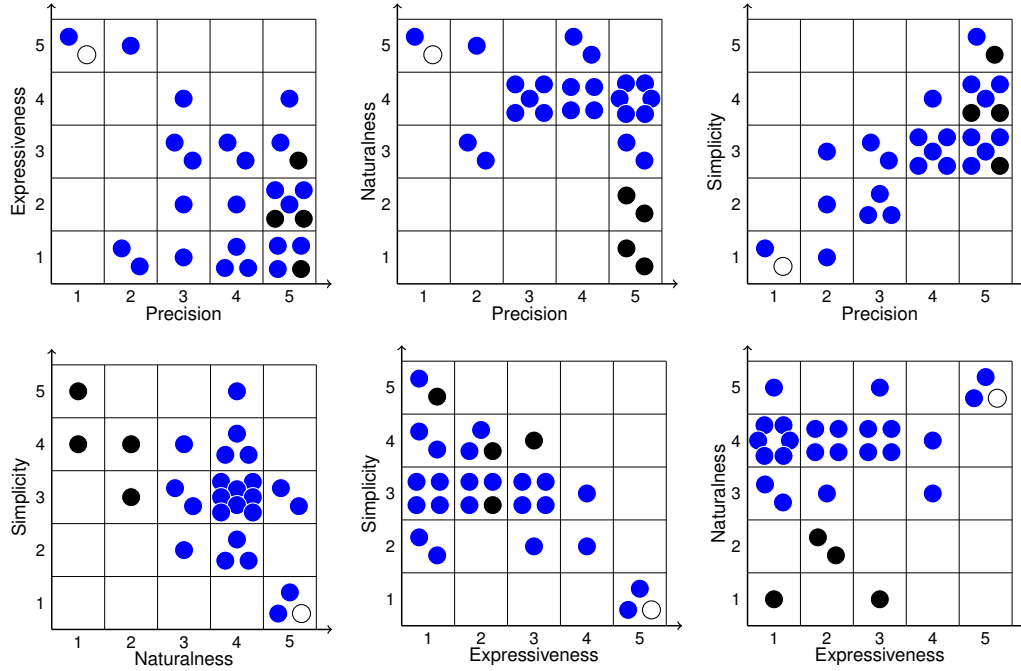
Table 2 summarizes the classes and properties of the discussed CNLs, which reveals some interesting patterns. Theoretically, there are $5^4 = 625$ possible PENS classes, but not all of them are observed “in the wild”. Some are even practically impossible, as far as we can tell, such as the perfect class $P^5E^5N^5S^5$. The CNLs introduced above cover

Table 2
Observed PENS classes and properties of CNLs

class	properties	languages
P ¹ E ⁵ N ⁵ S ¹	C T W I	IBM's EasyEnglish
	C W S G	Special English
	C W A	E-Prime
	C W G	Plain Language
P ² E ¹ N ³ S ²	C S D G	CAA Phraseology, FAA Phraseology, ICAO Phraseology, PoliceSpeak, SEASPEAK
P ² E ¹ N ³ S ³	C W D I	Airbus Warning Language
P ² E ⁵ N ⁵ S ¹	C T W D A I	ALCOGRAM, COGRAM
	C T W D A	CLCM
	C T W D I	ASD-STE, Avaya CE, Bull GE, CTE, CASL, CE at Douglas, DCE, General Motors GE, PACE, Sun Proof
	C T W D	Wycliffe Associates' EasyEnglish
	C T W I	iCE, SMART Controlled English
	C W D I	AECMA-SE, CFE, CASE, CE at Clark, CE at IBM, CE at Rockwell, EE, HELP, ILSAM, KISL, NCR FE
	C W D G	Massachusetts Legislative Drafting Language
	C W I	Boeing Technical English, NSE, SMART Plain English
	C W	Basic English
	T W D I	MCE, Océ Controlled English
	T W A	KCE
	T W I	CLOUT
P ³ E ¹ N ⁴ S ²	C F W D I	SLANG
P ³ E ² N ⁴ S ³	F W D A	RNLS
P ³ E ³ N ⁴ S ²	F W I	CPL
P ³ E ³ N ⁴ S ³	F W D A	PROSPER CE
	F W A	ClearTalk
	F W I	ITA CE
P ³ E ⁴ N ⁴ S ²	C F W I	RuleSpeak, SBVR-SE
P ⁴ E ¹ N ⁴ S ³	F W D A	Drafter Language, MILE Query Language
P ⁴ E ¹ N ⁴ S ⁴	F W A	Quelo Controlled English
P ⁴ E ¹ N ⁵ S ³	T F D A	PILLS Language
P ⁴ E ² N ⁴ S ³	F W A I	Gellish English
	F W A	GINO's Guided English
	F W I	CELT
P ⁴ E ³ N ⁴ S ³	F W A	ACE
P ⁴ E ³ N ⁵ S ³	F W D A	ICONOCLAST Language
P ⁵ E ¹ N ⁴ S ³	F W D A	CLEF Query Language
	F W A	Ginseng's Guided English
P ⁵ E ¹ N ⁴ S ⁴	F W D A	Coral's Controlled English
	F W A	PathOnt CNL
P ⁵ E ¹ N ⁴ S ⁵	F W A	Sowa's syllogisms
P ⁵ E ² N ³ S ⁴	F W A	OWLPath's Guided English
P ⁵ E ² N ⁴ S ³	F W A	CPE, CLIP, OWL ACE
	F W D A I	TBNLS
	F W D A	BioQuery-CNL, PERMIS CNL, ucsCNL
	F W A	CLOnE, DL-English, E2V, Lite Natural Language, OSE, SQUALL, SOS
P ⁵ E ³ N ⁴ S ³	F W G	Rabbit
	F W D A	CLM, ForTheL, Naproche CNL
	F W A	CLCE, First Order English, PENG, PENG-D, PENG Light, PNL
	F W I	iLastic Controlled English
P ⁵ E ⁴ N ³ S ³	F W A	FE

