E-Learning Design for Chinese Classifiers: Reclassification of Nouns for a Novel Approach

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Abstract. Chinese classifiers are found to be a category that creates true challenges for second language learners of Chinese to grasp its meaning and use it easily. It is also found that even native speakers of Chinese may lose their competence in using classifiers appropriately after years of living in a non-Chinese speaking community. This paper presents a novel approach in the design of an e-learning tool for Chinese classifier learning and teaching. With this approach, Chinese noun categories are reclassified according to their associations with the types of classifiers. The design is based on both theoretical studies of Chinese classifiers and empirical studies of Chinese classifier acquisition by both children and adults. It allows users to use cognitive strategies to explore and learn with a bottom-up approach the associations of classifiers with nouns.

Keywords: e-learning tool, Chinese classifier, semantic features, agent based model.

1 Introduction

Noun classifiers are a typical feature of Chinese that distinguishes itself from many other languages. In simple terms, a classifier is a morpheme or word used to classify a noun according to its inherent semantic features. Noun classifiers in Chinese are obligatory as a category of its own and used to specify a noun when it is used with a determiner or a numeral. In other words, A Chinese classifier is never used independently. It must occur before a noun with a numeral (e.g. *yī* 'one', *sān* 'three', *wǔ* 'five') and/or a determiner (e.g. *zhè* 'this', *nèi* 'that'), or certain quantifiers (e.g., *jǐ*'how many', *měi* 'every'). Such a combination is referred to as a classifier phrase.

However, the definition of Chinese classifiers is not a simple one. There are different types of classifiers in terms of their semantic functions. Some of them carry the unique features of the Chinese language; others are representative of the classifier languages, and yet all of them have the functions of measure words, which are of a universal category of all languages. Due to the complexity of classifier functions, different definitions and classifications have been found [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]. However, generally speaking, classifiers refer to common properties of noun referents

R. Kwan et al. (Eds.): ICT 2011, CCIS 177, pp. 186–199, 2011.

across domains and common relations of noun referents in the world, rather than to categories having to do solely with language-internal relations [11]. Some researchers take a functional approach and define Chinese classifiers based on their grammatical functions. For example, Chao [12] divides classifiers into nine categories. They are "classifiers or individual measures", "classifiers associated with v-o", "group measures", "partitive measures", "container measures", "temporary measures", "standard measures", "quasi-measures or autonomous measures", and "measures for verbs of action". From his classification we can see that he does not distinguish the concept of a classifier from that of a measure word. The advantage of such a classification is its inclusion of all the three types of classifiers mentioned above and being able to define them all as measure words, but the disadvantage is that those that are Chinese specific noun classifiers are all treated under the universal concept of measure words. This may be easy for learners to understand the grammatical functions of Chinese classifiers but the ontological nature of noun objects that classifiers are associated with is largely ignored.

In recent decades, researchers have started to take a cognitive approach to understand the links between nouns and classifiers and found it necessary to make a distinction between classifiers and measure words. For instance, Tai & Wang [13] state that "A classifier categorizes a class of nouns by picking out some salient perceptual properties, either physically or functionally based, which are permanently associated with entities named by the class of nouns; a measure word does not categorize but denotes the quantity of the entity named by a noun." This definition makes a clear distinction between a classifier and a measure word, which is believed to be helpful for second language learners to have a better understanding of the cognitive basis of a classifier system. This is because there are no measure words in English or other European languages that also function as classifiers in the same sense as Chinese classifiers do. A recent study done by Gao [14] has shown that Swedish adult learners of Chinese had a lower proficiency in classifier application than their general Chinese proficiency and that most of them were not aware of the difference between the concept of a classifier and that of a measure word. Another recent study done by Quek & Gao [15] shows that native speakers of Chinese tend to associate one noun with a number of classifiers based on their own perception and cognitive understanding of the shape and functions of the noun referent. We assume that this phenomenon would be mainly due to the fact that the cognitively based semantic properties of classifiers allow speakers to perceive and project the features of the associated noun objects from different angles or perspectives and that this phenomenon can be more distinctive in a Chinese speaking community where a number of Chinese dialects are spoken as well.

