A Vector Approach to Mandarin Resultative V-V Construction

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Content

1. Introduction

This thesis focuses on establishing a validated characteristics system of resultative V-V construction. Resultative V-V construction is a very complex structure and debates on what is a resultative and what kinds of V1 and V2's co-occurrence is licensed to have a resultative meaning seems endless. Thompson (1973) stresses "action + intransitive" co-occurrence is the lexical rule of resultative V-V construction. While studies like Y. Li (1990, 1995), Cheng and Huang (1994) etc. insist that argument number and argument distribution decide the distinction and classification of resultative V-V construction, Gu (1992) and Shi (2008) emphasize the importance of event types in deciding a resultative meaning for V-V construction. Almost all of the studies about resultatives notice the effect of context as a critical factors in deciding what is a resultative.

However, there are two problems when the generalized constraints entails that they insist these factors impact whether a V-V construction is resultative or not:

Firstly, their evidences about one factor's effect on whether a V-V construction is resultative or not are week. Most of studies generalize the constraints of V1, V2 and their arguments for resultative V-V construction based on a very little sample (sometimes, only several instances) and simple counting method. Such as Thompson (1973)'s co-occurrence constraints of "action + intransitive". There are too many counter-examples. It is the same for some of the English studies on resultative construction. Boas (2003) lists dozens of V1s that co-occur with a pivoted V2 with their frequency and also vice versa, but it helps nothing in deciding what is/are the distinctive(s) feature in deciding whether a construction is a resultative or not. He introduce *context* as an important factor in "revising" an unaccepted resultative, such as *hammer the iron safe*, to an accepted one based on construction coercion, however, only several instances are used to show how does this model work without proving his model's existence or the model's prediction performance.

Secondly, most of the studies focus on only one feature when they are trying to generalize the constraints of resultative V-V construction. Some include several factors but only give several examples. We never know to what extent, their account can be used to predict whether a V-V construction is a resultative or not. Gu (1992) insist that the co-occurrence constraint for V1 and V2 in resultative V-V construction is "activity + transition" which means only event type is considered. Shi (2008) holds the similar view but he includes transitivity and semantic property also. He shows these factors impact only by listing these words. The contribution of event type, semantic property and transitivity is impossible to decide.

Since the existence of these problems on deciding what is a resultative V-V construction, this thesis try to achieve the followed golds:

Firstly, validate all these factors previous studies mentioned including event type, semantic type, transitivity, transitivity, argument distribution and context based on big annotated corpus and text mining methods. Transitivity can be transformed to the valence of predicates; argument distribution and context can be represented by context itself because context actually include arguments and non-arguments.

Secondly, deciding these factors contribution to the distinctiveness between resultatives and non-resultatives based on random forest (RF).

Thirdly, coming up new features that can be used to differentiate between resultatives and non-resultatives in V-V contribution.

Fourthly, design predicting model by weighting these factors and implement recognition task to

recognize resultatives.

The linguistics value is that a validated characteristics system of resultative V-V construction can be built;

The application value is that a prediction model can be built by weighting these factors. By using this prediction model, recognition and classification of resultative V-V construction can be applied.

1.1. Research object

In this section, I will review the definition of resultative in previous studies and cast my challenges about their definition. It will be proven that the so-called resultative actually includes constructions with different relations. They may entail a kind of change of state or change of location meaning, however, causal relation is really hard to be defined and linguistics don't agree with each other even on the same examples about whether they are resultatives or not.

In this thesis, I don't intent to give a definition of resultative V-V construction based on a few examples and some linguistics description *ad hoc*. I insist that the distribution of V-V construction's arguments and non-arguments context and the event type and semantic type of V1 and V2 can be used to predict and differentiate the different relations between V1 and V2 in V-V construction including the so-called resultatives. If this relation does exist, classification and clustering tasks based on these information (distribution, event type and semantic type etc.) should be able to differentiate it from other relations to a large account. Thus, all of the V-V constructions will be included:

(1) a.审查，审核，访谈
    b.摔破，刺破，割破
    c.改称，难熬，好战

There are different relations between V1 and V2 such as coordination, resultative and modification (Hong & Huang, 2015) and maybe more. Among these, this thesis focus on resultative meaning such as (1b).

Previous studies have seek to generalize different constraints to differentiate resultatives from other V-V constructions based on different information such as event type, semantic type and argument distribution. Most of the studies treat resultative equal to causative. Shibatani (1976) insists causative has a complex event structure composed of a causing event and caused event. He defines that causing event must precedes caused event and there must be a dependent relation (or causal relation) between causing event and caused event. The complex event structure and causal relation have been accepted in a lot of studies such as Comrie (1989), Comrie and Polinsky (1993), Pustejovsky (1991, 1995), Goldberg (1995) and Boas (2003) etc. to define resultatives and causatives.

While it is easier to define a complex event structure, causal relation is hard to be depicted:

(2) a. The river froze solid.
    b. The bottle broke open.

While studies like Boas (2003) treat examples in (2) as resultatives, Pustejovsky (1991) and C. Li (2007) doesn't treat them as resultatives since *solid* only serve as an emphatic of the result already entailed in *froze* because the addition of the *solid* doesn't change the eventuality of *froze* (Pustejovsky, 1991). It seems that *solid* only serve as a natural result of *froze* instead of a caused result of *froze*. It is hardly to say that there is a causal relation between *froze* and *solid*. However, none of them give a definition of what is caused result and what is not.

Although change of state is comparatively easier to define compared with causal relation, debates still exist. Goldberg (1995) makes a distinction between caused motion construction and resultative construction. Caused-motion construction refers to change of location while resultative refers to change of state.

Their constructional meaning are represented as followed:

(3) a. X causes Y to move Z. (Caused-motion construction)
b. X causes Y to become Z. (Resultative construction)

She insists that resultative construction is a metaphorical extension of caused-motion construction. There are two evidence showing the close relation between these two constructions.

Firstly, resultative phrase cannot co-occur with directional PPs in a single clause:

(4) *a. Sam kicked Bill black and blue out of the room.
*b. Sam kicked Bill out of the room black and blue.
*c. Sam tickled Chris silly off her chair.
*d. Sam tickled Chris off her chair silly.

But resultative phrase can co-occur with other kinds of PPs:

(5) a. Lou talked himself blue in the face about his latest adventure.
b. Joe loaded the wagon full with hay.
c. He pried the door open with a screwdriver.

(Goldberg, 1995)

The hypothesis and logic behind this is that there is a Unique Path (UP) constraint which only allow one path to predicate the argument at the same time in a single clause. If resultative is a metaphorical extension of caused-motion construction, in other words, resultative is also a kind of path, they cannot co-occur in a single clause because they represent two distinct path. However, in my opinion, the UP constraint can also be used to prove that they belong to the same construction which we called resultative construction.

The reason why Goldberg make a distinction between them is that they entails different constructional meaning illustrated in (3), but [preposition + location] is also a kind of state:

(6) a. She has been in the house for more than one week.
b. The window has been broken for a while.

Both *in the house* and *be broken* belong to the event type of *state* since there is no change during the happening of the event which can be tested by durative adverbials.

Even if we accept that there is a difference between state represented by [preposition + location] phrases and by stative verbs or adjectives and there is a metaphorical relation between them, what is the reason that [preposition + location] phrases serve as the source domain and stative verbs or adjectives serve as the target domain. Usually speaking, concrete domain serve as the source domain while abstract domain serve as target domain. But sometimes it is hard to judge which is more concrete:

(7) a. John painted the house red.
b. Sam kicked Bill out of the room.

It is natural to assume that change of state is more abstract than change of location. But it is problematic since they have hyponymy relation. Change of color is also a kind of change of state in (7a). What's more, change of color is as concrete as change of location. If Goldberg's first evidence is accepted, the metaphorical extension can also be constructed between change of color and change of state. Similar metaphorical extension will be found between change of state and change of shape,

change of weight etc.

Why does Goldberg choose change of location as the source domain for change of state? The evidence is too week to divide resultatives into caused-motion construction and resultative construction.

The second evidence showing the close relation between these two constructions is that many verbs of directed-motion can be used metaphorically to code changes of state:

(8) a. He fell asleep.

b. He went crazy.

When the directed-motion verbs are used literally, they cannot co-occur with resultatives:

(9) *The boy ascended sick.

According to Goldberg's UP constraint, *fell* and *went* must encode same path with *asleep* and *crazy* while *ascend* must encode distinct path from *sick*. Otherwise, the grammaticality of (8) and ungrammaticality of (9) cannot be explained. While it sounds understandable to assume *fell* and *asleep* encode the same path, it is reluctant to interpret *went* and *crazy* encode the same path. Actually *went* will "encode" very different path according to this kind of co-occurrence test:

(10)a. He went into the room.

b. He went out of the room.