23 distinct classes, which might seem a small number with respect to the entire PENS space, but they are, as we will see, widely scattered. Even though some hotspots of classes and properties can be identified, the languages exhibit a broad variety.

Visualization of the languages in the conceptual space can give us a better picture of the data. Since the PENS scheme is four-dimensional, it is difficult to visualize all dimensions in a single diagram. Figure 1 shows a diagram for each of the six possible dimension pairs: the blue dots represent CNLs; the white dot stands for natural languages like English; and the black dots stand for the common formal languages used for comparison. Note that the dots represent PENS classes and not individual languages.

**Figure 1**

Visualization of the PENS dimensions of existing CNLs (blue dots), natural languages (white dot), and common formal languages (black dots). Each dot represents a PENS class containing one or more languages.

It is evident that the CNLs are widely scattered between the two extreme cases of natural English (white dot) and propositional logic (black dot in the corner). Seen from any angle, the set of existing CNLs exhibits wide variation. Except for the subspace with *naturalness* less than 3, where there can be no CNLs by our definition, they cover a large part of the conceptual space. This indicates that PENS is a powerful scheme for distinguishing different CNLs.

The diagrams also show that the CNL classes form one single cloud, from any perspective, and not two or more disconnected clouds. This means that it would be difficult to come up with a clean categorization scheme that would subdivide the large and diverse set of existing CNLs. This seems to justify the decision of using the term *CNL* in a broad sense and not replacing it by more specific terms.

For two dimension pairs, there seem to be clear correlations. Precision and simplicity seem to be positively correlated: more precise languages tend to be simpler. Expressiveness and simplicity seem to be negatively correlated: more expressive languages tend to be more complex. If we include the languages for comparison, naturalness and expressiveness seem to be, to a lesser degree, positively correlated. Precision/expressiveness, naturalness/simplicity and precision/naturalness each appear to be slightly negatively correlated. All these observations seem to be in line with what one would intuitively expect.

Let us turn to the properties. Table 3 shows the number of CNLs for each of the properties we considered. As some languages have been used more extensively and over longer periods of time than others, these numbers do not necessarily reflect the

Table 3
Properties of existing CNLs

	property	absolute	relative
C	comprehensibility	45	47%
T	translation	22	23%
F	formal representation	49	52%
W	written	89	94%
S	spoken	6	6%
D	domain-specific	50	53%
A	academia	46	48%
I	industry	42	44%
G	government	9	9%

actual importance or popularity of the different language types, but they nevertheless reveal some interesting facts.

For about half of the languages, the goal is to increase comprehensibility. Formal representation is the goal of another, slightly overlapping, half. About a quarter of all languages have translatability as their goal. Not shown in the table is that there is a huge overlap of the types C and T, whereas these two barely overlap with F. Existing CNL approaches can therefore be roughly subdivided into two groups of similar size: one consisting of languages for improved comprehensibility and translatability, and the other made up of languages that have formal representation as their goal.

When it comes to the distinction between written and spoken languages, we see a very one-sided picture: More than 90% of all languages are intended to be written; we found only six languages that are intended to be spoken (one of which is intended to be spoken *and* written). The reason for this might be that controlling a spoken language is much more difficult in practice. Written texts can be revised and given to a language checker before publication, whereas spoken language typically lacks this two-stage process.

Concerning domain-specificity, the data is balanced. About half of the languages are designed for a specific and narrow domain. The other half follow a more general-purpose approach.