Other previous studies of classifiers include descriptive and experimental studies of classifier systems of natural languages. For example, some descriptive studies make typological surveys of classifier systems in different languages (e.g. [16, 17, 18]); others provide semantic analysis of classifiers and their associated nouns (e.g. 19, 20, 21]), and some also propose that there is an ontological base on which classifiers and nouns are associated with [22, 23, 24].

Experimental studies using computer technologies to apply findings of classifier knowledge to natural language processing (NLP) have provided a new approach for the semantic analysis of classifiers (e.g. [25], [26]) and for computer-assisted language learning (e.g. [27]). However, no e-learning systems developed so far are found to be able to guide learners to use the semantic properties to understand the links between classifiers and their associated nouns.

Yet, the emergence of computer-assisted language learning (CALL) provides language learners with a user-friendly and flexible e-learning tool. CALL incorporates technology into the language learning process and also applies itself across a broad spectrum of teaching styles, textbooks, and courses [28]. Its bi-directional and individualized features make it possible for learners to use it effectively to improve different aspects of language skills (e.g. [29], [30]).

My idea of designing the e-learning tool of Chinese classifiers is similar to that of CALL. Empirical studies have shown that classifier learning is a big challenge for second language learners of Chinese. My argument with regards to Chinese classifier acquisition is that cognitive strategies with a bottom-up approach are the key to the understanding of the complexity of classifier and noun associations. Therefore, the design of the e-learning tool has a focus on guiding learners to explore the cognitive foundations of classifier-noun relations. The e-learning system is implemented in the e-dictionary of classifiers, which is part of the design, to promote various ways of self-paced accelerated learning. It consists of a database of the decomposed semantic features of classifiers and their associated nouns. These well-defined unique and non-unique features will help learners take a cognitive approach to explore case by case the matched pairs of classifiers and nouns. Currently the e-dictionary has included 168 noun classifiers and 680 nouns, of which 80 classifiers and 560 nouns have been analysed and entered into the e-learning database. My aim is to define and include all Chinese classifiers and their associated nouns [1] and eventually link them to the e-learning system.

2 Multi-Categorization of Classifiers

In cognitive linguistics, categories are defined by groups of features and relationships within a same family. From this viewpoint, the occurrence of a noun with a particular classifier is dependent upon the categorical features of both nouns and classifiers. However, the internal semantic network of categories may be ambiguous due to historical and social factors, which make categorization dependent on not only noun referents' intrinsic properties but also their functional and human perceptual ones. In other words, classifier and noun associations encode as well human cognitive understandings of the real world entities. As a result, classifiers are found to be able to link nouns cross-categorically. That is, one single classifier can associate itself with a number of nouns from different noun categories and at the same time one single noun can be associated with not one but two classifiers. This multiple-categorization nature of classifiers complicates the classification of classifiers and nouns for the purpose of providing an effective learning strategy. It is also virtually impossible for linguists to build a meta-theory for a systematic organization of any clear logical classifier-noun

[1] Based on the 11 classifier dictionaries (see details in the References) consulted, the number of classifiers ranges from 143 to 422 and the number of associated nouns is from 388 to 8609. However, if we follow Tai and Wang's (1990) definition of classifiers, there are 178.

categories and thus hard for lexicographers to find an effective way to illustrate the semantic connections between classifiers and nouns. However, one thing we are clear about is that the main obstacles in classifier acquisition are that the inhabited meaning associations in the nature of classifiers are opaque and that the complex classifier associations with nouns have caused noun categorizations to be linguistically unconventional. Yet, from a cognitive viewpoint, these associations and categorizations can provide cognitive motivations to learners if we can provide a learning tool that allows them to pay attention to the pragmatic use of classifiers from a cognitive perspective.