If *went*'s encoding path cannot be divided, how can we judge whether (8b) is grammatical or not according to UP constraint?

The distinction of caused-motion construction and resultative construction is hardly to be supported by Goldberg's evidence. Boas (2003) also hold similar view against Goldberg's distinction between change of state and change of location.

For V-V construction, the definitions of resultative are also debatable. There is no consensus on whether verb-direction construction (走进来), verb-derivation construction (挖浅了), verb-aspect construction (跑起来).

Let's begin with verb-direction construction. Li Wang (1943) proposes "*cause-to-become*" construction to refer to resultative V-V construction. This is similar to Goldberg (1995)'s definition but he doesn't make a distinction between caused motion construction and resultative construction. In his definition, causative contains a predicate and complement and there is a causal relation between the predicate and its complement. From the examples he cited in the book, both the so-called verb-result (动结式, such as 饿死) and verb-direction (动趋式, such as 爬进来) relation are included in the causative construction. For the former one, he actually only considers examples whose subjects of V1 and V2 have co-reference relation such as 打死 and 剪短. Shi (2008) calls these examples the most "typical" verb-result construction. However, he doesn't explain how to judge the examples' typicality and it is hard to know why these examples are typical verb-result construction. I assume that for these examples, the *causer* and *causee* are easier to assign to the components' arguments or the whole constructions' arguments.

Thompson (1973) roughly define resultative construction as a compound with a verb depicting an action and another verb indicating the result of the first verb in the compound. She explicitly include verb-direction construction into resultatives. C.-R. Huang and Lin (1992) also list 走进了教室 as an example which indicate that they treat verb-direction construction as resultative.

However, most of studies in Mainland, China don't consider verb-direction construction as resultative since the distinction of verb-result construction and verb-direction construction in Lv (1980). Shi (2008) also excludes verb-direction construction although he admits that verb-direction

construction is a kind of "broadly defined" resultative.

Other studies such as Y. Li (1990, 1995), Cheng and Huang (1994) and Lingling Wang (2001) don't consider verb-direction construction as resultative explicitly based on the cited examples. C. Li (2007) explicitly exclude verb-direction construction from his study scope which will be introduced in details latter.

Now let's turn our focus to the V-V construction with verb-derivation meaning and verb-aspect meaning.

Fan (1985) divides resultative V-V construction into three subtypes according to the relation between V1 and V2:

(11)a. Verb-result: 冻坏, 喂肥, 逗笑

b. Verb-degree: 吃多, 穿少, 来晚

c. Verb-aspect: 走到, 吃着, 唱上, 做完

He uses "verb-degree" to refer to examples in (11b). But these examples actually have a meaning of "the derivation of expected result" which is discussed in Lu (1990) and Z. Ma and Lu (1997a, 1997b, 1997c).

H. Wang (1996) uses "verb-evaluation" meaning to refer to them which is shared by Shi (2008). Fan (1985), H. Wang (1996) and Shi (2008) consider examples in (11c) as resultatives while other studies rarely discussed them.

C. Li (2007) gives detailed criteria to exclude V-V construction with verb-direction, verb-derivation and verb-aspect meaning from resultatives. However, his criteria are more likely to be used to define compounds instead of resultatives:

(12)a. Resultative construction is a complex predicate consists of two free components;

b. The two components must be in a single clause;

c. There must be a causal relation between the two components;

d. There must occurs a change of state or location of a certain entity and the change must not be entailed by the causing component.

e. The change must be brought out as a result of the causing component.

By (12a), he excludes examples which are not compounds:

(13)a. 洗干净, 哭红

b. 买到, 走开

Both 洗 and 干净 are free morphemes and they form a true compound while 到 serves as an affix and thus cannot form a true compound. If C. Li (2007) is defining resultative verb compounds (RVC), it is reasonable to firstly rule out non-compounds regardless of resultative or not. However, he is defining resultative construction instead of resultative compound. Why it is a resultative construction must be a compound? In his case, the question should be why a construction must be a compound. Actually, Li confuses between resultative verb compound, his studying object, and resultative construction.

(12b) has the same problem. (12b) excludes V-*de* construction, still, the question is why a resultative construction mustn't be a V-*de* construction. It should be noticed that resultative compound and resultative construction don't entail each other except explicit declaration that construction equal to compound which is still hard to be accepted by most linguists. What's more, it seems hard to define what a single clause is.

(12d) excludes examples in (14a):

(14)a. The river froze solid.

b. The bottle broke open.

In (14a), Li insists that *solid* only serve as an emphatic of the result already entailed in *froze* because the addition of the *solid* doesn't change the eventuality of *froze* (Pustejovsky, 1991).

(15)a. The river froze in 20 minutes.

b. The river froze solid in 20 minutes.

Similar examples in Mandarin Chinese such as (16) are thus not resultatives according to Li's definition:

(16)a. 头发终于长长了。

b. 李嘉诚又长高了，而且他那宽大的前额上已经现出浅浅的纹络。

However, Li doesn't explain why a sentence like (30a) is not a resultative construction if the change of state denoting by V2 is entailed in V1's meaning. I assume that this is because *solid* only serve as a natural result of *froze* instead of a caused result of *froze*. It is hardly to say that there is a causal relation between *froze* and *solid*. This can be also proved from his last criterion (12c) which excludes examples in (17):

(17)a. Robin danced out the room.

b. Bill rolled out the room.

c. John ran/walked/danced into the room.

d. The wise men followed the star out of Bethlehem.

(C. Li, 2007)

The reason why he rules out of these examples from resultative is they cannot be interpreted as causative. (17a) cannot be interpreted as "Robin cause himself out of the room by dancing"; (17b) cannot be interpreted as "Bill cause himself out the room by rolling" etc. and thus there is no causativity in these examples. These examples express that the process or activity denoted by the verb finally culminate in a change of location depicted by the preposition phrase (PP). Thus, in Mandarin Chinese, verb-direction constructions are excluded from resultatives according to Li's definition.

I think Li's view is representative on whether treat verb-direction (跑下去), verb-derivation (挖浅了) and verb-aspect (走完) as resultatives or not. They are debatable because of the vagueness of causal relation. Although most of the studies stress the key role of causal relation in defining a resultative, it is very hard to give a definition of causal relation. Following Shibatani (1976), Y. Li (1990, 1995), Gu (1992), Cheng and Huang (1994) and Lingling Wang (2001) point that for resultative V-V construction, V1 holds causal relation with V2.

However, even for examples other than verb-direction, verb-derivation and verb-aspect, consensus is not easy to reach. Gu (1992) insists that there is no causal relation between V1 and V2 for examples in (18):

(18)a. 李四醉倒了。

b. 张三惊呆了。

c. 李四饿死了。

Y. Li (1990, 1995), C.-R. Huang and Lin (1992), Cheng and Huang (1994) and Lingling Wang (2001) think there are causal relation between V1 and V2 although examples in (18) are not used in a causative way.

Yuan (2000) and Shi (2008) call examples in (18) internal causative whose *causer* and *causee* refer to the same argument. This implies that they admit there is causal relation between V1 and V2 in

(18). If *causer* and *causee* have no co-reference relationship, they are called external causatives:

(19)a. 其实烫酒是我的计谋。杰克布喝不惯黄酒，半斤酒就能醉倒他。

b. 此时，一道电讯从香港传来，震撼了大山，惊呆了淳朴厚道的参农们。

c. 在９４０天的坚忍困斗中，列宁格勒城内饿死了６３万居民。

醉倒, 惊呆 and 饿死 are used in a causative way in (19) compared to the unaccusative way in (18). Causative occurs between the arguments of the whole construction instead of the arguments of the components. Actually, there are difference between these three examples. 半斤酒 and 一道电讯从香港传来 are external causer which means they are not arguments of any componential Vs of the resultative V-V construction. (19c) doesn't explicitly specify the causer, but since 饿 and 死 are unaccusative word, only experiencer will be assigned which is 63 万居民, thus there should be an external causer.

Yuan (2000) and Shi (2008) make even more detailed distinction within external causatives or internal causatives:

(20)东部沿海的一个城市传来一个消息，说"一盒酸奶喝死了一个孩子！"

In (20), it is not an external argument that serve as the *causer* but 一盒酸奶, the *patient* of 喝 that serve as the *causer*. Yuan (2000) call it the externalization of the internal causative while Shi (2008) call it implicit causative. Cheng and Huang (1994) and Lingling Wang (2001) also propose this distinction although by using different terms:

(21)a. Individual *causer*: 这件事气死了周瑜

b. Agent as *causer*: 诸葛亮气死了周瑜

c. Patient as *causer*: 故事听乐了大家伙

It is clear that the difference of these causatives are all based on the arguments distribution and they even distinguish between the same word's different distribution such as 气死 in (21a) and (21b). However, it is hard to assume two different 气死 according to the difference between (21a) and (21b). Institutively, examples in (21) belong to the same category.

