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A Semantic Model for Indexing in the Hidden Web

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Abstract

We argue that that the use of the Carnap – Bar-Hillel principle of indexed expressions provides a suitable cognitive model to undergo the spread of information processes in the Semantic Net. To understand the stratification of the net into the surface Web and the hidden Web, a model structure is proposed that provides navigation through the net as a whole. For logical expressions, a relativized evaluation map is given, which is parameterized by the indexing system. It is allowed to use concepts that are generated using partial functions, the variables of which run over the range of possible individual information processes. A generalized operator providing virtualization is presented for individuals. The process is accompanied with the dynamic generation of Web-pages, which triggers their indexing. This way they are thereby transferred to the surface layer of the network. A commutative diagram is proposed that establishes a cognitive model of semantic constructions of variable domains, the connection of virtual individuals with actual ones which corresponds to transitions over the stages of knowledge. The knowledge stages are modeled by indexing systems.

Keywords: information process, knowledge stage, cognitive model, variable domain, indexed concepts

1. Introduction

Today's search engines do not reach most of the data on the Internet. The web quickly "deepened" at the expense of huge databases on the Internet and acquired an additional "dimension". Although the surface web has linked billions of static HTML pages, it is believed that much more information is "hidden" in the deep web behind searchable query forms in [9] databases. Google's deep web navigation computes the submitted data for each HTML form and adds the resulting HTML pages to the Google [13] search engine index.

According to some estimates, [6], [12] even up to 200,000 deep websites are added per day. Such information may not be available through static URL links. The fact is that it is collected in web pages as responses to requests

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sent through the "query interface" of the main database [2]. Since modern search engines cannot effectively "crawl" databases, such data is considered "invisible" and thus remains largely "hidden" from users.

For this reason, databases are often also referred to as *invisible* or *hidden* networks. Using an analysis of the overlap between search engine pairs [3], an approximate estimate of 43,000 'surface websites' can be obtained for 96,000 'deep websites', and their unofficial estimate is 7,500 terabytes of data – 500 times more than the surface web. This hidden web has always been highly regarded by researchers [4].

1.1. Indexing

As it turns out, a huge amount of data is hidden in databases behind search interfaces. On the other hand, in order to serve user requests, this data must be *indexed*. To adequately index these documents, the search engine requires a new indexing method, the research of which dates back to the work of H. Garcia-Molina [8], [7]) and which optimizes the speed and performance for finding relevant documents in the search query.

There is a definite picture of the indexing methods [5], among which *indexing by domain* is gaining popularity. This is a new method for detecting hidden documents viewed on the Internet [11], it uses the attributes and their values set to index the documents.

In favor of indexing objects on the Web, quite weighty and convincing arguments have been expressed more than once. The presentation of information images of objects on the Web, whatever their nature, relies on their appropriate indexing.

1.2. Domain separation

The deep Web, invisible Web or hidden Web, introduced into the practice of searching for information, are parts of the World Wide Web, the content of which is not indexed by standard search engines. The opposite of the term deep web is the surface Web, accessible to anyone using the Internet. The existing search engines retrieve content only from the public indexed network, that is, a set of web pages accessible only through hypertext links, ignoring search forms and pages that require authorization or pre-registration. In particular, they ignore the vast amount of high-quality content hidden behind search forms in large, searchable electronic databases.

Deep web content is hidden behind HTTP forms and includes many very common uses such as webmail, online banking and services that users have to pay for and which are protected by paid networks such as video-on-demand and some online magazines and newspapers. Deep web content can be found and accessed via a direct URL or IP-address and may require a password or other secure access outside of a public website page.

All this testifies to a certain proportion of incompleteness of the semantic modeling of information processes, and the available proposals are fragmented. At the same time, the key point is the development of a computational model that really represents the interaction of information processes. To overcome the difficulties and contradictions that arise, we will use the conceptual framework of variable domains, which allows us to develop a fairly productive parameterization.

This paper discusses the possibility of constructing a computational model for a deep network, while remaining largely in harmony with the ideas of possible worlds [10]. The section 2 discusses indexing models. Section 3 suggests a model division of network objects into classes. The section 4 builds a deep web domain model. In the 5 section, the deep web indexing model is built using the notion of possible worlds. The 6 section contains an operator constructor that allows us to organize access to a deep network at the model level.

2. Indexing Models and Related Works

It seems that in our world, all kinds of indexing have come to the fore. First of all, this applies to information technologies, where there is an ever-increasing tendency to increase the volume of stored and processed information. The available information is precisely indexed information, and other information falls into some other area, the existence of which we have an idea of, but we still do not know enough how to get to it. At least we don't have direct access to it.

It is becoming clear that the deep network is *software driven*; in accordance with the fairly fundamental ideas of the discipline of programming, to which there is a return.

