New Approaches for Natural Language Understanding based on the Information Architecture

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Abstract—First of all, please forget all you knew about the lexical classification, then let’s jump to the conclusion. This paper reclassified lexical chunks into data chunks, structure chunks, and pointer chunks. Almost all the data chunks are information sets. According to the difference of the set structures, data chunks can be further divided into attribute chunks and entity chunks. According to the different abstraction level and method, attribute chunks can be further divided into basic attribute chunks, extended attribute chunks, and advanced attribute chunks. All of the above classification principles are structural and functional-based discrimination, instead of artificially divide lexical chunks into a noun, adjective, pronouns, and so on.

Now, let’s back to the normal study process. The author believes natural language is one of the ways information is encoded and it has highly abstracted and conceptualized the information. Therefore, the study begins with disassembling the information represented by natural language and then discovered the classification coding system of attribute information, and the abstraction relations between attribute information and entities in the real world. To have a clear and better discussion, the author constructed corresponding data storage models, and extract three kinds of data reading modes on those data storage models, they are the defining reading mode which driven by the structural word “Be”; the set reading mode which is driven by the structural word “Have”; and the process reading mode which is driven by verbs. Sentences output by the above data reading modes can be further divided into the data description task, the data verification task, and the data search task, according to task types represented by these sentences.

With the above new classification of lexicons and sentences, corresponding data storage models, and data reading modes, the author implemented a spatial attribute information processing process on one of the spatial attribute spaces (the spatial projection map) and demonstrated the understanding process (the information processing process) on a dialogue example in section 3. And proved that the studies in this paper have achieved the goal of enabling machines to understand the information conveyed in the dialogue.

In section 4, the author gives out the new definition of understanding: 1) the understanding can be roughly divided into two parts: the understanding of the internal structural-relations between inputted data chunks; the understanding of variation rule of attribute information and the prediction of the variation boundary of attribute information in different attribute spaces. 2) the process of understanding is to locate the inputted information in the existing information storage system and then complete the steps in item 1).

The study in this paper provides a practical, theoretical basis and research methods for NLU. It also can be applied in large-scale multi-type information processing in the artificial intelligence (AI) area.

Keywords and Phrases: lexical decoding, attribute information, attribute space, the new classification of lexical chunks, classification coding system of attribute information, information architecture, set structure, memory-graph structure, data reading mode, graph-tree structure, spatial projection map, basic conditions of understanding, the definition of understanding.

I. RELATIONS BETWEEN INFORMATION, REAL-WORLD, AND NATURAL LANGUAGE

A. Introduction

Natural language processing (NLP) techniques based on statistical models have achieved great success in machine translation. However, we are still far from letting machines understand natural languages, even for the simplest words: “Apple.”

Most of the previous approaches of NLP are focused on the structure study of words in sentences and context. In contrast, this paper goes deeper to study the information represented by natural language. At first, the author tried to find out how human beings relate the text “Apple” to the physical “Apple”. Inspired by the elementary information perception, transformation, and processing mechanisms in Neuroscience [1], the author discovers that human beings perceive the color, shape, smell, taste, and other information of physical “Apple” through their sensory systems. In brains, all this attribute information related to physical “Apple”, such as color, shape, smell, taste, etc. forms an information set. Then, this information set can be encoded into texts, such as: “Apple,” “苹果,” “かんち,” and so on. As a result, the author discovered that the understanding process of natural languages takes place at the information level, not the lexical level (or morpheme).

This paper also inspired by the study on the relational model of data by E.F. Codd’s [2]; and draws on a wide range of elementary theories, ideas, and thinking methods in the following disciplines: discrete mathematics [3], information theory [7], computer operating systems [5], computer architecture [6], introduction to algorithms [17], and so on.

B. Some key concepts and relations between them

Human beings perceive the world through information received by neural systems; this information is a tiny fraction of all the information in the universe. The processes of information identification, classification, memorization, analysis, abstraction, association, etc., are the component activities of human thinking. To make the discourse more easily in section 2, we must first introduce some key concepts: entities, attribute information, attribute space, information set, information encoding, memory-sheet, and expound relations between them.
Entities in the real-world can abstract out lots of different attribute information. Some are the basic attribute information which sensed by human neural systems (e.g., vision, olfaction, gustation, audition, and somatic sensation, etc.), others are abstracted upon the basic information (e.g., classification, movement, relations, preference degree, etc.). Meanwhile, the entity also is defined and represented by all its attribute information.

The attribute information which is abstracted from entities in the real-world can be classified by its natural properties. Attribute space (AS) is used to group attribute information which has similar properties. AS is a dynamic information set, the elements (or attribute information) in it are strongly related to the personal experience and the cognitive basis. In the research of NLU, the understanding of the data structure and the related algorithms of specific ASs are the keys of NLU, which allow people to understand the change range and change method of entities’ attributes.

As illustrated in Fig.1, both entities in real-world and attribute information in attribute spaces (ASs) can be encoded into text information (natural language can be speech or text, in this paper, we only discuss the text.) Memory-sheet (in Fig.1) is a data structure that stores the entity words (text encoding of entities in real-world) and its attribute words or phrases (text encoding of attribute information) together. All the attribute words or phrases in a Memory-sheet form a set, the attribute words or phrases are the elements of the set; the entity word can be seen as the representation or the name of the set. Thus, a Memory-sheet can display the mathematic relations between the entity and its attribute information, Entity A can be written as:

Entity $A = \{ a_i \mid a_i \text{ is the attribute information of Entity A, } i \text{ is a natural number} \}$, $a_i \in A$.