Except examples in (18), Shi (2008) insists that there is no causal relation for examples in (22):

(22)a. 张三睡醒了。

b. 花开败了。

(Shi, 2008)

To summarize, there are too many debates on what is resultative and what is not. Some of the examples in V-V construction may entail a kind of change of state or causal relation. However, it is too vague to give a clear distinction and most of the studies are just based on several so-called "typical" examples to give the classification of V-V construction and resultative construction.

Thus, in this thesis, I focus on V-V construction and the different relations between V1 and V2. If the distribution of V-V construction really help to distinguish resultatives with non-resultatives and also differentiate different kinds of resultatives, classification task and clustering task based on distribution matrix pivoted by each V-V construction in the corpus should be able to achieve the followed targets:

Firstly, categorize most of them into correct group. Resultatives and resultative-like examples should be clustered tensely and closely. The so-called most "typical" resultative V-V construction should be classified into one group at least for most of the examples; V-V construction holding other relations such as coordination and modification should also be able to cluster tensely and closely but far away from resultatives.

Secondly, the debated resultatives such as verb-direction, verb-derivation, verb-aspect and examples like 睡醒 and 开败 should be clustered much closer to the so-called typical ones.
Thirdly, the internal causative and external causative should be classified into different group if they are distributed differently enough.
By using computational and statistical method, I intend to give a clear and precise description of resultative V-V construction and relevant constructions instead of a vague and subjective one.

1.2. Research questions and methodologies

This thesis tries to figure out the features that are used to distinguish resultatives from non-resultatives in V-V construction and measure the contribution of each feature in deciding whether a V-V construction is resultative or not.
Previous studies mainly focus on argument distribution and event type when trying to distinguish resultatives from non-resultatives and also classify resultative into different types.
Y. Li (1990, 1995), C.-R. Huang and Lin (1992), Cheng and Huang (1994), Lingling Wang (2001) and C. Li (2007) classify resultative into different type such as unaccusative, unergative, transitive and causative to name a few. They are actually classify resultatives based on argument number and argument distribution. But most of the generalization are based on several examples. Non-resultatives can also be classified in this way and thus it cannot be used to distinguish resultative from non-resultatives.
Some of them such as Gu (1992) and C. Li (2007) noticed the importance of context. However, only several examples are listed to account for some of the exceptions or ungrammatical examples and they simply own context to pragmatics which means linguists don't need to consider or discuss.
In my opinion, context, including arguments and non-arguments, are the basic feature that decide whether a V-V construction is resultative or not. The distribution decides the meaning in language (not concept world) to a large extent which is based on distributional hypothesis (Harris, 1954). The problem is the how big is the accounting contribution for context compared to other features.
Gu (1992), C. Li (2007) and Shi (2008) mentioned event type as constraints of licensing a verb to be V1 or V2 in a resultative V-V construction. However, their generalizations, although seems solid, are based on little sample and only "typical" examples are chosen. It seems too arbitrary and simple to declare that V1 must be an activity predicate and V2 must be a transition predicate. Once exception occurs, they try every efforts to explain that these are not real exceptions. I am not sure the importance of event type in deciding a resultative in large data. An annotated ontology with event type information should be built to test its prediction precision.
A few studies such as Hong and Huang (2015) take semantic type into consideration. However, the precision is around 56% which, to some extent, prove that semantic type is relevant to resultatives' identification.
However, none of them consider these features in a systematic way. Especially, none of them pay much attention to the importance of context. This thesis focus establishing a distinguished feature system with all of the features contribution degree in deciding whether a V-V construction is resultative or not. The basic methodologies is as followed:
Firstly, extract all of the V-V construction in the corpus. A combined corpus of *Sinica* and *Chinese Gigaword* is built which is in traditional Chinese. The extracted V-V candidates will be checked manually to rule out the unreasonable ones such as two Vs in two different but neighbored structures.
Divide all of the V-V constructions into two datasets including a training dataset and a test dataset.

Secondly, annotate the semantic type and event type of V1 and V2 in the training dataset. Semantic type is mapped from SUMO similar to Hong and Huang (2015) and event type is mapped from Guo (1993). All are checked manually.

Thirdly, extract all of the context vectors of the training dataset in the combined corpus. Different methods will be taken to construct the context vectors including the counting method and predict method named in Baroni, Dinu, and Kruszewski (2014).

Fourthly, all of the features including the semantic type, event type and context will be used to construct the vector matrix. All of the V-V construction are listed in different rows in the matrix while all of the features are listed in columns.

Fifthly, validate all of these features by applying PCA (principle component analysis), clustering and classification method.

Sixthly, determine each features' contribution degree in deciding a resultative based on RF (random forest).

Finally, a characteristics system with their contribution degree is built.

In this thesis, I am not trying to give a clear cut on resultative V-V construction and non-resultative V-V construction. It is obvious that diverse relations exist between V1 and V2 for V-V construction including the so-called resultative and non-resultative based on previous studies. However, they are not distributed in a distinct way. If they are all distributed in a two-order matrix, V-V constructions with similar relations will cluster closely and thus all of the V-V constructions will form several dense clusters in the coordination. The so-called most "typical" resultatives cluster closely while the less typical one is a little far from this cluster and they may form their own cluster if they hold similar relation between each other.

The assumptions is that context, semantic type and event type can be used to predict and measure the similarity between different V-V constructions and help to cluster them into different groups.

Their contribution is validated and measured based on vector matrix by applying different computational or statistical methods.

2. Critics of previous studies

In this section, I will briefly introduce previous studies on resultative V-V construction. Various approaches have been applied to account for how the components' arguments derived to be the resultative construction's arguments including lexical approach, syntax approach and construction approach such as Thompson (1973), Y. Li (1990, 1995), C.-R. Huang and Lin (1992) , Gu (1992), Cheng and Huang (1994), Lingling Wang (2001), C. Li (2007), Han-Chun Huang (2008) and Shi (2008). For these studies, the thematic relation and argument arrangement in the syntactic structure of the componential verbs occupy the largest part and thus less attention is paid to the co-occurrence constraints of V1, V2 and their arguments except Thompson (1973).

Some linguistics studied constraints of V1 and V2 in details such as Zhao (1979), Lu (1990), H. Wang (1996), Z. Ma and Lu (1997a, 1997b, 1997c). Most of them simply list all of the predicates that can be placed in the resultative V-V construction. They are roughly based on structuralism approach.

Computational approach is also applied to predict the co-occurrence of V1 and V2 of resultative V-V construction such as T. Ma and Zhan (2015) and Hong and Huang (2015).

2.1. Lexical or generative syntax approach

Thompson (1973) is one of the very first studies to systematically analyze resultative verb compounds[1]. She proposes a structure of lexicon in Figure 1 which enable the speaker to generate new words according to lexical rules before inserting them into the syntactic representation.

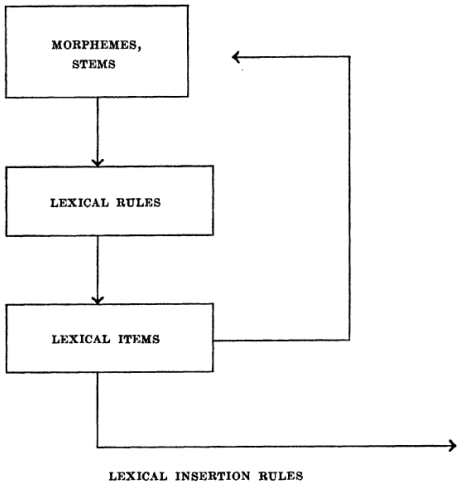

Figure 1 Lexicon structure proposed by Thompson (1973)

C. Li (2007) argues against this lexicon structure because he assumes that the lexicon will be too large to be stored in our brain if the generated V-V compounds are also a part of lexicon. However, Thompson doesn't explicitly state that the generated words should be stored. On the contrary, she explicitly notice that some irregular combinations which cannot be predicted by his lexical rules such as 想出来, 明白过来 and 听进去 should be listed in the lexicon. Thus, it is lexical rules and irregular lexical items that should be stored in Thompson's theory. I intend to agree with Thompson that resultative V-V constructions are created by lexical rules which give constraints on the co-occurrence of V1, V2.

The most general lexical rule for the generation of a resultative verb compound is to specify an action verb plus an intransitive verb which generate an action RVC.

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[1] In this section, the original name instead of resultative V-V construction in these studies will be used.