3 Semantic Decomposition of Classifiers and Nouns

Table 1 is a demonstration of the semantic features of some most commonly used noun classifiers and their associated nouns. A total of 168 classifiers are collected and sorted out according to the number of noun categories each classifier is associated with. One special feature of this e-dictionary design is that the classifiers' associated nouns are grouped into categories based on the real-world entities as noun referents. Currently I have defined 11 categories and entered them in the e-dictionary. They are: "nature, humans & body parts", "animals", "vegetables & fruits", "man-made objects", "buildings", "clothing", "food", "furniture", "tools" and "vehicles". A hierarchy of noun classifiers is built up based on the number of the noun categories they enter into. For instance, the classifier *liàng* occurs only in the "vehicles" category, (e.g. car, lorry, bicycle, etc.) and thus it is ranked at the bottom in terms of complexity. Out of the 168 classifiers, 149 occur in fewer than 3 noun categories. The cognitive mapping between these 149 classifiers and their associated nouns are straightforward. Hence it is relatively easy for users to picture quickly how a classifier is associated with certain type(s) of nouns. For the rest of the 19 classifiers listed in Table 1, each occurs in at least 3 noun categories. At the current stage my work focuses on individual noun classifiers; the other types of classifiers will be added in the future when more people are involved in the project. In the e-learning part of the dictionary, I temporarily exclude the general classifier *gè* because pedagogically it is not a challenge and it is possibly among the first few classifiers that learners master in order to make grammatical phrases.

Through semantic decomposition, the cognitive mapping between a classifier and its associated nouns are revealed. Take the classifier *tiáo* for example. It is associated with nouns such as *rainbow*, *leg*, *snake*, *cucumber*, *road*, *scarf*, *potato chip*, *boat* and *necklace*, which are from 9 of the 11 noun categories listed in Table 1. Despite of the different categories they belong to, the 9 nouns share one same cognitive property – the shape of the noun referents, which we define as "longitudinal". This shows that the classifier *tiáo* is inhabited with this semantic feature as a cognitive basis on which speakers perceive it and link it to the nouns accordingly.

Similarly, the classifier *gēn* is used with the nouns such as *stick*, *bone*, *banana*, *pillar*, *sausage*, *needle* and *ribbon* that belong to 7 noun categories respectively. These nouns possess the same "longitudinal" feature as *tiáo*. This shows that extracting one same feature from *gēn and tiáo* is not helpful enough for learners to understand the differences between the two classifiers though classifying nouns into categories can constrain the cross-category interference to learners to some extent.

What needs to be carried out is to define each noun with a unique feature of its own, either from its lexical semantic meanings, pragmatic functions, or human perceptions. For instance, besides “longitudinal”, “for walking” is added as a feature to *stick*, “a piece of human skeleton” to *bone*, “turns from green to yellow when ripe” to *banana*, “one end stuck to the ground” to *pillar*, etc. etc. until finally each noun is distinguished from other nouns that are associated with the same classifier. These definitions are the core part of the database for the e-learning tool linked to the e-dictionary.

Table 1. Classifiers sorted by the number of noun categories they are associated with

Classifier in Chinese	Classifier	No. of categories the classifier is associated with	Examples of nouns the classifier is associated with
条	tiáo	9 (nature, humans & body parts, animals, vegetables & fruits, buildings, clothing, food, vehicles, other man-made objects)	rainbow, leg, snake, cucumber, road, scarf, potato chip, boat, necklace
根	gēn	7 (nature, humans & body parts, vegetables & fruits, buildings, food, tools, other man-made objects)	stick, bone, banana, pillar, sausage, needle, ribbon
块	kuài	6 (nature, humans & body parts, clothing, food, tools, other man-made objects)	stone, scar, handkerchief, candy, eraser, soap
层	céng	5 (nature, humans & body parts, building, clothing, other man-made objects)	wave/fog, skin, building storey, curtain, paper
张	zhāng	5 (humans & body parts, food, furniture, tool, other man-made objects)	mouth, pancake, bed, bow, map
只	zhī	5 (humans & body parts, animal, clothing, vehicle, other man-made objects)	ear, tiger, sock, sailing boat, watch
粒	lì	4 (nature, vegetables & fruits, food, other man-made objects)	sand, cherry, rice, sleeping tablet
段	duàn	4 (nature, vegetables & fruits, building, other man-made objects)	wood, lotus root, city wall, iron wire
口	kǒu	4 (humans & body parts, animal, tools, other man-made objects)	person(people), pig, sword, well
面	miàn	4 (buildings, tools, furniture, other man-made objects)	wall, drum, mirror, flag
节	jié	4 (building, food, tool, vehicle)	chimney, sugarcane, battery, railway carriage
道	dào	3 (nature, humans & body parts, building)	lightening, eyebow, dam