Actually, people understand an entity by understanding its attribute information. The more attribute information is known, the better the entity is understood. The changes of an entity essentially are the changes of its attribute information in one or several ASs. Thus, when we say: “Give me an apple.”, in essence, it is a request to change the spatial-position attribute of the apple. The verb “give” is a text encoding that represents change features of a sequence spatial-position attribute information.

Words in natural language are symbols that encode information. Besides the above entity words, attribute words or phrases, and changing feature words (verbs), we also can find the measurement words, interrogative, preposition, conjunction, punctuations, and specific sentence structure in natural language. Thus, understanding the information carried by words, punctuations, and specific sentence structures; distinguishing the function of the words, punctuations, and sentence structures in information transmission is the fundamental work in NLU.

C. The relation between Natural Language and Information

Let’s think again about the relation between natural language and information. Natural language is a tool that human beings use to communicate with the outside world; it is also one of the carriers of information. Information constantly changes its carriers (or forms) in the process of transmission and processing: in real-world, information exists in the forms of electromagnetic wave, chemical molecules, and ions, the kinetic energy of air, etc; human beings perceive this information and transform them into biochemical and bioelectricity signals then process them in brains [1]; when people communicate with outside world information is then transformed into the form of natural language, body gesture, body movements, etc; in CPU, information is processed in form of binary code. Obviously, the kinds and density of information contained in natural language are much higher than in other forms. Natural language has highly abstracted and conceptualized the information. In the next section, we will take the first step of NLU by classifying lexicons according to the information they contain.

II. NEW CLASSIFICATION OF LEXICAL CHUNKS, INFORMATION ARCHITECTURE

According to the grammar function, morphological standard, and the meaning standard, modern Chinese lexicons have been divided into nouns, pronouns, verbs, adjectives, adverbs, prepositions, quantifiers, onomatopoeia, etc. [8]. On this basis, the author dismantles and analyzes the information carried by each type of lexical chunks, then reclassifying them into the data, structure, pointer, and task chunks, according to their functions and the roles they played in information transmission. As shown in Fig.2, the task chunk is build up by data, structure, and pointer chunks.
It is easy to classify the related attribute words to the above sensory systems, see examples in below:

- **Color** \{red, blue, green, orange\}
- **Shape** \{square, round, cubic\}
- **Taste** \{sweet, salty, sour, bitter\}
- **Smell** \{smelly, balmy, pungent, apple-flavored\}
- **Somatic sensation** \{smooth, soft, furry\}

The attribute words in the above braces are adjectives. Besides the above descriptive attribute information, human beings also invent lots of extended attribute information, such as:

- **Kinds** \{fruit, vegetable, meat\}
- **Kindship** \{father, mother, son, wife\}
- **Profession** \{teacher, doctor, police, chef\}
- **Titles** \{professor, teaching assistant, student\}

One thing to notice is that most of the extended attribute words in the above braces are not adjectives but nouns.

b) **Attribute Space Chunks (ASCs):** ASCs are the representation of specific ASs. In the above paragraph, the underlined words outside the braces are the ASCs. The ASC is a kind of set that all its elements have similar properties, the sets which have this kind of constituent form are called lengthwise set.

c) **Verbs:** Verbs are the representation of change features which abstract out from sequences of attribute information. Finally, the abstracted change features are recorded and encode as verbs, but the corresponding sequences of attribute information won’t be recorded in memory. Thus, this type of set is called change features sets.

- **Fall** – an abstraction of the change features of a sequence’s spatial-position attribute information in spatial AS.
- **Sweetened** – an abstraction of the change features of a sequence’s taste attribute information in taste AS.
- **Run** – an abstraction of the change features of sequences’ spatial-position information and body posture information in spatial and body posture ASs.

d) **Measurement Chunks:** Compare to the basic and extended attribute chunks, measurement chunks once again abstract out the group characteristics of the same kind basic attribute information, the extended attribute information, or the selected measuring clusters. There are various abstraction methods and standards: according to the different frame of reference, it can be divided into the subjective measurement and the objective measurement, according to the number of measurement dimensions (or ASs), it can be divided into the single-dimension measurement and the multi-dimension measurement. And if the measuring result only has two values, such as “like” and “dislike”, “agree” and “not agree”, “yes” and “no”, they can be called the binary measurement; if the measuring result has multiple values, such as “good”, “better”, “best” and “fast”, “faster”, “fastest”, they can be called the distribution measurement. Some examples are given below for better understanding.

- **Distribution measurement:** Describe the distribution area of target objects after performing the statistical analysis on the attribute information in the selected...
measuring area. A distribution model is given in Table I to describe the data distribution, and each distribution area has the corresponding measurement words to describe it. Some examples of distribution measurement words are given in Table I.

- **Subjective measurement:** This type of measurement is adopted a unified measuring standard to minimize the recognition tolerance of the same thing between individuals. E.g., Area (km², m²), Speed (m/s, km/h), Temperature (°C, °F), Weight (g, kg, ton), Pressure (Pa), etc.

- **Quantity/Order/Ranking measurement:** We assume that the quantity measurement is based on the shape and spatial attribute, the order measurement is based on the quantity, time, spatial-position and other attributes, and the ranking measurement is based on the order and other attributes.