According to J.R. Abrial [1], the discipline of programming is constructed with clusters of actions that help the programmer's understanding by establishing relationships regarding variables that are invariable throughout the text of the program. The program is being formulated as a control interpreter, and records in the form of relations can improve both efficiency and understanding of some common types of programs.

It remains to add that the web – whether surface or deep – is tacitly considered to be an area inhabited by *individuals* or, even better, by the *individual information processes*.

Taking into account the network stratification, there is a need for an associated stratification of the computation itself – computing. Surface computing operates with a surface network, but the hidden network requires *virtualization of computing* when it is required to clarify the technological features of computing with separate generators or objects [15]. Their interaction is considered in an application environment that allows us to clarify the internal structure of ordinary operations, the knowledge of which allows us to understand their properties. This approach can be used to "enter" the hidden layer of the net.

As a preliminary study of the computing virtualization model shows [14], that a computing activity is now at the forefront of research. Computing and information processes themselves are recognized as fundamental, and only recently their importance and versatility has begun to be recognized by the society of network researchers.

Modern resource integrity techniques such as sub-resource integrity (SRI) are not applicable to unknown content, for example, in a hidden net, and preventing attacks along this vector remains an open problem [16]. Complex interdependencies on the Internet have implications that go beyond security, leading to unwanted manipulation of information processes. Cognitive intervention, based on the deliberate obfuscation of information processes, is increasingly spreading across the web.

It is believed that entangled processes occur simultaneously, as coexisting processes having a common source of origin, and the state of their system is represented by a superposition of components. As it turns out, the integrity of resources is violated when the conditions for the emergence of a variable property architecture arise in the tangle of process dependencies. This creates confusing information processes. This happens when vulnerabilities appear in the web environment, such as XSS cross-site scripting. The models and mechanisms of complex interdependencies on the Internet are still poorly understood.

Modeling the information process and the peculiarities of its distribution with varying the defining property is also an open problem [17]. Finally, the study of the emergence, distribution and safe interaction of semantic processes in information modeling systems, including the hidden part of the net, can apparently be considered one of the key problems of cognitive research.

In general, the semantic image of a net needs a computational model in which both nodes and arcs of the network are information processes [18]. On its basis, it is possible to reflect and maintain dynamics on the WWW. Directional transformation provides the generation of target metadata in the form of parameterized concepts. This simulates the development of the process, which corresponds to the spread of cognitive interference and allows for the interpretation of the latent time factor.

This state of research raises more new questions than it answers.

3. Search scopes: domain separation of individuals

Let us refer the data of the deep, invisible or hidden web to the domain of D of possible individuals, while we refer to the data of the surface web to the domain of actual individuals A.

As a result, we come to the distinction between virtual, possible and actual objects. Denoting by V the domain of virtual objects, by D the domain of possible objects, and by A the domain of actual objects, we take $A \subseteq D \subseteq V$. The distinction between A and D usually does not show up in database models, but becomes a decisive factor when considering information processes on the Web. In the case of the Web, the collection of actual individuals A is replaced by a family of domains $A_i \subseteq D$ for $i \in I$, where i is the *index value* in the I indexing system, since indexing mechanisms play a decisive role on the Web. In fact, for an individual, from the point of view of information processes, "becoming valid" means in fact "being presented on the Web", which in turn is understood as "being indexed":

$$A = \bigcup_{i \in I} \{A_i \mid A_i \subseteq D\},$$

which makes it accessible to search engines. For the sake of fairness, we note that for published articles, their indexing is the main indexes in the scientific activity of the researcher, but in this case we are talking about other indexing systems.

Effective index structures need to be created to support hidden web data, which is then accessed to provide correct answers to many types of user queries.

At the same time, the question of how the computational model of access to the deep network should look like also remains open. This hidden web has always been highly regarded by researchers [4]. This high quality information can be recovered for normal access as a result of a hidden part scan using an external web database query with a standard HTML form attribute. The documents recovered by such a hidden part of the crawler are the most suitable, although these documents are available through dynamically generated pages that are delivered only in response to a request.

The indexed network, or, in other terminology, the surface network is indexed by the main search engines, and the web crawling with the help of search robots is performed only for its indexed part, and this is only a small part of the overall network. The hidden network is 500 times larger than the public network. The hidden network grows much faster than its surface form, while still providing high quality data.

4. A problem domain

4.1. Relativization

Based on the subdivision of individuals into classes, we come to the conclusion that quantification by *all* virtual individuals are not allowed, which means the relativity of interpretation. So practically quantification by *parts* of virtual individuals may well be useful. This opens up the possibility of constructing logical constructs useful in conditions of net stratification.