Table 1. *(countinue)*

滴	dī	3 (nature, humans & body parts, other man-made objects)	water/rain, blood, ink
件	jiàn	3 (clothing, tools, other man-made objects)	shirt, (music) instrument, toy
把	bǎ	3 (furniture, tools, other man-made objects)	chair, knife, cello
截	jié	3 (nature, tools, other man-made objects)	rope, pencil, pipe
颗	kē	3 (nature, humans & body parts, other man-made objects)	star, tooth, artillery shell
片	piàn	3 (nature, food, other man-made objects)	leaf, loaf, tablet
枝	zhī	3 (nature, tools, other man-made objects)	rose, pen, arrow/rifle

4 Methodology

The database of the cognitive-based e-learning tool is designed with two types of words stored separately, one type being Chinese classifiers and the other Chinese nouns. A semantic decomposition method is used to classify and project the semantic features of nouns and classifiers on the basis of which their associations are made categorically. An agent-based model is applied for setting up the goal of making the e-learning tool select automatically classifier-noun associations as learners explore its functions to learn the different aspects of their associated semantic features. The method used in designing the e-learning tool makes it possible for its database to be used in its own as an e-dictionary of Chinese classifiers. It is easily accessed via an interface designed for quick learning.

The e-learning system has currently linked 11 classes of nouns (more will be linked later) with their associated classifiers. The feature-based classifications of nouns and the semantic decomposition of noun and classifier properties are able to show learners of Chinese the cognitive mapping of linguistic constructions. The proposed agent-based model utilizes the match between pseudo-binary-bit strings to indicate the probability of interactions between agents. It hence predicts how likely a classifier and a noun will occur in a classifier phrase.

4.1 Application of Cognitive Strategies in Noun Classifier Acquisition

In this section I will describe an approach that can enhance the practical use of the e-classifier dictionary. Developed in the software environment of FileMaker Pro 8.5 (see Fig.1), the dictionary is established on a database system. Categorical records created as data files are used to store the associated nouns. The records created so far include 11 categories of nouns described in Section 3. Such a categorization appears explicit, but its top-down approach fails to reveal the feature-based mapping between a classifier and its associated nouns. The objective of the e-learning approach, on the other hand, is to guide users to search for correct classifier and noun pairs by looking for the defined features of the noun referents, firstly from those broadly defined as "animacy", "shape", "size", "thickness", "length", "function", etc., then to those specific ones extracted from each particular noun referent.