Looking back at all the above Attribute chunks, the ASC and verbs are the one more time abstract representation of the basic attribute information cluster. The measurement chunks are the one more time classification of basic attribute information, the ASC, and verbs. Therefore, all the attribute chunks in natural language also is a classification coding system of attribute information. The understanding of the attribute information coding mechanism is the key to NLU. Meanwhile, the application of the coding mechanism in natural language greatly reduces the number of words and improve expression efficiency.

| TABLE I. EXAMPLES OF THE DISTRIBUTION MEASUREMENT CHUNKS |
|----------------------------------------------------------|
| **Normal Distribution Model** | **Measurement Chunks** | **Attribute Spaces (ASs) being Measured** |
| | | **Volume** | **Speed (distance + time)** | **Temperature** |
| Never, beyond | Never seen, Beyond the limit |
| Extremely, very, -est | Biggest | Fastest | Extremely hot |
| A little bit, -er | Bigger | Faster | Hot |
| Average, Proper | Average size | Proper speed | Warm Cool |
| A little bit, -er | Smaller | Slower | Cold |
| Extremely, very, -est | Smallest | slowest | Extremely cold |
| Never, beyond | Never heard, Beyond the cognitive |

2) **Entity Chunk (EC):** This type of words and phrases which represent the entities in the real-world are called entity chunks (ECs). According to their different physical properties, ECs can be divided into the explicit EC and the implicit EC, some examples are given in Table II to help the understanding. The Explicit EC can be further divided into the dynamic EC and the static EC, according to the obvious difference in the spatial-position attribute. In spatial-position AS, static ECs are used to build up the relative reference coordinate system, which will be elaborated in section III.

| TABLE II. CLASSIFICATION OF ENTITY CHUNKS |
|------------------------------------------|
| **Classification** | **Examples** |
| Explicit EC | Dynamic EC | Human being, cat, car, cloud |
| | Static EC | Apple, bag, laptop, cup |
| Implicit EC | Sofa, house, school, shopping mall |
| | | Protein, carbohydrate, oxygen |

Identifying the EC in a sentence is crucial to understanding the sentence. Because, all information conveyed in a sentence revolves around the EC, no matter the target of the sentence is to convey the information or to request an action. So, it is very important to understand the information architecture of all kinds of data chunks and to distinguish them from the perspective of the information constitute structures.

![Figure 3. Structural classification of data chunk sets](Image)
information clusters, except that the properties of elements in ASC are the same, while those in EC are different. Refer to how the Memory-sheet (in Fig.4) divide attributes information, ASC can be called as the longwise set, while EC can be called as the crosswise set. Verbs re-abstract the change features of a sequence record of the same attribute information and are called the change features set. The measurement chunk is called the benchmark set, which re-classify attributes information in specific ASC or selected measuring area. Or we can regard verbs and measurement chunk as the output result of running a specific program on a selected attribute information cluster. Thus, verbs and measurement chunk are not the direct representation, here, they are called the soft set.

3) Information architecture: There is no isolated information in brains, any information must be connected to other information. Both the internal structure between EC and all its attributes information, and the hierarchical structure between ECs are parts of information architecture. Let’s use memory-sheet, memory-tree, and memory-graph data structures to explore information architecture.

a) Memory-sheet: This type of data structure can well display the EC and all its attributes information. As shown in Fig.4, the EC is stored in the head of the Memory-sheet. In the body part, all its relevant attribute chunks are listed in corresponding ASs. For an EC, its basic attribute information is relatively fixed, its extended attribute information increases as the deepening of the understanding.

b) Memory-tree: It is a data structure that focuses on displaying the information’s hierarchical abstract structure. As shown in Fig.4, the “Fruit” is the abstraction of “Apple,” “Banana” and “Orange,” and “Food” is the abstraction of “Fruit” and “Vegetable,” we can continually do this abstraction again and again in higher layers. This structural abstraction also is transmissible, which means “Food” also is the abstraction of “Apple,” “Banana” and “Orange,”; “Fruit” also is the abstraction of the set that contains all the basic attributes in “Color,” “Taste” and “Shape” ASs. This kind of structural relation can be described by the inclusion relations of sets in math. Up to now, “Fruit” and “Food” are seen as EC, but things are not that simple, let’s look at the following three sentences.

- Apple is red. / Apple is fruit. / Apple is food.

All the underlined chunks in the sentences are the attributes to the EC “Apple,” therefore, the author prefers to consider the attribute chunk and the EC as structure-based definitions rather than mutually exclusive concepts. So, if we thinking in this way, the data chunk which is higher than the target EC, can be seen as the extended attribute to the target EC; And the data chunk which is lower than the target EC, can be seen as the subset of the target EC (Food ⊃ Fruit, Fruit ⊃ Apple.)

But EC’s basic attributes won’t change, which map the information of space, time, and matter. Actually, all human thoughts are building upon the basic attribute information which is perceived by the sensory system, and the perceived information has been expanded with the progress of technologies (for examples: electron microscopy, radio telescope, endoscopy, MRI, and so on).

It is easy to see that the more abstract a data chunk is, the more information it represents, the more efficient the communication is. For instance: “School” is the representation of the set {classrooms, playground, canteen, students, teachers, blackboards, chalks, books, courses, etc.} and the interactive activities between the elements in the above set. When we use the word “School,” all its subsets and attribute information are been incorporated in. The use of a higher abstract EC enables the invocation of information on a larger scale and requires better information processing capability.

c) Memory-graph: Memory-graph is a cluster of memory-trees, and these memory-trees are connected in many ways. See the example of the memory-graph in Fig.5. When people build up their memory-graph, they take themselves as the center of this graph. In the process of growing and learning, people continually knit new information into their memory-graph by connecting the new information with the existing. Other important or close
human beings can be set as the vice centers. These kinds of data structure which have one center and several vice centers are beneficial to improve the efficiency of search operations.