(1) a. V + V → [V-V]$_{RV}$

b. Action + intransitive → action

It is apparently that Thompson doesn't differentiate between action and transition verbs from (52). (52) covers a large part of the resultative verb compound but still fail to predict some instances while also over-generate some others.

According to (52), only intransitive verb is allowed to enter slot V2. However, several examples deny this lexical rule:

(2) a. 她已经可以做些简单的家务,更重要的是,她还练会了 10 多首中外歌曲,平时见人也大方了许多。

b. 自然这部大书向我们打开着，但我们只有学会并熟悉它的书写符号才能读懂它。

There is no doubt that most of V2s are intransitive verb or adjective. But transitive verbs such as 会、忘、怕、烦、习惯、漏、掉、丢 are allowed to appear in V2 although the number is limited.. (52) also overgeneralize. Thompson herself has realized this problem by listing followed examples:

(3) *a. 推白

*b. 漂动

But she insists that these examples are grammatical although they don't make any sense. It is the word knowledge that limit its usefulness. However, there is no evidence supporting that rule (52) must be true and (53) even deny it. Her claim, which is generalized from partial data, is too strong to be believed. Even rule (52) is accepted by us, how to account for the difference between the acceptability of 推白 and 推动 and what kind of word knowledge that limit its "usefulness"?

Thompson also lists directional rule:

(4) a. V + V → [V-V]$_{RV}$

b. motion + direction

Some directional verbs don't have a literal meaning such as 看下去 which have a grammaticalized meaning and thus cannot be accounted by rule (55). An additional rule should be added to account for it:

(5) V + 下去 → [V-下去]$_{RV}$

I think Thomson is on the right tract to generalize lexical rules for these grammaticalized suffix. However, V-下去 is not a resultative because there is no change of state. V-过 is not a resultative either since it doesn't explicitly specify a change of state.

Y. Li (1990)'s classical work on V-V compound predict the argument structure of a V-V compound under the assumption that V1 is the head of the V-V compound and the principle of head feature percolation mustn't be violated when assigning arguments of V1 and V2 to the syntactic position. Such as the famous example:

(6) 宝玉骑累了马。

There are two different meaning for (3), 宝玉骑马，马累 and 宝玉骑马，宝玉累 respectively. According to head feature percolation, the argument structure of V1 must be kept and after theta-identification, only <1,2-1'> and <1,1-1'> can be generated.

Although Y. Li (1990) is the first one to give a strict formal account for the argument selection of resultative V-V compounds, several problems exist.

Firstly, Li assumes that V1 is the head and the theta prominence must be maintained. But just as C.-R. Huang and Lin (1992) pointed out, this claim is without neither argument nor evidence and he doesn't explain why is it that only the theta prominence is percolated rather than other head properties such as case assignment.

Secondly, Y. Li (1990) fails to account for the so-called inverted causatives:

(7) a. 故事听乐了大家伙。

b. 眼前的景象惊呆了老太太。

In (58a), 故事 is the patient role of 听 and be raised to the subject position while in (58b), 眼前的景象 does not serve as any arguments of any verbs in 惊呆 and be raised to the subject position. There is no way to keep the head's theta prominence in (4) and (5) but they make sense which means Y. Li (1990)'s principle cannot predict these two examples.

Y. Li (1995) introduces causative theta roles, *causer* and *affectee* to account for (58). He follows Grimshaw (1990)'s aspectual hierarchy and proposes causative hierarchy which override the thematic hierarchy. But examples like 他踢破了球鞋 remains unexplained.

There are more examples remained unexplained:

(8) a. 宝玉骑累了马。

?b. 宝玉骑舒服了马。

*c. 宝玉骑漂亮了马。

(9) a. 张三追累了。

*b. 自行车追累了。

(10) a. 张三吹灭了蜡烛。

b. 张三按灭了台灯。

*c. 张三吹灭了台灯。

*d. 张三按灭了蜡烛。

(11) a. 数量减少了。

*b. 数量减多了。[2]

(12) a. 李四追上来了。

*b. 学校追上来了。

(13) a. 战士爬上了泸定桥。

*b. 战士爬进了泸定桥。

Taking (59) as an example, (59a), (59b) and (59c) have same thematic relation, if Y. Li (1990, 1995)'s account is accepted, the acceptability of (59) should be the same. However, while (59b) is reluctant for native speaker, (59c) is totally unacceptable. Li's analysis never takes the co-occurrence constraint into consideration.

(59) is only an example, the co-occurrence constraint of which exists between V1 and V2. Other examples have various constraints.

(59-61) are causatives while (62-64) are inchoatives. (59) and (62) show the co-occurrence constraint between V1 and V2; (60) and (63) show the co-occurrence constraint between subject and the resultative V-V construction; (61) and (64) show the co-occurrence constraint between resultative V-V construction and object. It will be shown in chapter 3 that by using qualia structure, these examples can be accounted for.

C.-R. Huang and Lin (1992) propose a very different way by introducing a process of argument selection. They firstly deny the assumption that V1 is the head of the resultative V-V construction. In this way, the argument structure of V1 will not be supposed to be kept in the thematic structure of the whole resultative V-V construction.

They propose that resultative V-V construction has a composite semantic structure including two

[2] When it is used for verb-evaluation construction which means decrease more than expected, the example is grammatical

events and none of the component event control the other. Since resultative V-V construction contains two events, all of the participants of the events will compete for the thematic role of resultative V-V construction.

The thematic structure of the whole resultative V-V construction is directly mapped to the syntactic structure. The agent-like role is assigned to the subject position while the patient-like role is assigned to the object position in accusative template; both the agent-like and patient-like roles are assigned to the subject position in unaccusative template.

In this way, the key point falls on the selection of arguments from the participants of component events. C.-R. Huang and Lin (1992) introduce Dowty (1991)'s definition of the proto-roles into the process of argument selection.

To account for examples with external causer or individual causer, they assume the causative hierarchy which they called the activation of casualization.

(14) 论文**写老**了他。

By introducing the causative meaning, 论文 in (65) matches the proto-agent's property "causing an event or change of state in another participant" and thus be assigned the proto-agent role and then be raised to the subject position.

But just as C.-R. Huang and Lin (1992) conclude, the prediction of the verb class of V1 and V2 and the possible co-occurrence constraints are not addressed. They propose that the verb class can be defined by lexical semantic features which is on the right track if extended to the co-occurrence constraints. The problem is how to choose the semantic features and what kinds of lexical semantic features should be used to define the co-occurrence constraints? One of the basic hypnoses is that the co-occurrence constraints are defined by the event structure and qualia structure of resultative V-V construction and their arguments.

Gu (1992) turn some attention on the constraints of V1 and V2. She starts with V2 with a conclusion that predicates that can be used to express a change of state are possible to appear in V2. Thus all of the *achievement* verbs such as 死, 塌 which entail a change of state are able to be served as V2. Shi (2008) and C.-R. Huang and Lin (1992) also take the similar view. C.-R. Huang and Lin (1992) uses the followed examples to show the aspectual properties of 哭 and 看:

(15) a. 他哭了。
b. 他看了。

(C.-R. Huang & Lin, 1992)

(66a) has two meanings. One is "he cried" and the other is "he begins to cry". (66b) only has one meaning which is "he saw." Only the second meaning of (66a) express a change of sate. Actually, only the second meaning of (66a) has an event type of *achievement* while the first meaning of (66a) and the meaning of (66b) have an event type of *activity* or *process*.

According to Gu (1992), adjectives which have an event type of state are possible to appear in V2 because they can be used to express a change of state.

(16) a. 张三的手绢很湿。
b. 张三的手绢湿了。

(Gu, 1992)

Gu (1992) uses *individual level* and *stage level* to refer to the usage of adjective in (67a) and (67b). *Individual level* usage doesn't express change of state while *stage level* usage does. Actually, when adjectives have a stage level usage, their event types are *achievements* instead of *states*.

For V1, Gu (1992) argues that unaccusative verbs usually are not licensed in V1 because V1 requires an event type of *activity*, the agent of which is able to volitionally evolve into the event. But she doesn't explain why these constraints should be postulated for V1. Shi (2008) explains that the *activity* verb is able to throw impact or force on some themes or experiencers to make it change by its own action. However, this is actually based on causal relation to account for the constraint instead of result.

As is discussed in the previous section, result entail change of state instead of causal relation which is also supported by both Gu (1992) and Shi (2008)'s constraint of V2 which serves as the result part in resultative V-V construction. The change of state is not necessarily caused but also happens by its self.

(17) a. 李四下棋下赢了。

b. 张三考试考砸了。

Both 下 and 考 in (68a) and (68b) are *activity* verbs, but they have no impact on the result 赢 and 砸 but rather they serve as an initiated event before the result or change occurs.