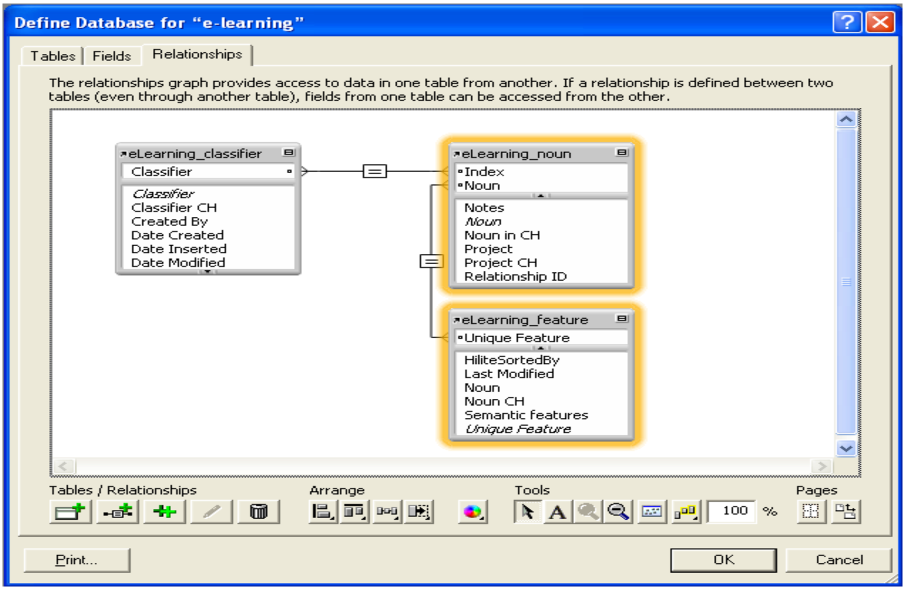

Fig. 1. A display of the database in the e-learning environment

With such a bottom-up approach, the e-dictionary allows users to learn the interrelated features of a classifier and its associated noun referents in a case-by-case fashion. In this way, learners can better understand the point that a classifier reflects the cognitive classification of its associated noun referents. Each individual record thus contains both general and specific information of a classifier and its associated nouns as data entries. The features decomposed from the noun referents are recorded as independent data entries linked to the e-learning tool. For instance, if a learner wants to know which classifier is the correct one for *boat*, he enters the word *boat*, finds its category as "vehicles", chooses its shape as "longitudinal" and then *tiáo* should automatically pop up because in this case *boat* is the only noun referent from the "vehicles" category (see Table 2). In other cases where there are two or more items that are featured as "longitudinal", the user will be guided to look for a more specific or unique feature with a few more clicks on the users' interface.

The e-learning environment in the dictionary also provides users the noun-classifier phrases that are commonly used but they may not be easy for learners to acquire. Take the noun classifier *zhī* for example. It is associated with noun referents that belong to "animals and body-parts" and "man-made objects", such as *bird*, *hand*, *pen*, etc. The unique perceptual features of these noun referents are identified but all are built into the e-learning system correspondingly so that users can click different categories in the interface to make particular associations as long as they have some general knowledge of the entities in terms of their functions and perceptual features.

Table 2. Examples of noun-classifier phrases of tiáo

English equivalent of Chinese classifier phrase	Classifier phrase in Chinese			Properties	
	numeral	classifier	noun	cognitive	intrinsic
a rainbow	*yì*	*tiáo*	*căihóng*	longitudinal	nature
a leg	*yì*	*tiáo*	*tuǐ*	longitudinal	human
a snake	*yì*	*tiáo*	*shé*	longitudinal	animal
a cucumber	*yì*	*tiáo*	*huángguā*	longitudinal	vegetable
a road	*yì*	*tiáo*	*lù*	longitudinal	building
a scarf	*yì*	*tiáo*	*wéijīn*	longitudinal	clothing
a potato chip	*yì*	*tiáo*	*shŭtiáo*	longitudinal	food
a boat	*yì*	*tiáo*	*Chuán*	longitudinal	vehicle
a rope	*yì*	*tiáo*	*shéngzī*	longitudinal	man-made tool
a necklace	*yì*	*tiáo*	*xiàngliàn*	longitudinal	jewelry