Connections: In a memory-graph (see the example in Fig.5), connections between data chunks are represented as the directed edges (arrows). There are two types of connections:

- Solid arrow: represent the real connection that implicates structural hierarchy, and always been used in memory-tree structures in a memory-graph;
- Dashed arrow: represent the virtual connection that does not implicate structural hierarchy, and has always been used to connect subtrees in a memory-graph (see subtree of “Cat” and subtree of “Dog” in Fig.5). The usage of a dashed arrow assumes that there is no hierarchical relation between different tree structures.

Based on the above structures, the identification, memorization, classification, and even association operations of information are possible. Classification activities are structural based discrimination. For NLU, we still need to implement analysis activities on various attribute information in models of corresponding ASs. In section III, the author will introduce a spatial-position AS model and analyze the spatial information processing mechanism in it.

B. Structure Chunk

Connections between data chunks can be interpreted as various kinds of relations, for example, the representation relation (defining relation), the inclusion relation, the causal relation, and so on. In this section, we will discuss the defining relation and inclusion relation represent by structure chunks: “Be,” “Of,” “’s” and “Have,” and elaborate on two corresponding data reading modes: the defining reading mode and the set reading mode.

1) “Be”: In dictionaries, “Be” and “Have” are classified as verbs, which is against the verb classification rule introduced in the data chunk section. In natural language usage habits, we can observe that the data chunks after “Be” always are used to represent or define the data chunk before “Be”. Although the author has said that an entity is defined and represented by all its attribute information, but people do not need and impossible to fully describe an entity in the usage of natural language. Usually, people just partially describe an entity by giving one or several of its attributes. In natural language, the data chunk after “Be” is used to describe and define the data chunk before “Be”.

2) “Of”, “’s” and “Have”: These words interpret the connections as inclusion relations between data chunks. We assume that there are no equal sets in a memory-graph. So, the inclusion relation of sets can be written as:

- A ⊆ B → A has B. or A’s B.

Now, we can simulate the process of how brains read the data in memory-graph (in Fig.5) in below two modes, the read-out sentences are list in Table III.

- B ⊆ A → B of A.

Figure 5. Queen’s memory-graph

a) Defining Reading Mode (DRM): or we can call it the full reading mode, which read whole data chunks from a selected reading chunk. As we can see in Table III, though the article and punctuation are missing in those sentences, we still can roughly get the information they conveyed. In defining reading mode, if the following attribute chunk’s connotation (the data chunk after “be”) can cover the current ASC’s, the ASC can be omitted in expression. It is rare to see this phenomenon in Modern Chinese because the classification coding system of Modern Chinese is more efficient.

b) Set Reading Mode (SRM): this is an inclusion relation reading mode, which only reads the sets and the inclusion relation between them from a selected reading chunk. We can find three typical patterns in natural language usage:

- A ASC [B] A ⊆ ASC, b ∈ ASC.
  “b” is the elements of “ASC”, and b is not a set, thus, only read the “A ⊆ ASC” part from “A ASC [B]”, and omit the “b ∈ ASC” part. E.g., items 1, 2, 3, and 4 in Table III.

- A ASC [B] A ⊆ ASC ⊆ B.
  In this case, we select A as the target description object, then, we can choose the “A ⊆ ASC” part, or the “A ⊆ B” part to read-out which is according to the requirement. E.g., items 5 and 6 in Table III.

- A ASC [B] ASC ⊆ A, B ⊈ A.
  Due to there is a virtual connection between A and B, structurally, there is no inclusion relation between A and B, just the virtual abstract relation. This virtual abstract relation can be unidirectional or bidirectional. In this case, we can choose the “ASC ⊆ A” part to read-out. E.g., items 7a, 8a, 9a, and 9c in Table III.
3) **Punctuations and conjunctions**: Punctuation and conjunctions segment the information on a larger scale, for the following purposes:

- Distinguish the task type of segmented information chunks (e.g., period, question marks, exclamation marks.)
- Distinguish the processing order of segmented information chunks (e.g., punctuations: commas, semicolons, parentheses.)
- Indicate structural relations of segmented information chunks (e.g., conjunctions: and, or, therefore, so.)

Except for structure chunks listed in Fig.2, sentence structures and paragraph structures segment information chunks on an even larger scale. The structural relations represented by those structural forms are also more diversified. The sentence structures will elaborate in the task chunk section.

**C. Pointer chunk:**

These words are used to point out or emphasize the target objects in sentences; they play pointer roles in the process of information transmission. It is easy to understand words: the, this, that, these, and those are the pointer to point out the target object. For the interrogatives, they are used to point out the area or scopes that should carry out the information search operation in data search tasks. The detailed elaboration of the data search task will be given in the task chunk section.

Prepositions used upon different ASs represent different kinds of positional information. In spatial-position AS, the prepositions are used for positioning the target object in space. On the timeline, the prepositions are used to positioning target objects on the timeline. Thus, the understanding of prepositions is relying on the understanding of the characteristics of the corresponding ASs.