What's more, even omitting the difference between causative and resultative, other event types except *activities* are found in V1:

(18) a. 陆小凤笑道："我为什么不敢放？难道我还怕臭死她？"

b. 真是亮瞎了我的狗眼！

c. 战士王雁栋顺手拣起一米多长的橡胶水管向歹徒抡去，水管子顿时碎成好几截。

臭 and 亮 in (69a) and (69b) are *states* while 碎 in (69c) is *achievement*.

Gu (1992) argues against *achievement* can be licensed in V1 by listing some unacceptable examples in (70):

(19) *a. 张三死哭了。

*b. 张三来烦了。[3]

*c. 那块手绢湿丢了。

(Gu, 1992)

However, when changing V1 and V2 with same event type, they become acceptable:

(20) a. 那夹山口也没有回来一个人送信，难道都死光了？

b. 你以为他们愿上哪里?外国?差不多都已经去烦了,而且那终不是可以久待的地方。

c. 她只是哭，伤心痛苦地哭，难以自抑地哭，哭了很长时间，泪水湿遍 了我的胸膛。

Gu's doesn't notice these examples and give account for them if she insists that only activity verbs are licensed in V1.

C. Li (2007) mentions some examples showing the co-occurrence between V1, V2 and their arguments:

(21) *a. 张三砍倒了空气。

b. 张三吹倒了蜡烛。

c. 张三吹倒了秘密。

He proposes that it is pragmatics that decide their acceptability. The problem is what kind of knowledge of pragmatics that can be used to account for these examples and how they are accounted according to these knowledge. It doesn't make any sense with just throwing everything into the "dustbin" of pragmatics when the theory cannot be used to account for these "exceptions".

[3] It's acceptable according to my intuition.

Since Cheng and Huang (1994), Lingling Wang (2001) and Han-Chun Huang (2006) don't pay much attention to the constraints of V1 and V2 and co-occurrence constraints of resultative V-V construction, these studies won't be reviewed here.

In total, for lexical approach, generative approach and construction approach, most of the studies focus on the thematic relation and arguments arrangement of resultative V-V construction and thus their theories are mainly used to account for the derivation of different meanings of resultative V-V construction. Y. Li (1990, 1995), Gu (1992) and C.-R. Huang and Lin (1992)'s classical work make good and strict although not perfect prediction of the derivation of thematic relations of resultative V-V construction. I assume that most of the studies pay little attention to the constraints of resultative V-V construction is because these knowledge used to account for the constraints belong to world knowledge instead of linguistic knowledge. However, I agree with Song (2015)'s words[4] saying that there is no clear distinction between these two kinds of knowledge, if rules are found, word knowledge is able to transfer to the scope of linguistics area.

2.2. Structuralism approach

In China, Mainland, quite a few studies pay attention to the licensing of verbs into V1 and V2 position of resultative V-V construction under the structuralism approach or pure describing approach. They don't intend to give theories to account for these data. Most of them list all of the words that are licensed in V1 and V2, only a few studies try to give some generalization of these listing words. Few of them give accounts for these listing words or generalizations. The studies only listing words will be briefly introduced, the attention is mainly focus on Z. Ma and Lu (1997a, 1997b, 1997c) which apply detailed description of "V+A+了" construction.

For V1, Zhao (1979) proposes that almost all of verbs can be licensed in slot V1. This is a very abstract generalization for the whole resultative V-V construction (Shi, 2008). Xu (2000) insists that if a verb stressed the inception of the action or the change of state, it can be licensed in V1. Luo (2009) lists all of the verbs that can be licensed in V1 in Meng (1999) without generalization of constraints.

For V2, Zhao (1979) listed 127 adjectives and 26 verbs that are licensed in V2; Lu (1990) listed 944 adjectives licensed in V2 for V+A+了 construction. Both Z. Ma and Lu (1997c) and Y. Liu, Gu, and Pan (2001) noticed that most of the monosyllable adjectives can be licensed in V2 while multi-syllable adjectives rarely can be licensed in V2.

Z. Ma and Lu (1997a, 1997b, 1997c) analyze resultative construction with adjectives serving as V2. They don't give any definition of resultative V-V construction, but the research scope can be told from the examples and construction meaning they list:

(22) a. The realization of expected result: 晾干了，洗干净了
b. The appearance of unideal result: 洗破了，搞坏了
c. The appearance of natural result: 长高了，变红了
d. The derivation of expected result: 挖浅了，买贵了

The problem of their definition has been discussed in section 1.1, no more discussion about it is about to be given here. According to the examples, (77a) and (77b) belong to causative, (77c) belongs to inchoative and (77d) belong to verb-evaluation construction which is not resultative construction.

Z. Ma and Lu (1997c) proposes that the construction meaning is decided by adjectives (V2), verbs

[4] In the preface of Song (2015) written by Prof. Chen Baoya.

(V1), the impact on V2 imposed by V1 and the context.

Firstly, appraise of adjectives is relevant to the construction meaning. Adjectives are divided into positive, negative and neutral ones.

(23) a. Positive adjectives can only be used to express (77a) and (77c): 修好了，变好了;

b. Negative adjectives can only be used to express (77b) and (77c): 骑坏了，变坏了;

c. Neutral adjectives can be used to express (77a), (77c) and (77d): 放大了，长大了，买大了.

For (78a), the positive adjectives can be further divided into three types:

(24) a. The property expressed by the adjective can be controlled and realized though some concrete actions: 干净;

b. The property expressed by the adjective can be controlled but cannot be realized through some concrete actions: 虚心;

c. The property expressed by the adjective cannot be controlled by human: 晴.

(79a) are usually used to express the realization of expected result but sometimes they are also used to express the appearance of natural result.

(79b) are usually used to express the appearance of natural result, but sometimes they are also used to express the realization of expected result.

(79c) can only be used to express the appearance of natural result.

Their analysis is in detailed and they list all of the adjectives according to (79), the situation is the same for negative adjectives and neutral adjectives. Thus, the constraints of positive adjectives are taken as example to be reviewed.

With a full word list of all kinds of the adjectives, it seems that their analysis is solid. However, the construction meaning themselves are too subjective to be judged. 光 belongs to (79a), and thus it should be used to express the realization of expected result:

(25) a. 这几段精彩的文字全被他删光了。

b. 他删光了所有不合法的内容。

While (80b) entails a relation of expected result, (80a) express an appearance of unideal result which violate their constraints.

晴 belongs to (79c) and thus it should be used to express the appearance of natural result:

(26) 这一阵大风把天儿都刮晴了。

Is 刮晴 natural or not? How to define natural? If natural is defined as not caused by other event, (81) cannot be interpreted as the appearance of natural result.

In fact, most of the meanings are generalized based on verb-evaluation construction instead of resultative construction according to their examples. The differentiation between different results is too subjective and thus the constraints become useless.

2.3. Computational approach

Computational approach usually focus on the prediction or recognition of resultative V-V construction. Both of the two studies which are about to be reviewed actually transfer the constraints of V1 and V2 of resultative V-V construction into their distribution probability in the training data which means the V-V construction which have been tagged as resultative construction. Hong and Huang (2015) uses likelihood to simulate the constraints of V1 and V2 while T. Ma and Zhan (2015) uses word similarity and conditional probability to simulate the constraints. Hong and Huang (2015) doesn't care about the order of V1 and V2 and simply add their likelihood scores while T. Ma and

Zhan (2015) care about the order because the test data's V1 is only compared with the training data's V1 according to their word similarity and V2 is the same. The conditional probability is also used to simulate the order of V1 and V2.

Hong and Huang (2015) build a model (or methodology) to differentiate between different relationships of V1 and V2 for V-V compound. There are different relationships between V1 and V2 in V-V compound such as coordinate, modifier-head and resultative one. The recognition of resultative V-V construction actually means the successful prediction of the relationship between V1 and V2 for their model.

Since all of the verbs can be classified into an event type (or concept type), the identification of the relationships between V1 and V2 can be transformed into the recognition of relationships between the event types of V1 and V2. They use sinicaBOW (C.-R. Huang, Chang, & Lee, 2004) to map the concept type in SUMO (Pease, Niles, & Li, 2002) to V1 and V2 of resultative V-V construction. They use likelihood score to represent to what extent a concept type can occur in a certain relationship. Since only coordination, modifier-head and resultative relation will be considered, each concept should have three likelihood score.

$$L - Score_{c,s} = \frac{tf_{c,s}}{\sqrt{\sum_{1}^{n} (tf_{i,s})^2}}$$

Figure 2 Likelihood function in Hong and Huang (2015)

The likelihood of one concept in a relation means among all of the occurrences of the concepts within a relation, how frequently is a certain concept occurs.