4.2 Implementation of An Agent-Based Model in Classifier E-learning

The e-learning tool linked to the classifier e-dictionary is targeted for automatic classifier-noun associations. By adopting an agent-based model [31], we[2] have developed a classifier-noun classifier network for users to learn step by step classifier phrases. Included in the prototype model would be nouns and classifiers, divided into two groups of agents. To design a semantic interface between the two types of agents in a computational perspective, a tag is attached to each agent. The tags are of opposite polarity, one to a noun, and another to a classifier. Each tag is a pseudo-binary-bit string of {0, 1, #}, where "#" is the "doesn't care" symbol. The position a symbol occupies in the string corresponds to a particular semantic feature of the agent, with "#" indicating that the corresponding feature is not critical for the formulation of the classifier phrase, even though the noun referent owns such a feature. When a noun agent meets a classifier agent, we line up the two tags and match the digits in one string with those in the other position by position. To report a match score at the end of this comparison, three match rules are listed as follows: (i) it scores 1 given there is a match between two "1"s or between two "0"s; (ii) it scores 0 given there is a match between a "1" and a "#" or a "0" and a "#" or between two "#"s; (iii) it scores -1 given there is a match between a "1" and a "0". The aggregate match score indicates the likeliness of a correct classifier phrase with the involved classifier and noun.

The first simple model is illustrated as follows. In this model each tag consists of 4 pseudo-binary bits. Out of the noun's many semantic features, we selectively

[2] Acknowledgements to Ni Wei, research student, for his contributions to the technical trials.

represent two of them: the first feature with the first two symbols, and the second with the last two. For example, a tag “1100” is assigned to the agent (noun) *leg* to represent the noun’s features defined as “longitudinal” and “body-part” respectively. In this case, “longitudinal” might be considered as the most salient feature of *leg* with regards to the selection of a classifier. Hence, it is represented by “11”. On the other hand, if “longitudinal” is by no means an external or internal feature of the associated noun referent, the symbols at the corresponding positions would be “00”. Other possible combinations of symbols such as “01” and “10” are reserved for fuzzy states, which are associated with marginally accepted classifier phrases. Besides, the noun referent *leg* also has a “body-part” property listed, but it is not of primary importance for finding its classifier match. Therefore, it is represented by “##” at the last two string positions, rather than explicitly indicated by any of the four combinations mentioned above.

We assign the tags to classifier agents in a similar way. For instance, “11##” may be assigned to the classifier *tiáo*, due to the fact that *tiáo* often occurs in a classifier phrase with nouns defined as having “longitudinal” features. On the other hand, “##11” may be assigned to the noun classifier *zhī*, which is commonly applied to noun referents of body-part.

Regarding the agent’s interaction with those agents of classifiers, when the tag “1100” of *leg* is compared with the tag “11##” of the agent *tiáo*, the match score is 1+1+0+0 = 2. In contrast, its match score with the tag “##11” of the agent *zhi* is reported as 0+0+0+0 = -2. The match score 2 indicates *tiao* is more likely to be linked to *leg*, and the match score -2 implies an undesirable match between *leg* and *zhī*. It is noteworthy, however, that if a user assigns “1111” to *leg*, they will obtain a match score of 2 (0+0+1+1) with *zhī*. They will hence conclude that, beside *tiáo*, *zhī* is another correct classifier for *leg*.

In addition, we include the defined features of nouns and classifiers as a group of interactive agents. Interactions between agents are controlled by tags and conditions defined with pseudo-binary bit strings. This group is designed to facilitate the learning process from learner’s perspective. Let’s take second language learners for example. First they may learn that *tiáo* is the correct classifier for *leg* because the noun referent of *leg* has the longitudinal attribute. Next, they tend to look for other nouns with the longitudinal feature, such as *necklace* and *snake*, and to verify whether *tiáo* is also the correct classifier for these nouns. By establishing the mapping between the defined features of nouns and classifiers, the agent-based model explicitly shows learners the possible connections between these groups of agents.

Among the semantic features, some are defined as unique features which distinguish their corresponding nouns from the rest in the nouns’ group. For instance, we may define “chained jewel” as the unique feature of a necklace, and “limbless reptile, some of which produce venom” as that of a snake (see Fig. 2). We assign two kinds of tags respectively, one for non-unique feature agents and the other for unique feature agents. Each non-unique feature agent is attached with an adhesion tag [31]. When adhesion tags match, the corresponding agents group together – that is, they form aggregates. Thus, adhesion tags provide the possibility of forming multi-feature agent aggregates with individual unique feature agents.