Let's try to choose the set I as the base of relativization; then $i \in I$ could be called *reference points*, so how to determine the truth value of an expression it is necessary to "assign" it with a point from I. Note that this terminology is more neutral and more general than possible worlds. In addition, it harmonizes with indexing on the web, and the "index" becomes a good term, it is used to give individuals in the net a certain status, namely:

indexing transforms possible individuals into the status of real individuals,
actually inhabiting the surface web.

In any case, when constructing an interpretation for some language the set I together with $A_i \subseteq D \subseteq V$ must be fixed in advance.

As a result, we distinguish between *virtual*, *possible* and *actual* objects. If denoted by the letter V virtual object domain, D – possible, and A – actual, then for simplicity we can assume that

$$\begin{array}{ccccc} \text{domain of} & & \text{domain of} & & \text{domain of} \\ \text{actual} & \subseteq & \text{possible} & \subseteq & \text{virtual} \\ \text{individuals} & & \text{individuals} & & \text{individuals} \end{array}$$

or $A \subseteq D \subseteq V$. This means that it is expected

$$\begin{array}{ccccc} \text{domain of} & & \text{domain of} & & \text{domain of} \\ \text{surface} & \subseteq & \text{deep} & \subseteq & \text{virtual} \\ \text{net} & & \text{net} & & \text{net.} \end{array}$$

The difference between A and D, although not evident in normal systems, but becomes decisive in modal logic, which gives the net *model structure*.

Indeed, in this case A must be replaced by a whole family of domains $A_i \subseteq D$, where $i \in I$.

5. Possible worlds

The very idea of possible worlds has a long and rich history. The idea seems so good that it works well when discussing net computing.

Index method in fact, is more fundamental. Let's see these indices in action. The essence is in the fact that in the expressions of the language themselves an undefined reference to the index is made – hence our terminology.

5.1. Property verification

Here is one example that is sufficiently indicative to describe the effects that arise when performing search operations on the net. In this example, the case with identification is considered. Suppose we have a quantifier $\forall x$ ranging over the domain D.

Now let's introduce a quantifier for "valid" individuals $\forall .x$, where the dot indicates an undefined index. Thus, even if we know the value of the predicate P, which expresses the *property* of interest to us (i.e. $P \equiv$ property), then we cannot say whether

$$\forall .x \text{ property}(x)$$

true or false. However, if we select some $i \in I$, then with respect to this index the sentence has a certain truth value; namely, it is true if $P(a)$ is true for all $a \in A_i$. But while we do not point to some $i \in I$, the range of the quantified variable remains unknown. In this example, we see a sentence whose truth value is not constant, but changes as a function from $i \in I$. This is the easiest situation to imagine in the case of time-dependent statements, then it is in the case when I represents the set of moments of time. Obviously, the same statement can be true one moment and false another.

5.2. Relativization of truth values

So, we can conclude that the truth value of the statement depends on $i \in I$. To install the relationship between statements and their parts, we will need some designations. First, we take the notation for truth values: we will write 1 to denote truth and 0 – to denote a false. This choice is based on the fact that $2 = \{0, 1\}$ is a simple and convenient symbol for designation of a set of two truth values.

Further, the statement Φ is associated with the function $\|\Phi\|$ (value of Φ in this interpretation) defined on I with values from the set 2. In other words, we will write $\|\Phi\|_i = 1$ when Φ is true with respect to i.

Others are possible notation, and below we will consider several of their options. Note that we use the f_i notation as an equivalent writing the value of the function $f(i)$. Sometimes we have to talk about the set of all functions defined by I, with values from 2; it will be denoted by 2^I, and we we can write $\|\Phi\| \in 2^I$, if a $\|\Phi\|_i \in 2$, where $i \in I$.

In order to interpret quantifiers, it is necessary to introduce into the language the constants $\bar{a}$ for all $a \in V$.

6. Variable binding statements

6.1. Hidden net: generalized operator

A special operator Θ is needed to simulate navigation on a hidden net. Taking into account the specifics of the organization of information on the net, intensional relations or intensional operators acting on statements. However, we need more degree of commonality, although difficult to achieve. In particular, requires intensional counterparts of extensional operators such as quantifiers and operators of description.

Consider now first of all the operator Θ, which binds one variable and hangs on one term and one formula. Terms will model URL transformations, and formulas will be responsible for logical filtering. In addition, we need an evaluating mapping

$$\| \cdot \| \cdot \ : \ \text{expressions} \times \text{matching} \to \text{Web pages},$$

operating over a surface net.

Expressions with the operator Θ can be used in the language in the following expressions:

$$\Theta \text{ variable [term(variable), formula(variable)]},$$

hence, $\Theta x[\tau(x), \Phi(x)]$. Now we have to choose: whether it is considered as a term or as a formula.

We will accept the first, that is, we will consider Θ as a *term-generating* operator. For the web, this means that the deep web allows the dynamic generation of Web pages that will be dynamically generated and possibly include an URL that will be used as a dynamically generated link as a result of the deep web Θ-search.