### Data Reading Mode and Set Reading Mode

| Data Reading Mode | Defining Reading Mode (Full Reading Mode) | Set Reading Mode (Inclusion relation Reading Mode) |
|-------------------|------------------------------------------|--------------------------------------------------|
| Structural CLS | | |
| Lexical CLS | | |
| Items | Reading Chunks | Attribute Chunks | Entities | ASC | Entities | ASC | Entities |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | [ASC, B] | Apple | color | is | red | Apple | has | color |
| 2 | [ASC, B] | Apple | spatial-position | is | in fridge | App | has | spatial-position |
| 3 | [ASC, A] | Dog | name | is | Wirote | Dog | has | name |
| 4 | [B, A, C, D] | Tail and paw | color | are | black | Tail and paw | have | color |
| 5 | [ASC, A] | Queen Elizabeth | jewelry | is | crown | Queen Elizabeth | has | jewelry |
| 6 | [A, ASC, C, D] | Queen Elizabeth | pet | are | cat and dog | Queen Elizabeth | has | pet |
| 7a | [ASC, C, E] | Queen Elizabeth | son | is | Charles | Queen Elizabeth | has | son |
| 7b | [ASC, A, B] | Queen Elizabeth | is | mother of | Charles | Queen Elizabeth | has | mother |
| 8a | [ASC, A, B] | Charles | mother | is | Queen Elizabeth | Charles | has | mother |
| 8b | [A, ASC, A, B] | Charles | son | of | Queen | Queen | has | son |
| 9a | [ASC, A, C] | Dog | friend | is | cat | Dog | has | friend |
| 9b | [ASC, A, A] | Dog | is | friend of | cat | Queen | has | friend |
| 9c | [ASC, A, A] | Cat | friend | is | dog | Cat | has | friend |

**TABLE IV. NEW CLASSIFICATIONS OF SENTENCES**

| Data Reading Mode | DRM | SRM | PRM |
|-------------------|-----|-----|-----|
| A. Data description task | A-DRM | A-SRM | A-PRM |
| B. Data verification task | B-DRM | B-SRM | B-PRM |
| C. Data search task | C-DRM | C-SRM | C-PRM |

Before introducing the classification of task chunks, the author would like to introduce another type of data reading mode: the process reading mode (PRM). As the name implies, PRM reads entity chunks and their attribute-
changing processes. Items 6, 7, and 8 in Table V are the sentences read out in PRM, attribute-changing processes of entities in sentences are represented by verbs which are the change features abstract out from sequences of attribute-changing records. Attribute-changing processes can be interactive or noninteractive. Item 6 in Table V is the description of the noninteractive attribute-changing process of the entity. Items 7 and 8 are the description of interactive attribute-changing processes between entities. In interactive attribute-changing processes, it is important to distinguish the active role and the passive role. Usually, entities before verbs are active roles; entities after verbs are passive roles (the passive voice won't be discussed in this paper).

Now, the author will put the information processing entity (IPE) in the natural language receiver’s shoes, and then elaborate on the understanding process of each type of task chunks in Table IV. The scenarios that put IPE in the natural language sender’s shoes won’t be discussed in this paper.

TABLE V. EXAMPLES OF NEW SENTENCE CLASSIFICATIONS

| Task Type | Data Reading Mode | Column A | Column B | Column C |
|-----------|-------------------|----------|----------|----------|
| DRM       | Text-pointer words; Text-structure words; Text-measurement words; Text-verbs; “Be”, “Have” and verbs that need to be verified are marked in | This apple is red. | Is this apple is red ? | What color is this apple ? |
| 2a DRM    | The dog’s name is Wirote. | The dog’s name is Wirote. | Is the dog’s name is Wirote ? | What Wirote is the name of the dog ? |
| 2b DRM    | The dog’s name is Wirote. | The dog’s name is Wirote. | Is the dog’s name is Wirote ? | Whose the dog’s name is Wirote ? |
| 3a DRM    | They are Queen’s crowns. | They are Queen’s crowns. | Are they are Queen’s crowns ? | Whose Queen’s crowns are they ? |
| 3b SRM    | They are Queen’s crowns. | They are Queen’s crowns. | Are they are Queen’s crowns ? | Which Queen are Queen’s crowns ? |
| 4 SRM     | The cat has a black tail. | Does the cat has a black tail ? | Who has a black tail ? |
| 5a SRM    | Queen has twelve crowns. | Does Queen has twelve crowns ? | Who Queen has twelve crowns ? |
| 5b SRM    | Queen has twelve crowns. | Does Queen has twelve crowns ? | Who Queen has twelve crowns ? |
| 6 PRM     | Run away. | Does Run away ? | Who Run away ? |
| 7 PRM     | Queen read the book. | Did Queen read the book ? | Which book did Queen read ? |
| 8 PRM     | Queen likes coffee and tea. | Does Queen likes coffee and tea ? | What kind of drink does Queen likes ? |

Notes: Auxiliary words which highlight in yellow are still under study.

1) Type A tasks: When IPE gets information input of data description type tasks, they understand input information by activating or mobilizing the data chunks described by input information in memory-database. The activating or mobilizing processes of the data chunks described by input information are also considered as data reading operations in IPE’s memory-database (the data reading operation is highlighted in bold in Fig.8.) The understanding of A-DRM and A-SRM types of sentences focus on the understanding of structural relations between data chunks in sentences. The understanding of A-PRM type of sentences focuses on the understanding of attribute-changing progress of entity chunks in sentences.

It is easy to find out that Imperative Sentences are the abridged expression of A-PRM type of sentences that emphasize the immediate action. And Exclamatory Sentences are the abridged expression of data description type sentences that emphasize on the extraordinary attributes of target objects.