All of the V-V compounds are extracted from sinica corpus (Chen, Huang, Chang, & Hsu, 1996) excluding the ones whose relationships between V1 and V2 can be simply described in rules. 20% of the V-V compounds are selected as the training data. Training here means these data will be used to calculate the likelihood score of each concept in three different relations. To meet the requirements of the function of likelihood, the concept type and relationship of V1 and V2 in a resultative V-V construction should be annotated and checked. Then the frequency of a concept occurs in a relationship can be figured out, which can be used to further figure out the likelihood score according to the function above.

Three scores of each concept can be put into a vector (three-element tuple) like

(27) *vectorW* = <a1, a2, a3>

W refers to a word and the three dimension refers to coordinate, modifier-head and resultative relation respectively.

Each relation can also represented by a vector:

(28) a. *vectorSc* = <1,0,0>

b. *vectorSm* = <0,1,0>

c. *vectorSr* = <0,0,1>

Sc, *Sm* and *Sr* refers to coordinate, modifier and resultative relation respectively.

A test V-V compound will be firstly assigned the concept type to its V1 and V2; the concept vector can be checked from the trained model. The vector of the whole test V-V compound will be the sum of the vectors of V1 and V2.

Then the *cosine* value between the sum vectors of the tested V-V compound and the vectors of each

relation will be calculated and highest *cosine* value determine the relation type.

Before introducing special rules, the model's result is as follow:

Table 1 Result before applying specific rules in Hong and Huang (2015)

	Coordinate	**Modificational**	**Resultative**	**Average**	**All Data**
Recall	43.81%	58.54%	69.14%	57.16%	55.97%
Recision	50.00%	52.75%	58.95%	53.90%	53.96%

There are two problems about their methodology:

Firstly, 20% of the whole data serve as the training data to get the likelihood and vectors of the concepts V1 and V2 But how to guarantee that all of the concepts in SUMO can be mapped? In other words, if the test compound contains concept that doesn't exist in the training data, how to predict the relationship between V1 and V2?

Secondly, the methodology actually don't take the order of V1 and V2 in a V-V compound into consideration when they calculate the sum of vectors. If we just switch the order of V1 and V2 in a V-V compound, it should also predict its relationship as the normal one which decrease the reliability of the model.

There is still one puzzle about the model. They use *cosine* value to predict the relationship but it seems that likelihood scores themselves are enough to help to judge which relationship the sum of likelihood of V1 and V2 belong to. Why bother to use *cosine* value and vectors?

Because of the unsatisfactory result, they introduce rules generalized from PoS and V2 occur in resultative relationship:

(29) V-V compounds with a VH (stative intransitive verb) as V1 must be modificational;

(30) V-V compounds with V2s which don't belong to the set extracted from Qiu, Luo, and Chen (2004) are not resultative compounds.

In this way, the prediction result has been improved dramatically:

Table 2 Result after applying specific rules in Hong and Huang (2015)

	Coordinate	**Modificational**	**Resultative**	**Average**	**All Data**
Recall	68.06%	67.67%	82.24%	72.32%	73.23%
Recision	53.26%	65.93%	92.63%	70.61%	70.86%

Hong and Huang (2015) actually uses a supervised way for the differentiation between different relationships of V1 and V2 in V-V compounds. The result is excellent for resultative relationship. The problem is that the likelihood score and V2's type completely depend on the annotate ontology and dataset which means if vectors of a certain concept don't exist or the V2's dataset is not complete enough, there will be data sparse.

T. Ma and Zhan (2015) takes a different way for the recognition of resultative V-V construction. They don't consider the differentiation between resultative V-V construction and other V-V compounds, but focus on the identification of causal relationship.

They propose two methods to measure the causal relatedness between V1 and V2. One is probability-based and the other is ontology based.

For the first method, they use conditional probability to estimate the relatedness of V1 and V2. It's true that conditional probability can be used to measure two elements can co-occur but it is hard to use it as a measurement of the causal relationship.

Their second method is much reasonable. For the a candidate such as 吃懂, they extracted all of the V2 co-occur with 吃 and all the V1 co-occur with 懂 in the ontology (Zhan, Ma, Tian, &

Sunaoka, 2015).

Then the semantic similarity will be calculated between 吃 and all of the V1s that can co-occur with 懂 and also the semantic similarity will be calculated between 懂 and all of the V2s that can co-occur with 吃.The value of semantic similarity of 吃 and 懂 will added.

The measurement of semantic similarity is calculated according to Q. Liu and Li (2002). The similarity is based on the distance between two nodes in the a hyponymy hierarchy in HowNet (Dong & Dong, 1999).

Finally, they add the conditional probability and the similarity value together weighting 0.5 respectively. The more the value is near to 1, the more likely it is a resultative V-V construction.

Since they don't have a threshold for the value to predict the causal relationship, their evaluation is quite different and only give the precision. They use this model to extract all of the candidates in a test corpus and exclude all of the ones existing in the ontology and then manually check the precision. The result is 48.30% which is far from OK.

Hong and Huang (2015) focus on the differentiation between different relationships of V1 and V2 in V-V compound and have good result but it cannot be used to differentiate between different meanings within resultative V-V construction such as the cause-result relation, verb-evaluation and verb-endpoint meaning and also there are data sparse problem. T. Ma and Zhan (2015)'s result is not good, but the method concerning semantic similarity is quite different from Hong and Huang (2015)'s.

Their problems have been mentioned in the previous part.

Most of the linguistics studies are only based little sample to define what a resultative V-V construction is. Their generalizations are not validated in a systematic way but only in a simple counting method. The features such as arguments distribution, event type and context are just supported by listing several examples.

For computational studies, Hong and Huang (2015) only considers semantic type and precision is far from good. What's more, their definition of resultative is not clear. T. Ma and Zhan (2015) takes context into consideration. However, conditional probability is too week to simulate context's contribution. None of them use a systematic way to validate all of the features and measure their contribution in defining the relation between V1 and V2 for V-V construction.

3. Theoretic framework

Using tensor[5] to represent a word has been a tradition for a long time in computer science area. Such as we use hash table to record all of the word in a corpus and it's called one-hot representation which use a long vector containing elements of dictionary size to represent the word. But there will be no other information except the position information for a word in the dictionary. Vector can overcome this problem to some extent as it is a two-order tensor. Since it is two-order, we can construct a matrix. The row refer to words while the column refer to context ranging from bigram to n-gram and finally to a document such as the following one:

Table 3 Sample for VSM matrices

	d_1	d_2	…	d_j	…	d_m
w_1	f_{11}	f_{12}		f_{1j}		f_{1m}
w_2	f_{21}					
…						

[5] Non-vector scalar is one-order tensor and vector is two-order tensor.

w_i	f_{31}	f_{ij}	
…			
w_n	f_{n1}		f_{nm}

If we use w_i refers to the *i*-th word arranging in different rows, use d_j refers to the j-the document arranging in different columns and use f_{ij} refers to the frequency w_i occurs in d_j, a matrix in table 5 is constructed.

VSM was developed for the SMART information retrieval system since Salton (1971); Salton, Wong, and Yang (1975) and has been quickly and widely used for the measurement of word similarity and document similarity and latter be used for pattern or relation similarity (Turney & Pantel, 2010). Other approaches on measuring the similarity between words to a large extend depend on language resources like WordNet and the usually calculation is based on the number of nodes that between two words in a hyponymy hierarchy constructed according to the language resource such as Miller, Leacock, Tengi, and Bunker (1993) for English and Q. Liu and Li (2002) for Chinese. However, VSMs don't need database like WordNet and the vector matrices are constructed based on corpus (with or without PoS) and the result is better (Turney & Pantel, 2010).

3.1. The semantic hypothesis hehind VSMs

VSM is also called distributional semantic model (DSM) since its basic hypothsis is that words have similar context tend to be more similar semanticly (Harris, 1954). This lead vector matrix an excellent two-order tensor to reprent words under different context ranging from construction to sentence and even document.

(1) Distributional semantics hypothsis: words that have similar context tend to have simialr meaning. (Harris, 1954) in other words, words that have similar vectors in a row in the vector matrix tend to have similar meaning.

And there is a inferences from this basic hypothesis:

(2) Bag of words hypothesis: if words vectors in a document (d_1) are simmiar to words vectors in anther document (d_2), two documents are simialr with each other. (Salton et al., 1975). In other words, if two columns of vectors is similar with each other, they tend to be similar with each other semanticlly.

Actually, this is a inverted application of the distributional hypothesis as (1) focus on rows in matrices while (2) focus on columns in a matrices.