To implement this feature, each unique semantic feature is attached with a two-segment tag: (i) the first segment plays the same role as the classifier/noun tag, which controls the agent's interaction with agents of other groups, i.e. nouns and noun classifiers; and (ii) the second segment functions simply as an adhesion tag. To decide whether to form a multi-feature agent aggregate, we can match a non-unique feature agent's adhesion tag and the second segment of a unique feature agent's tag. The match score is calculated in a similar way with that between noun's agents and classifier's agents. To simplify the discussion, we can state that adhesion only occurs between one unique feature agent and one or more non-unique feature agents. In other words, adhesion does not occur between either two unique feature agents or two non-unique feature agents.

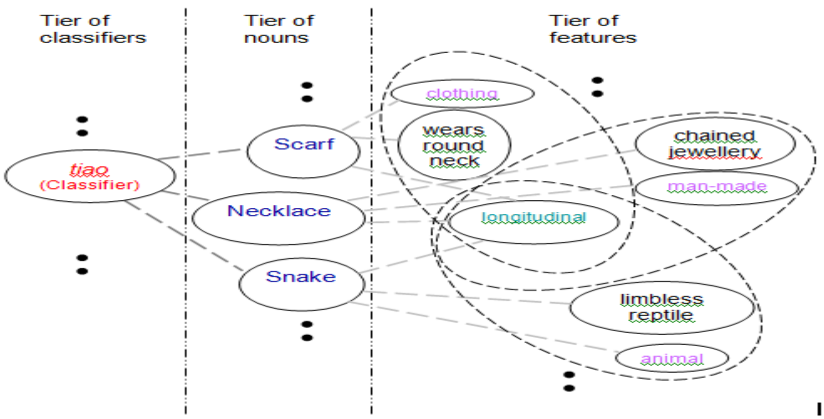

Fig. 2. Mapping among the tiers of classifiers, nouns, and defined features

To explicitly show the cognitive mapping between classifiers/nouns and their features, we use a collection of condition/action if-then rules [31]. In this model, both the condition and the action are linguistic variables, which are in turn represented by pseudo-binary-bit strings. The rules represent the interconnection among the agent group of classifiers, the agent group of nouns, and the group of defined features. For instance, the same noun classifier tiáo occurs in the classifier phrase yì tiáo xiàngliàn 'a necklace'. Let ①, ② and ③ respectively denote the features of "chained jewel", "man-made", and "longitudinal", where ① is the unique feature to identify the noun referent of necklace. As discussed earlier, the individual features ①, ②, and ③ can form a multi-feature agent aggregate, which we denote as ①②③. The if-then Rule 1 can be implemented as:

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Rule 1: {If (①②③) Then (necklace)}.
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Following the tag interaction approach discussed previously in this section, Rule 2 can be implemented to reflect the inter-agent communication between the noun and its classifier:

Rule 2: {If (necklace) Then (*tiáo*)}.

Based on these two rules, Rule 3 can be implemented as

Rule 3: {If (①②③) Then (*tiáo*)}.

Note that Rule 3 has the same input (condition) with Rule 1 and the same output (action) with Rule 2. Rule 1 outputs its action as a message, which is subsequently received by Rule 2 as its condition. This is an example of transitivity, a property of the rule-based network. The condition and action part in each of the three rules could also be exchanged to implement three inverse rules.

Now let's take the noun snake as another example. Given that ④ represents "animate" and ⑤ represents "limbless reptile, some of which produce venom", we can retrieve ③, ④, ⑤ from the features' group and form them as another multi-feature agent aggregate as ③④⑤. Here ⑤ is the unique feature of snake. We add another three if-then rules concerned with snake and tiáo as follows.