2) Type B tasks: Human beings do information recognition all the time while they are awake. Information recognition is the operation to compare input information with the existing information in their memory-database. When the input information is new and does not have a related record in IPE’s memory-database, the IPE can complete this round of information recognition by calling someone else’s memory-database.

In natural language, the information sender use data verification task type of sentences to express data verification requests to the information receiver, and request to invoke corresponding information in information receivers’ memory-database to help to complete the data verification task. As shown in Table V, the sentences in column B express the verification request for data chunks described in column A. Specific implementation methods are as follows:

a) For the B-DRM type of sentences: this type of sentences request to verify the “Be” structural relation between the input data chunks. The request is achieved by pop out the “Be” in verification data chunks and relocate it to the beginning of data verification chunks, and add question marks to end these data verification chunks.
b) For the B-SRM type of sentences: this type of sentences request to verify the inclusion relation between the input data chunks. The request is achieved by add “Do” at the beginning of data verification chunks, and also add question marks to end these data verification chunks.

We can find some clues in Fig.5 for why the extra auxiliary words “do” are needed in B-SRM type of sentences. It is obvious that the “Be” is a bidirectional structure relation, and “Have” is a unidirectional structure relation. Thus, “Have” needs to be kept between the set chunk and its subset chunk to indicate this unidirectional structure relation. Therefore, extra auxiliary words “Do” are added at the beginning of the sentences to express the inclusion relation verification requests.

c) For the B-PRM type of sentences: this type of sentences request to verify attribute-changing processes represented by verbs. Same as B-SRM type of sentences, the B-PRM type of sentences express the attribute-changing process verification request by add “Do” at the beginning of data verification chunks, and add question marks to end these data verification chunks.

All attribute-changing processes are directional, so verbs also need to be kept in sentences, and extra auxiliary words “Do” need to be added at the beginning of the sentences to express the attribute-changing process verification requests.

This paper won’t discuss the usage of variants of the words “Be”, “Have”, “Do” and verbs. The classification of the auxiliary word “Do” is still under study.

3) Type C tasks: In the process of information processing, if some information is found missing, IPE can send requests to other IPEs through data search type of sentences for assistance in searching the missing information. In data search chunks, the missing information is substitute by interrogative chunks (the red text in Table V). And interrogative chunks indicate the area or scopes where a search operation is to be performed.

In data search task sentences, the interrogative chunks are always been placed at the beginning of the whole data search chunks. Thus, when the missing part is at the lower-leveled position in a structural relation or the missing parts are the passive roles in attribute-changing processes, the data chunk reading order needs to be adjusted accordingly. Different scenarios discussed below:

a) For the C-DRM type of sentences: Due to the “Be” structure relation is bidirectional, no matter the missing data chunk is before or after the “Be,” take the missing data chunk as the start reading point, then to read the whole data chunks one by one. The readout sentences list in column C and mark out with underlines. Of course, the missing data chunk needs to be substituted by an interrogative chunk, and a question mark is added to end this data search chunk.

b) For the C-SRM type of sentences: “Have” represents the unidirectional structure relation, the data chunk behind “Have” is the subset of the data chunk which before “Have”. Thus, when the missing data chunk is before “Have”, the order of data chunks in the sentence won’t be changed (e.g., items 4 and 5a in Table V); but when the structurally lower-leveled data chunk (the data chunk behind “Have”) is the missing part, the missing data chunk still be set as the start reading point, but the “Have” need to be attached behind the higher-leveled data chunk (the data chunk before “have”) to indicate its position in the unidirectional structure relation, extra auxiliary words “Do” is added between the lower-leveled data chunk and the higher-leveled data chunk to separate them (e.g., item 5b in Table V), the readout sentences are listed in column C and mark out with underlines. Of course, the missing data chunk is substituted by the interrogative chunk, and a question mark is added to end this data search chunk.

c) For the C-PRM type of sentences: same as C-SRM type of sentences, when the missing data chunk is the active role in the attribute-changing process, the order of data chunks in the sentence won’t be changed; but when the missing parts are the passive roles, the whole data search chunk needs to start with the missing passive part, and the verbs need to be attached behind the active role to indicate its active position, the extra auxiliary word “Do” is added between the active role and the passive role to separate them (e.g., item 7 and 8 in Table V.) Finally, a question mark is added to end this data search chunk.

All the above studies do not involve tense. The tense system in natural language is the description of the relative position relation between the current time position on the timeline and the time position when data is recorded on the timeline.

So far, the author briefly introduced the research thinking of the information architecture and new classifications of lexical and sentence type. In the next section, the author takes the spatial-position attribute information as an example to illustrate how the spatial-position information is been organized and processed in spatial AS.

III. SOME EXAMPLES

A. One Spatial-position Attribute Space Model

The attribute space (AS) that represents the spatial relations between entities in the real-world is called spatial-position AS. In spatial-position AS, the spatial information is recognized by the human visual sensory system, then abstracted out the scope and direction relations between entities, and then stored these entities and their spatial scope and direction relations in the corresponding models. Before introducing the spatial projection map (SPM) which is one of the spatial-position AS models, two concepts need to introduce in advance:

1) Spatial-positioning words (SPW) and space-assisted positioning points (SAPP):

   a) Spatial-positioning Words (SPW): SPWs are used to represent the position information in spatial-position AS. There are not many words used for spatial-positioning in natural language, and according to different recognition and judging mechanisms, they can be divided into the spatial scope relation recognition, the spatial direction relation recognition, and the spatial distance relation recognition. According to the coordinate system used, the spatial direction recognition can be divided into the relative
direction recognition and the absolute direction recognition, see the examples in Table VI.