Lin and Pantel (2001) and Turney and Littman (2003) latter propose another two hypothesis aiming to solving different appilcation tasks:

(3) Extended distributional hypothesis: patterns that co-occur with similar pairs of words are similar with each other. In other words, in a word pair-pattern matrix, if a column of vectors (hence a particular pattern) is simmialr to another column of vectors (hence another pattern), they tend to represent similar meaning.

(4) Latent relation hypothesis: pairs of words co-occur in similar patterns tend to have similar relations between them. In other words, if words pairs have similar row vectors in a pair-pattern matrix, they are supposed to hold similar semantic relations.

One of the obvious problem for these hypothesis is that all of them ignore the word-order's role in deciding the semantics of a language structure compared to the ditributional anaylysis in linguistics. (Turney & Pantel, 2010)

Some of the VSMs optimize the model to be sensitive to word order such as Mitchell and Lapata

(2008) which basically allow for weighting the semantic contructions from word order after construcing the matrix however, the result seems to be no better than VSMs without considering the word order.

3.2. Different VSM matrices

Turney and Pantel (2010) classified the matrices in VSM into three different types based on the difference of the tiems in rows and columns in the matrices including word-document, word-context and pair-pattern. Document and context are just different window sizes for computational linguistics and sometimes, a window of 5 words (that is five words before the target word and five words after the target word) may exceed a document if the document only contains only one sentence with less than ten words to be extrmely. And thus the three different types of matrices can be generalized by two inclduing word-context and pair-pattern.

The VSM was first used by Salton et al. (1975) to measure the similarity between two documents. They constructe a word-document matrix like the matrix in table 5. Based on the bag of words hypothesis which stating that documents with similar word vectors tend to be simialar with each other. Thus it can be meaured by comparing the vectors in one column which represent one document.

Deerwester, Dumais, Furnas, Landauer, and Harshman (1990) noticed that the same matrices can be used for the measurement of word similarity based on word-contex matrix. It is actually the same type matrix as Salton et al. (1975) with words as its rows and columns as its context or documents. However, Salton et al. (1975) use the matrix to measure the similarity between columns (hence the documents or contexts) while Deerwester et al. (1990) uses it to measure the similarity between rows (hence the words). They are actually based on different hypothesis. While Salton et al. (1975)'s method is based on bag of words hypothesis, Deerwester et al. (1990) is based on distributional hypothesis.

But latter when evaluate the model with different length of context on TOEFL test (Landauer & Dumais, 1997), the result tend to decrease as the expanding of the window. (Turney & Pantel, 2010) in other words, for the measurement of word similarity, only the instant near context near the target word contribute to their semantics, words far way from the target word cannot help to measure the simialrity between words.

Lin and Pantel (2001) pair-pattern matrix for the measurement of similarity between patterns. In the pair-pattern matrix, the words represented by rows are replaced by word pairs with certain relations such as "*carpernter:wood*" and "*mason:stone*" while the documents represented by columns are replated by patterns like "*X cuts Y*" and "*X works with Y*". They use this matrix to measure the similarity between columns (hence the patterns). They propose the extended distributional hypothesis to be verified by this task.

Following the same step as in Deerwester et al. (1990), we can measure the similarity between rows (hence the word pairs) in pair-pattern matrix. Turney (2008) propose that word pairs with similar row vectors in a pair-pattern matrix tend to have similar semantic relations which acutally forms the latent relation hypothsis which can be used to predict the semantic relation between word pairs.

All of matrices constructed above are based on the frequncy of words or word pairs occur in contexts or patterns. Baroni et al. (2014) call these matrices count matrices.

However, we have to weight the vectors according to their informativeness. In information theory, a surpring event has higher information than expected one and thus *tf-idf* (term frequncy * inversed document frequncy) or pointwise mutual information (PMI) is introduced to weight the vectors'

informativeness.

$$p_{ij} = \frac{f_{ij}}{\sum_{i=1}^{n_r}\sum_{j=1}^{n_c} f_{ij}}$$
$$p_{i*} = \frac{\sum_{j=1}^{n_c} f_{ij}}{\sum_{i=1}^{n_r}\sum_{j=1}^{n_c} f_{ij}}$$
$$p_{*j} = \frac{\sum_{i=1}^{n_r} f_{ij}}{\sum_{i=1}^{n_r}\sum_{j=1}^{n_c} f_{ij}}$$
$$\mathrm{pmi}_{ij} = \log\left(\frac{p_{ij}}{p_{i*}p_{*j}}\right)$$

Formula 1

What's more, since there is data sparcity, we have to smooth the model. And because of noise vector and zero vector, we need to decrease the dimmenstion to decrease the algorithem complexity.

Instead of count the words or word pairs occurance in a context or pattern, Mikolov, Chen, Corrado, and Dean (2013) predict a word's vector in a context based on neural network.

They propose two arcitechture to predict the word's vectors including Skip-gram and CBOW (continuous bag of words):

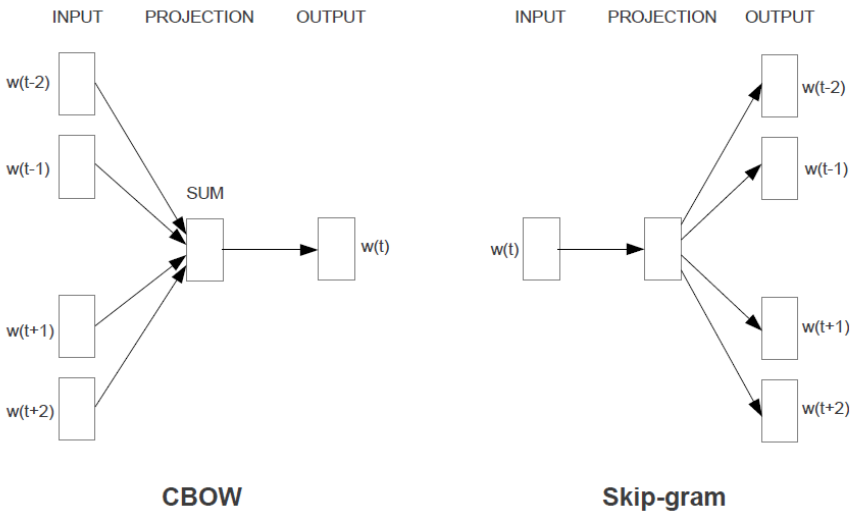


Figure 3 CBOW and Skip-gram in Mikolov, Chen, et al. (2013)

As is shown above, CBOW architecture predicts the current word based on context while the Skip-gram use the current word to predict the surrounding words (hence the context). No matter which one, the architecture will construct a word-context matrix efficiently. These two models learn the word vectors based on a simple neural network and thus the complexity for computing is much lower and "can learn a model from billions of words in hours"(Mikolov, Sutskever, Chen, Corrado, & Dean, 2013).

Baroni et al. (2014) makes a comprehensive comparison between count models and predict models. The comparison includes their performances on the task of semantic relatedness, synonym detection, concept categorization, selection preferences and analogy. Baroni et al. (2014) Following is the result:

Table 4 The Best Performance of Count and Predict Models on All Tasks in Baroni et al. (2014)

	rg	ws	wss	wsr	men	toefl	ap	esslli	battig	up	mcrae	an	ansyn	ansem
best setup on each task														
cnt	74	62	70	59	72	76	66	84	98	41	27	49	43	60
pre	84	75	**80**	**70**	**80**	91	75	86	**99**	41	28	**68**	**71**	**66**
best setup across tasks														
cnt	70	62	70	57	72	76	64	84	98	37	27	43	41	44
pre	83	73	78	68	**80**	86	71	77	98	41	26	67	69	64
worst setup across tasks														
cnt	11	16	23	4	21	49	24	43	38	-6	-10	1	0	1
pre	74	60	73	48	68	71	65	82	88	33	20	27	40	10
best setup on rg														
cnt	(74)	59	66	52	71	64	64	84	98	37	20	35	42	26
pre	(84)	71	76	64	79	85	72	84	98	39	25	66	70	61
other models														
soa	**86**	**81**	77	62	76	**100**	**79**	**91**	96	**60**	**32**	61	64	61
dm	82	35	60	13	42	77	76	84	94	51	29	NA	NA	NA
cw	48	48	61	38	57	56	58	61	70	28	15	11	12	9

Among the table, rg, ws, wss, wsr and men are datasets used for the evaluation of semantic relatedness; toefl is a dataset used for the task of synonym detection; ap, essli, battig are datasets used for the task of categorization; up and macrae are datasets used for the task of selectional preferences; an, ansyn and ansem are used for the task of analogy.

It is clear that for most of the tasks and datasets, predict model (word2vec) performe much better than count one and on seven datasets, its performance exceeds the state-of-art one.