Rule 4: {If (③④⑤) Then (snake)};
Rule 5: {If (snake) Then (*tiáo*)};
Rule 6: {If (③④⑤) Then (*tiáo*)}.

So far only multi-feature agent aggregate, rather than single feature agents are used as conditions. It is also noteworthy that non-unique feature agents are incapable of interacting directly with noun agents or classifier agents, since their adhesion tags cannot be matched with the classifier/noun tags. The property of transitivity implies, however, that we can establish the mapping between nouns and non-unique feature agents indirectly. For example, we can represent the relation between the noun *necklace* and the unique feature agent ① "chained jewel" by Rule 7 as follows:

Rule 7: {If (necklace) Then (①)}

We also represent the relation between the noun *snake* and the unique feature agent ⑤ "limbless reptile, some of which produce venom" by Rule 8 as follows:

Rule 8: {If (snake) Then (⑤)}

Either ① or ⑤ is related with the non-unique feature agent ③ "longitudinal", which could be represented by Rules 9 & 10.

Rule 9: {If (□) Then (③)}
Rule 10: {If (⑤) Then (③)}

The mapping between *necklace/snake* and the non-unique feature agent ③ "longitudinal" could then be implemented by Rules 11 & 12.

Rule 11: {If (necklace) Then (③)}
Rule 12: {If (snake) Then (③)}

In Rules 11 and 12, the noun is taken as the input and its non-unique semantic feature as the output. By swapping the two kinds of agents' roles in the message-processing rules, we may inversely implement Rule 13 by taking the non-unique feature as the input and the noun as the output. If a user chooses ③ as the single input agent, two possible outputs pop up for his selection.

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Rule 13: {If (③) Then (necklace or snake)}
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More rules could be added in the classifier network by selecting different agents from the three groups, in a similar way as we implement Rules 1-13. With these rules set as conditions, the if-then rule-based network explicitly shows the cognitive mapping between the classifiers and their corresponding nouns. Learners will find out the association between the target words and their features that are essential for their classifier acquisition. So far we have tested the commonly used classifiers and their associated nouns selected from the e-dictionary and tried them within the agent-based model. The automatic matching is successful, though more pairs need to be tested.

5 Conclusion

This paper presents a feature-based approach in designing a classifier e-dictionary with an e-learning environment created for learners to use cognitive strategies to explore and learn the classifier and noun associations.

The current dictionary as a learning system is based on a database with classes of nouns (11 classes at present) and classifiers (168 added) that are stored as individual records. The records are not organized according to the lexical meanings of the words; instead, their classification schemes are built based on the noun referents' external or functional features. The objective of the design is to use such features to set up a classifier network that can automatically associate all possible nouns. A computer-based model with such a design is expected to show learners of Chinese the cognitive mapping of linguistic constructions. The proposed agent-based model utilizes the match between pseudo-binary-bit strings to indicate the probability of interactions between agents. It hence predicts how likely a classifier and a noun will occur in a classifier phrase. The relations among the agent groups are shown within the framework of the if-then rule-based network. Learners can explore case by case, within the e-learning environment, the classifier and noun associations and the defined features that the association is based on. A future task is to include the rest of the classifiers and all possible associated nouns. Linguistically, a challenge to carry out the task would be the definitions of the unique features of the nouns and classifiers that have fuzzy boundaries. Technically, the challenge would be the solution to making perfect matches of those cases where one classifier agent as input is expected to link a number of noun agents as output and demonstrate them effectively from users' perspective.

Acknowledgments. I would like to thank the editors, the two anonymous reviewers' valuable comments and suggestions on the earlier draft of this paper, research student, Ni Wei, for his assistance in testing the model, and Nanyang Technological University (NTU) for a grant to H. H. Gao for this research. A special thank-you note goes to Prof. John Holland for his inspirations and thought provocative questions

raised in his series of lectures on language modeling delivered at the workshops organized by Santa Fe Institute, the Centre for the Study of Complex Systems at the University of Michigan, and Nanyang Technological University.

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