Concerning the last three properties, the data shows that there are about the same number of academic and industrial CNLs: 46 and 42 languages, respectively. On the other hand, only nine CNLs were found that originated from a governmental environment. It has to be noted, however, that information about CNLs from industry is typically much scarcer than about languages from academia or governments. It is therefore likely that most of the languages that escaped this survey (because of missing or hard-to-find information) are industrial ones. Such a bias might also be present in the case of some of the other properties discussed above.

5.2 Timeline

Since CNLs have been defined and used over many decades and have influenced each other, it is helpful to draw the evolution of these languages on a timeline, as Figure 2 does. Each bar represents the “life” of a language and has a color and line thickness that is derived from its PENS class, as shown in the legend.

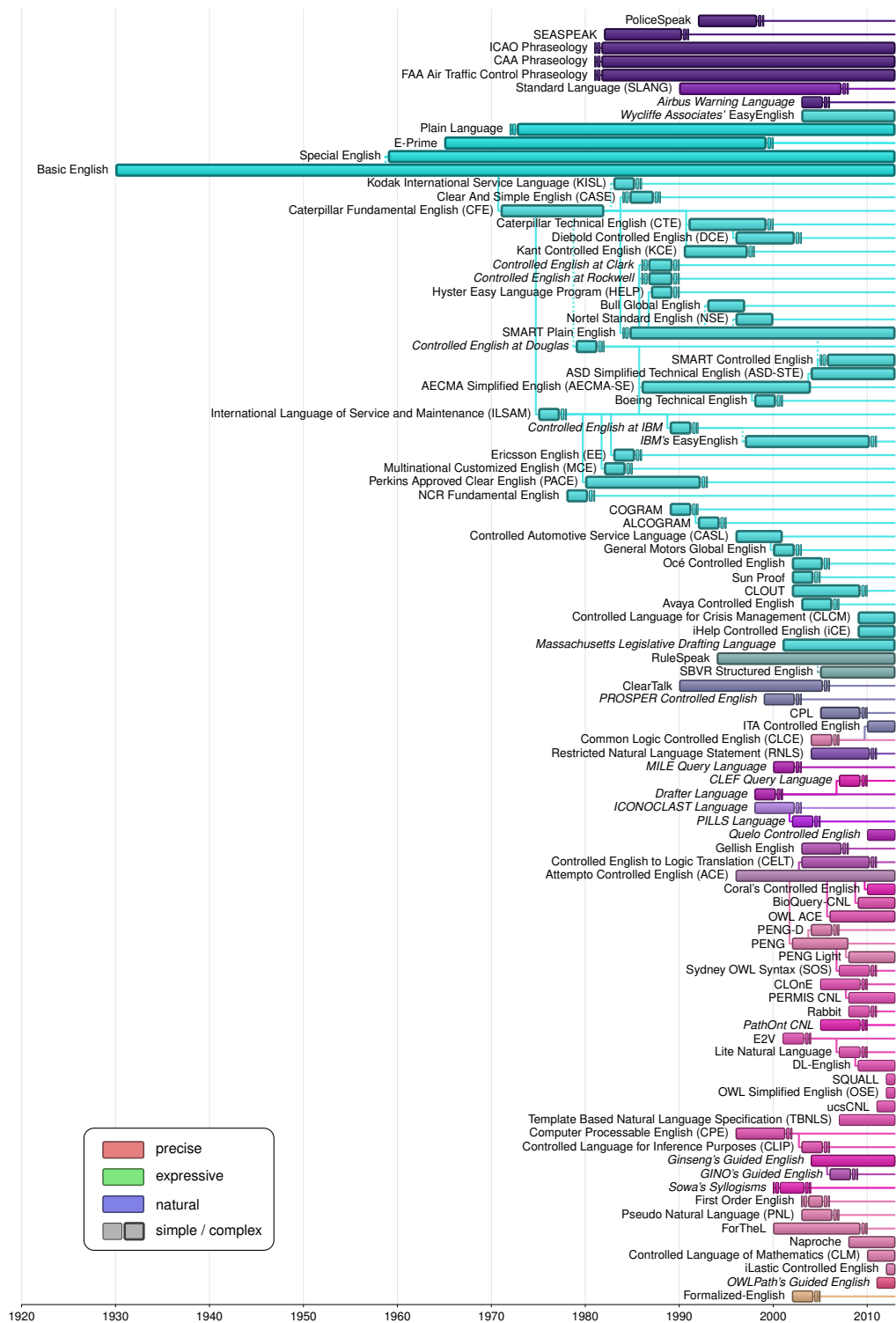


Figure 2
The timeline of the evolution of controlled English.