Thus, the meanings of this complex term there can also be virtual objects (compare the expression $\bigcup_{x \in A} \tau(x)$ in a class theory: it essentially depends on the domain of actual individuals A and on the values of the term $\tau(x)$).

But since we are engaged in the organization of navigation in the layer of the surface net, the *intensional logic* will be of interest, and therefore *values* will be (virtual) *individual concepts*. So, let us assume that $\|\Theta x[\tau(x), \Phi(x)]\| \in V^{(I)}$, insofar as $\|\Theta x[\tau(x), \Phi(x)]\|_i \in V$ for $i \in I$.

Let's use a slightly different notation system, writing: $v : I \to V$, $a : I \to A$. Then

$$V^{(I)} = \{v \| \, v : I \to V\} \equiv H_V(I), \; A^{(I)} = \{a \| \, a : I \to A\} \equiv H_A(I)$$

and we get the diagram in Fig. 1. In this case, $\tau \circ a \in H_V(I)$. To understand what happens to a when events unfold along f, we write:

$$H_A(I) \ni a \mapsto a_f \in H_A(I'), \;\; H_A(I') \ni a_f \mapsto \tau \circ a_f \in H_V(I').$$

Virtualization occurs along this chain of transformations.

More strictly, a set is formed (generated)

$$C_A(f) = \{a_f \mid a : I \to A \text{ for } f : I' \to I\}$$

and the set

$$C_V^{\tau}(f) = \{\tau \circ a_f \mid a : I \to A \text{ for } f : I' \to I\}$$

as well. In the diagram, they are marked as subsets of the domain variables $H_A(I')$ and $H_V(I')$, respectively.

Let us show how the value depends on $\tau(x)$ and on $\Phi(x)$. These expressions are functions of x, and all the related variables range over D. So we come to the statement that

$$\|\Theta\| \in (V^{(I)})^U,$$

where $U = (V^{(I)})^D \times (2^{(I)})^D$, and $(V^{(I)})^D$ is a set of all the functions the values of which are the concepts and the the domain is D; $(2^{(I)})^D$ there is a set of given on D functions whose values are propositional concepts. Thus:

$$\begin{tikzcd}
I & & I' \arrow[ll, twoheadrightarrow, "\text{stage transition}"', "f"]
\end{tikzcd}$$

$$\begin{tikzcd}
A = \bigcup_{i \in I} A_i \subseteq D \arrow[d, twoheadrightarrow, "\text{contiguity}"', "\tau"] & H_A(I) \arrow[r, twoheadrightarrow, "H_A(f)"] \arrow[d, twoheadrightarrow, "H_\tau(I)"'] & C_A(f) \arrow[r, twoheadrightarrow, "\subseteq"] \arrow[d, twoheadrightarrow, "H_\tau(I')"] & H_A(I') \arrow[d, Rightarrow, "H_\tau(I')"] \\
V & H_V(I) \arrow[r, twoheadrightarrow, "H_V(f)"] & C^\tau_V(f) \arrow[r, twoheadrightarrow, "\subseteq"] & H_V(I')
\end{tikzcd}$$

Fig. 1. Computational model of indexical domains.

$$(\Theta) \qquad \|\Theta x[\tau(x), \Phi(x)]\|_i = \|\Theta\|(t, F)_i,$$

where $t \in (V^{(I)})^D$ and $F \in (2^{(I)})^D$ are determined as follows: $t(a)_i = \|\tau(\bar{a})\|_i$, $F(a)_i = \|\Phi(\bar{a})\|_i$ for all $a \in D$.

7. Conclusions

To understand the stratification of the net into the surface Web and the hidden Web, a model structure is proposed that provides navigation through the net as a whole.

1. A model division of the net into classes of individuals has been established, which reflects the semantics of network stratification.

2. For logical expressions, a relativized evaluation is introduced, which is parameterized by the indexing system. It is allowed to use concepts that are generated using partial functions, the variables of which range over the domain of possible individuals.

3. It is shown that checking a property on a stratified net is provided with respect to a predefined indexing system.

4. The generalized operator Θ is presented, which provides virtualization of individuals, which corresponds to the dynamic generation of Web pages, which is accompanied by their indexing. Thus, they are transferred to the surface layer of the web.

5. A commutative diagram is presented that establishes a cognitive model of semantic constructions of variable domains, the connection of virtual individuals with actual ones against the background of transition over the stages of knowledge. Knowledge stages are modeled by indexing systems.

6. "Sliding" on the URLs of the generated pages is provided by the evolvent of stages of knowledge, which is reflected in the indexes.

The application of the developed model is expected to make the rich content of the hidden web more accessible by applying a semantic modeling approach.

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