**TABLE VI.** SPATIAL-POSITIONING WORDS AND PHRASES

| Category                  | SPWs Examples         | Symbol & Coordinate System |
|---------------------------|------------------------|----------------------------|
| **Scope Relation Recognition** |                        |                            |
| Inside                    | In, at, inside, within, among |
| Outside                   | Out of, outside, beyond |
| **Direction Relation Recognition** |                    |                            |
| Relative direction        |                        |                            |
| Upside                    | on, above, up, over |
| Downside                  | under, below, beneath |
| Front side                | before |
| Backside                  | after, behind |
| Left side                 | on the left side |
| Right side                | on the right side |
| Others                    | against, toward |
| Absolute direction        |                        |                            |
| East                      | East, west, south, north, middle |
| West                      |                        |
| South                     |                        |
| North                     |                        |
| **Distance Relation Recognition** |                |                            |
| By                        | By, beside, alongside, nearby |
| Side                      | around, close to, next to |

a. The absolute concept exists within a specific range and scale, which won’t be discussed in this paper.

b) **Space-assisted Positioning Point (SAPP):** The static EW (as shown in Table II) which used for space-assisted positioning purpose in natural language, are called SAPP in this paper.

![Figure 6. Graph-tree structure of SPM](image)

2) **Spatial Projection Map (SPM):** Now, we will model the spatial relation between entities using SPW and SAPP. Spatial projection map (SPM) is a graph-tree model representing the scope and relative direction relations between relative static entities. Static entities are being abstracted out as vertices elements of the model. Scope and relative direction relations are being abstracted out as edges elements of the model. As we can see in Fig.6, SPM is a hybrid model combined with horizontal graph structures and vertical tree structures. The relative direction relations are stored in the horizontal graph structure, and scope relations are stored in the vertical tree structure. The author use the adjacency matrix to represent the graph structure of the SPM in Fig.6, details are as follows:

a) **Graph Structure Model (in-layer or horizontal structure):** The vertices or SAPPs are stored in graph structure according to their relative direction relations in the real-world. They also can be represented in mathematical as below:

- Graph \( G = \langle V, E \rangle \) consists of \( V \), a set of all the SAPPs in the same layer called vertices, and \( E \), a set of six fixed relative direction relation of \( V \) called edges.

\[ G_j = \langle \bigcup_{i=1}^{n} G_j^i, E \rangle, \quad i: \text{serial number of layer}, j: \text{serial number of the subgraph} \]

Take the red dotted box portion of Layer 0 in Fig.6 as an example, Table VII is adjacency matrix which represents the sub graph \( G_0^j = \langle V_0^j, E \rangle \). In the sub graph \( G_0^j \), the vertices set \( V_0^j = \{ \text{table, fridge, sofa} \} \) and the edges set \( E = \{ \text{left side, right side, front side, backside, upside, downside} \} \), the elements in the vertices set can be added or subtracted according to the actual situation, but may not be repeated, the edges set is a tuple consisting of six fixed spatial direction relation. If vertices are not on these six directions, the spatial direction relation between the subject and object needs to be calculated, the calculation method won’t be discussed here.

**TABLE VII.** ADJACENCY MATRIX REPRESENTATION OF SUBGRAPH

| SN | \( V_0^j \) | Left side | Right side | Front side | Back side | Upside | Downside |
|----|-------------|-----------|------------|------------|-----------|--------|---------|
| 1  | Table       | \( \Phi \) | \( \Phi \) | \( \Phi \) | \( \Phi \) | \( \Phi \) |
| 2  | Fridge      | \( \Phi \) | \( \Phi \) | \( \Phi \) | \( \Phi \) | \( \Phi \) | \( \Phi \) |
| 3  | Sofa        | \( \Phi \) | Table      | \( \Phi \) | \( \Phi \) | \( \Phi \) |

a. “Apple” and “Cat” are Dynamic EW, thus, we do not list them in \( V_0^j \) set.

b) **Tree Structure Model (between-layer or vertical structure):** As shown in Fig.7, the tree structure is the vertical structure of the graph-tree model, which is a between-layer structure. It represents the spatial scope relation of vertices between adjacent layers. A graph-tree model can consist of many trees. The root, leaves, and internal vertices of each tree can be distributed in different layers. The spatial scope of each vertex is represented by the union of the spatial scope of all its children vertices. As shown in Fig.7, the spatial scope of the internal vertex “House” is the union of {Table, fridge, sofa ……}.

![Figure 7. Vertical Tree Structure in SPM](image)
In the tree structure, the spatial scope of the children vertices that own the same parent should be independent of each other; If not, they should be moved up or down until all the children vertices are independent of each other on the spatial scope.