The oldest CNL, Basic English, is also the most influential one. It influenced CFE, and indirectly ILSAM, both very influential languages in their own right. Altogether, more than 20 languages were directly or indirectly inspired by Basic English. Among the more recent languages, ACE is the most influential in terms of offspring languages.

Looking for an overall theme in the evolution of CNL, one can identify something that could be called three “eras”: the *general*, *technical*, and *logical* eras. The *general era* lasted until the late 1960s or early 1970s. Only a few languages were defined and used during this time, all of which were designed to improve human comprehension and to serve as general languages with no specific application domain or narrow community in mind. Most of these languages survived in their small niche, when during the subsequent *technical era* that began in the early 1970s, CNLs were applied to technical documentation for improved human comprehension as well as improved machine translation. Again, this branch of languages did not disappear at the end of the era and continues to be used today, but a new type of CNL emerged. During the *logical era* that began in the mid 1990s, many CNLs were created with some sort of mapping to formal logic, which enabled not only automatic processing but actual automatic interpretation. These three eras roughly correspond to the three different goals introduced in Section 2.3: the first CNLs were of type C, type T emerged in the technical era, and type F in the logical era.

5.3 Evaluations

Finally, we can turn to a crucial aspect that we have not yet discussed: do CNLs actually achieve the goals they were designed for? A number of studies have been reported that evaluate the supposed advantages of these languages (though it seems that the number of principled studies is far lower than the number of CNLs). The relevant research question obviously depends on the goal the language is supposed to achieve. In their most general forms, the research questions for the types C, T and F can be stated as follows:

- C Does a CNL make communication among humans more precise and more effective?
- T Does a CNL reduce overall translation costs at a given level of quality?
- F Does a CNL make it easier for people to use and understand logic formalisms?

Each of these general research questions can be broken down, and most studies target more specific questions.

For type C, two studies on AECMA-SE showed that the use of controlled English significantly improves text comprehension, with a particularly large effect for complex texts and non-native speakers (Chervak, Drury, and Ouellette 1996; Shubert et al. 1995). The results of other studies were similar but not significant (Stewart 1998)

Concerning type T, it has been reported that the use of the controlled language MCE for machine-assisted translation leads to a “five-to-one gain in translation time” (Ruffino 1982). Similar results have been presented for the language PACE, with which post-editing of machine-assisted translation is “three or four times faster” than without (Pym 1990).

Studies on type F can be subdivided into those that test the general usability of CNL tools and those that specifically evaluate the comprehensibility of the actual languages.

Starting with the usability studies, it has been shown for the language CLOnE that its interface is more usable than a common ontology editor (Funk et al. 2007). Similarly, Coral’s controlled English has been shown to be easier to use than a comparable common query interface (Kuhn and Hoefler 2012). Positive usability results for CNL tools have also been reported for GINO (Bernstein and Kaufmann 2006), CLEF (Hallett, Scott, and Power 2007), CPL (Clark et al. 2007), PERMIS (Inglesant et al. 2008), Rabbit (Dimitrova et al. 2008), and ACE (Kuhn 2009). Turning to the comprehensibility studies, it has been shown for the CLEF query language that common users are able to correctly interpret given statements (Hallett, Scott, and Power 2007). ACE has been shown to be easier and faster to understand than a common ontology notation (Kuhn 2013), whereas experiments on the Rabbit language gave mixed results (Hart, Johnson, and Dolbear 2008).

In general, there seems to be good evidence for each of the language types that the use of CNL can be advantageous. This does not mean, of course, that CNL approaches always perform better. This depends heavily on the precise problem domain, the background of the users, and — perhaps most importantly — the quality of the design of the language and its supporting tools.

6. Conclusions

Let us draw some general conclusions from the survey and its analysis. The following three findings seem to be the most important.

First, there exist many more CNLs than have been found in any previous survey. Previously, the most comprehensive census counted 41 CNLs (Pool 2006) based on various natural languages, whereas this survey covers close to 100 languages for English alone.

Second, CNLs cover the conceptual space between natural languages on the one end and formal languages on the other in terms of precision, expressiveness, naturalness and simplicity. The informal statement that “CNLs are more formal than natural languages but more natural than formal ones” is substantiated and verified.

Third, we can confirm earlier claims that CNL approaches exhibit a very wide variety in terms of properties that range from superficial to fundamental. Existing CNLs form a widely scattered but connected cloud in the conceptual space described above.

I would like to conclude with the observation that the study of controlled languages is a dynamic, highly interdisciplinary field, for the most part occupying small niches in the academic, industrial, and governmental worlds. However, adding all these niches together gives us a large body of past and ongoing work, and because humans will have to interact even more closely with computers in the future, I am convinced that we will see much more work in this area.

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