3.3. Application of different VSM matrices

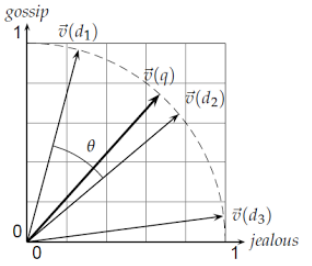
Different VSM can be used to achieve different tasks. While the word-context matrices are usually used to measure word similarity and cluster words, the pair-pattern matrices are usually used to measure the relation similarity and relational clustering or classification.

The basic application for vectors is to measure the similarity and thus we will introduce the how to measure similarity between vectors firstly. It can be used to measure the similarity between words, patterns and documents. The most popular way for measuring similarity is to take the vectors' *cosine*. (Turney & Pantel, 2010) and the angle$\theta$is defined as:

$$\begin{aligned}\cos(\mathbf{x},\mathbf{y}) &= \frac{\sum_{i=1}^{n} x_i \cdot y_i}{\sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sum_{i=1}^{n} y_i^2}} \\ &= \frac{\mathbf{x}\cdot\mathbf{y}}{\sqrt{\mathbf{x}\cdot\mathbf{x}}\cdot\sqrt{\mathbf{y}\cdot\mathbf{y}}} \\ &= \frac{\mathbf{x}}{||\mathbf{x}||}\cdot\frac{\mathbf{y}}{||\mathbf{y}||}\end{aligned}$$

Formula 2

Cosine doesn't consider the length of vectors and only important thing the angle between the vectors:



Cosine similarity illustrated. $\text{sim}(d_1, d_2) = \cos\theta$.

Figure 4 Vector Cosine Illustration

3.3.1. Application of Word-Context Matrices

Deerwester et al. (1990) uses the word-context matrix to measure the similarity if words. But there is no evaluation for their model and thus Landauer and Dumais (1997) introduces TOEFL test which is designed for human to evaluate the result of measurement of word similarity based on word-context matrix. The TOEFL set contains 80 multiple-choice questions with one target word and four synonym candidates. Subjects are required to choose the correct synonyms from the four candidates. Such as for *levied*, there are four candidates: *imposed*, *believed*, *requested* and *correlated* while *imposed* is the correct answer. Deerwester et al. (1990) achieves 64.4% precision compared to the 64.5% precision of human. This model consider the context with a length of 151 words.

Lund and Burgess (1996) measures the word similarity based on a word-context with shorter context containing ten words while Rapp (2003) only consider context with four words. The latter achieves 92.5% precision.

Above are all count models. Baroni et al. (2014) completely compare different models with the predict model (CBOW) and achieve 91% precision.

Other applications include word classification and clustering. Turney and Littman (2003) used a word-context matrix to classify words into positive (*honest*, *intrepid*) and negative (*disturbing*, *superfluous*)

3.3.2. Application of Pair-Pattern Matrices

Lin and Pantel (2001) firstly introduced the pair-pattern matrix for the purpose of measuring the similarity between patterns. It is actually a simulation of the document similarity because both of them are actuall compariting the similarity between vectors in different clolumns. Based on this matrix, their algorithm is able to find similar patterns of "X solves Y" like "Y is solved by X", "Y is resolved in X" and "X resolves Y".

Inversely, Turney and Littman (2003) introduce the pair-pattern matrix to measure the pair similarity based on the row vectors and Turney (2006) evaluate this approach with 374 multiple-choice analogy questions from SAT college entrance test:

Stem:		mason:stone
Choices:	(a)	*teacher:chalk*
	(b)	*carpenter:wood*
	(c)	*soldier:gun*
	(d)	*photograph:camera*
	(e)	*book:word*
Solution:	(b)	*carpenter:wood*

Figure 5 Analogy question in SAT from Turney (2006)

The algorithm achieves 56% precision compared to 57% precision of human.

We tend to introduce Mikolov, Chen, et al. (2013)'s method which also concerns the analogy task although it is based completely different methods. Mikolov, Chen, et al. (2013) predict word vectors instead of word pair vectors and thus it is impossible for it to apply the same steps as Turney and Littman (2003). They transform the analogy task into a process of add and subtract vectors. Such as the question in figure 5:

(1) *vector* (*mason*) – *vector* (*stone*) + *vector* (*carpenter*) ≈ *vector* (*wood*)

In this way, their algorithm achieves 66% performance while the state-of-art algorithm is 61% (Baroni et al., 2014).

It is safe to say that vectors predicted by Mikolov, Chen, et al. (2013) has improved a lot compared to the current count VSMs no matter in performance or in training speed. (Baroni et al., 2014)

4. Pilot study

In this section, I take the validation of context as a distictive feature for resultative V-V construction as an example by applying a classification method. The classification is based on word similarity which is represented by vector *cosine*. All of the V-V constructions are represented by hundreds of vectors which actually represent their context.

The context is defined as *m* words[6] around the target word (V-V construction). If *C* refers to context, *w* refers to word, *f* refers to word's frequency in a context and a matrix can be built:

Table 5 VSM matrix for resultative V-V construction

	C_1	C_2	…	C_j	…	C_n
w_1	f_{11}	f_{12}	…	f_{1j}	…	f_{1n}
w_2	f_{21}	f_{22}	…	f_{2j}	…	f_{21}
…	…	…	…	…	…	…
w_i	f_{i1}	f_{i2}	…	f_{ij}	…	f_{in}
…	…	…	…		…	…
w_m	f_{m1}	f_{m2}	…	f_{mj}	…	f_{mn}

The dimension of the matrix is *n* and the size of the matrix is *m*. Different methods will be used to weight f_{mn}. Finally, each pair are represented by an *n*-dimension vector. The unknown V-V pairs are firstly transferred to *n*-dimension vectors and then are compared with the resultative V-V construction's vectors by calculating their similarity which is represented by vector *cosine*.

As mentioned in previous chapters, predict VSMs are better than count VSM no matter in result or speed, count model, *word2vec* (Mikolov, Le, & Sutskever, 2013), is chose in this thesis while K-means algorithm is used for the unsupervised classification.

The model is trained on a combined corpus of *Sinica* (Chen et al., 1996) and Chinese *Gigaword* (Hong & Huang, 2006) whose size is 8 GB in text files.

The stop words are excluded based on Harbin Institute of Technology's stop word list. Resultative V-V construction instances are erased from stop word list.

The window size is 5 around the target word and the dimension size is 100.

Based on the vectors representation and vector cosine, we will implement a categorization task which we call clustering of VRC task based on K-means method.

Here is a sample of the closest words for 摔破:

[6] Stop words which are proven to contribute little to the similarity between words or pairs are erased.

Table 6 Similar Words in V-破 Construction for "摔破"

Relata	PoS	Vector Cosine	Relata	PoS	Vector Cosine
刺破	VC	0.816970587	刮破	VC	0.684495926
割破	VC	0.76387465	撞破	VC	0.676289022
敲破	VC	0.744902432	磨破	VC	0.663869321
穿破	VC	0.73968178	烧破	VC	0.659816325
擦破	VC	0.720208824	扯破	VC	0.657685339
剪破	VC	0.708227217	压破	VC	0.650183618
抓破	VC	0.707941949	吹破	VC	0.646278918
钩破	VC	0.695374966	划破	VC	0.644872069
砸破	VC	0.692652464	撑破	VC	0.643182099
啄破	VC	0.689641953	戳破	VC	0.626732588

Based on vector cosine, a classification task is implemented on several V-V constructions and here is the classification result:

(1) a. Cluster 1['审查(Nv)', '审核(VC)', '审议(VC)', '审查(VC)', '审议(Nv)']
b. Cluster 2['访谈(Na)', '采访(VC)', '询问(Nv)', '提问(VC)', '征询(VE)']
c. Cluster 3['摔破(VC)', '刺破(VC)', '割破(VC)', '撞破(VC)', '穿破(VC)']

Resultatives and non-resultatives are correctly classified into different groups based on context vectors.

Other factors can be tested in the similar way by constructing different matrix with the same training words but with different impacting factors. The columns in our matrix within this example is context. When testing the impact of semantic type, context will be replaced by semantic types (we intend to use SUMO in our later work since the semantic type in PKU's dictionary is unreliable);

When testing the impact of event type, the columns will be filled by event types etc…

The same test dataset will be used. The test words are the ones taken from our collected data which are not used for training. Here only coordination V-V construction and resultative V-V construction are included. Later in our test, modification V-V construction will also be added.

Their result will be compared and to analyze which one has better prediction.

Then it can be proved that the one with better prediction have more impact on the co-occurrence of V1 and V2 in resultative V-V construction.

We are also about to implement a prediction task by including all of the factors without weighting to compare the result with the ones only consider one factor.

If it is better, it prove that all of the factors should be included when trying to account for the co-occurrence constraints of V1 and V2.

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