3) Typical Expression of Spatial-position Information in Natural Language: We can position a target object by deducing its spatial relations with the SAPPs in specific SPM. We use two typical ways to represent the spatial-position of the cat in Fig.6.

a) Type A expression method: This is the spatial direction relation method that executes on the graph structure of SPM, which needs to find out the adjacent nodes of the target object on the fixed six directions. As shown in Table VIII, we respectively take the “Cat” and “Sofa” as target objects to find out their adjacent nodes (SAPP) and the relative direction relation between them on graph structure of SPM and output the sentences. When people (the IPE) use this expression method, they (the IPE) and the target object are usually in the same layer of the SPM.

| Target Object | Spatial-position attribute | Output sentences |
|---------------|----------------------------|------------------|
| Cat           | Fridge Back side (behind)  | The cat is in the fridge. |
| Sofa          | Fridge Left side (on the left side of) | The sofa is in the fridge. |

b) Type B expression method: This is a spatial scope recognition method that executes on the tree structure of SPM, which needs to find out the parent node of the target object, then use the parent node to assist in positioning the target object. In Fig.7, the parent node of “Apples” is “Fridge”, the parent node of “Cat” is “House”, and the parent node of “House” is “**community”. We use the parent node to define the scope of the target project. People (the IPE) prefer to use this expression method when they (the IPE) are not in the same layer with the target object in SPM.

| Target Object | Spatial-position attribute | Output sentences |
|---------------|----------------------------|------------------|
| Apples        | Fridge Inside (in)         | The apples are in the fridge. |
| Cat           | House Inside (in)          | The cat is in the house. |
| House         | **community Inside (in)    | My house is in **community. |

In general, when people (the IPE) need to describe the position of an object, they need to find out the location of both the object and themselves (IPE) in their SPM, and then to decide which method to choose to express the spatial-positioning information in natural language.

The author just takes the spatial-position AS as an example to elaborate on the spatial attribute information processing mechanism in SPM. Similarly, different attribute information is been processed in different corresponding ASs, the corresponding information-processing mechanisms are the foundation of NLU. Understanding Process of a Dialogue

Since the author has briefed the new classification of the words and introduced the information process mechanism in one of the spatial-position AS. Now let us put the theory into practice through the example below. The example of a Dialogue and the background information is given in Table X, and the understanding process is listed in Table XI.

| Background information: | Dialogue (CTS 5: 1st Oct, 17:05): |
|-------------------------|----------------------------------|
| Jack: the owner of the house and the home service robot. | Jack: “Nana, do we have any apple?” |
| Nana: the home service robot. | Nana: “Yes.” |
| Default setting: the ownership of all the things in the house are belongs to Jack, which means the ownership here can be defined by the spatial attribute. The SPM in Fig.6 is taken as the spatial-position AS in Nana’s brain. | Jack: “Give me an apple.” |
| Nana: “Sure.” |

**TABLE IX.** TYPE B EXPRESSION METHOD OF SPATIAL-POSITION INFORMATION

| Target Object | Spatial-position attribute | Output sentences |
|---------------|----------------------------|------------------|
| Apples | Fridge Inside (in) | The apples are in the fridge. |
| Cat | House Inside (in) | The cat is in the house. |
| House | **community Inside (in) | My house is in **community. |

**TABLE X.** DIALOGUE EXAMPLE AND THE BACKGROUND INFORMATION

| Sentence 1: “Nana, do we have any apple?” | Sentence 2: “Give me an apple.” |
|------------------------------------------|---------------------------------|
| IPE-1: Jack | IPE-2: Nana |
| IPE-2: Nana | IPE-2: Nana |

**TABLE XI.** INFORMATION UNDERSTANDING PROCESS ON NANA SIDE
ensures that different individuals have the same information
NLU. The same physiological structure of human beings
same information storage database are the basic conditions of
systems, the same information processing systems, and the
is easy to find out that the same information perception
information reading, information verification, and so on.) It
implemented on existing information storage database (e.g.,
data, and the information processing operations
sentence types, which mainly involves the storage structure
U
in natural language.

So far, Nana still needs to figure out how to deliver
the apple into Jack’s hands instead of to deliver it into the sofa.
There are still many details to deal with, and the
understanding is not entirely precise, but Nana (the home
service robot) is already able to understand commands given
in natural language.

IV. THE BASIC CONDITIONS AND DEFINITION OF
UNDERSTANDING

We roughly discussed the information architecture
through introducing the new classification of lexical and
sentence types, which mainly involves the storage structure
of data, and the information processing operations
implemented on existing information storage database (e.g.,
information reading, information verification, and so on.) It
is easy to find out that the same information perception
systems, the same information processing systems, and the
same information storage database are the basic conditions of
NLU. The same physiological structure of human beings
ensures that different individuals have the same information
perception and processing system. And learning from each
other can make up for differences in information storage
databases in different brains, thus reducing differences in
understanding.

Now, the author tries to define the “understanding” in
following ways:
• the understanding can be roughly divided into two
parts: the understanding of the internal structural-
relations between inputted data chunks; the
understanding of the variation rule of attribute

Figure 8. The simplified diagram of the process of reading, transmitting,
and understanding of information between information sender and receiver
information and the prediction of the variation boundary of attribute information in different attribute spaces.

• the process of understanding is to locate the inputted information in the existing information storage system and then complete the steps in the above item. That is why different people interpret the same inputted information differently. Usually, people use their existing information storage database to interpret and understand the new inputted information. The understanding varies when the information storage database is different. When the inputted information is new, other procedures will be involved in which won’t be discussed in this paper.

Just like human learning in infancy, the construction of the information memory-database needs to start from the most basic information related to human beings. After having the basic and necessary information memory-database, more abstract information systems such as discipline research and the corresponding knowledge-graph can be built on it. The researches of different disciplines actually are the researches and constructions of specific ASs. In this way, all the knowledge in human history can be incorporated into the information memory-database, and been inherited and applied. When this becomes a reality, all human beings will have a shared decision-making system, and humanity will enter a whole new era.

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