www.cadanda.com
Computer-Aided Design™
AND APPLICATIONS

Command Search for CAD System

S. Xue[1], X. Y. Kou[2] and S. T. Tan[3]

[1]University of Hong Kong, micxue@hku.hk
[2]University of Hong Kong, kouxy@hku.hk
[3]University of Hong Kong, sttan@hku.hk

ABSTRACT

In this paper, a Command Search Interface is proposed for contemporary CAD systems. The proposed Interface can help users quickly locate the desired commands by a list of key words and thus helping newbie users boost modeling efficiencies without the need of substantial familiarization of graphical user interfaces. In order to enhance the search intelligence, accuracy and robustness, we developed a novel search mechanism based on a proposed CAD Lexicon List, which is constructed from the help manuals of CAD systems and integrated with synonym word sets. This search engine has been initially designed to search CAD modeling commands from textual input, and further incorporated in our Voice-Enabled CAD systems. The definitions and structure of the CAD Lexicon List is presented in detail. The algorithms of the proposed search engine and its applications in our prototype system are also demonstrated.

Keywords: command search, CAD, lexicon list, interface.
DOI: 10.3722/cadaps.2010.899-910

1 INTRODUCTION

When working with CAD systems, it is not uncommon to transverse among hundreds of icons/menu items and toggle on/off various command panels in order to do a single modeling task. The following scenarios might occur very frequently for inexperienced users:

- *Users know the desired button, but they might not know where it is located in a GUI interface.*
- *Users know the functionality of the command, but they might not know the name of its button not to mention its location in the GUI panel or toolbars.*
- *Users know their design, but they do not know the right command to model the design with the CAD system.*

These make inexperienced CAD users stay away from using CAD systems. Interface upgrades of the commercial products are also witnessed in CAD systems (e.g. different user interface is used in SolidWorks 2008 compared with the earlier versions), and it costs users additional time to adapt themselves to these upgraded interfaces, e.g. different command names, button locations and icon images. Besides, it is also very time-consuming for users to transit from a familiar CAD system to a new one [10]. All of these limitations will elongate the learning curve and heavy users' cognitive loads during modeling [12].

In order to tackle these limitations, a CAD specific Command Search Engine based on CAD systems' help manual and synonym sets is proposed. It can help newbie users quickly locate the desired commands by a list of key words and thus helping them to boost modeling efficiencies without the need of substantial familiarization of graphical user interfaces. Moreover, it is further incorporated into our Voice-Enabled CAD system [5, 16] in understanding command phrases. The rest of the sections are structured as follows: Section 2 describes the motivations of this CAD Command Search Interface. Section 3 presents the methodologies of the proposed search mechanism. Section 4 implements two sample applications with some preliminary results. Finally, section 5 discusses the merits of this search engine and describes some future improvements.

2 MOTIVATIONS

CAD systems become more and more powerful nowadays enabling users to perform almost all of the design tasks. However, these powerful systems are also becoming more and more complex. Even for some small CAD systems, it is unsurprising to see hundreds of command buttons and many groups of toolbars. Users might have to click hundreds of these command buttons in a single modeling task, and clearly remembering their functions, names and locations is essential and important for staying productive. However temporarily forgetting the location of a button is not rare for CAD users especially for inexperienced ones. Once it happens, users are faced with problems on how to find the "lost" buttons.

Graphic User Interface (GUI) has gained its advantage over the old Command Line Interface (CLI) by using metaphors in the form of icons, menus and so on. However, GUI demonstrates its limits when the modern systems become complex [11] and it works well only when the number of alternative items or actions (e.g. the number of buttons and menu items) is small [9]. For example, in SolidWorks 2008, the 500+ commands make it difficult for users to precisely remember their names, locations and functions during the modeling work. To remedy the limitations, ideas about reusing the CLI is proposed by some researchers. For instance, a menu-based command line interface proposed for the OSCAR installer [1] is aimed at providing users with a limited list of available commands at a certain operation stage. Another example is Enso [2] which is capable of suggesting users with commands literally connected with users' inputs (see **Fig. 1**), which is similar to Google Suggest. Even though these new CLIs are regarded as capable of lessening users' cognitive loads to some extent, they still cast restrictions on users' inputs and require users to have certain knowledge about command names and especially command syntax.

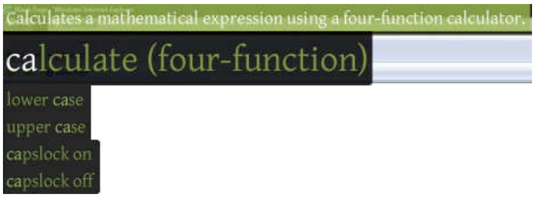

Calculates a mathematical expression using a four-function calculator.

Fig. 1: Sample Input of "ca" in Enso.

Similar CLIs have already been used in current CAD systems. One example is the SolidWorks 2D Command Line Emulator (similar to AutoCAD Command Line). When "circle" is input into the command line, a prompt for the next procedure is shown like "3p/2p/<center point>" in a strange syntax. And inside the GUI of CAD system, a textbox is used to specify the radius when a circle is being created. Compared with CLIs such as Enso, these existing CLIs in CAD systems cannot help users to remember the 500+ commands contained in SolidWorks. On the contrary, they might add to a user's cognitive load by requiring users to clearly remember all the commands and distinguish all the strange expressions like "3p/2p/<center point>", which might cause higher error rate and steeper learning curve compared with existing GUIs [1].

As introduced by Norman [9], Search Engine is a modern form of CLI, which offers a solution to retrieve the intended objects (e.g. htmls and documents) based on something related to these objects. Compared with old-fashioned CLI (such as SolidWork 2D Command Line Emulator) and new CLI (Such as Enso), users need not clearly remember all the command names and complex command syntax owing to the unrestricted expressions of the input in the search engine. This characteristic indicates the possibility of search engine serving as the additional interface to access commands in CAD systems to ease users' cognitive load and enhance users' working efficiency.

This paper is motivated to implement a CAD Command Search Engine. With this engine, users can find the commands with their name known or partially known or even unknown but something related to this command (e.g. some parameter names and synonymous expressions). Alternatively, users can use it as an additional way to access and perform CAD commands in the modeling process. For example, users may use expressions as "round the edge" and "erase it" to locate and execute commands "FILLET" and "DELETE" respectively. However, in these expressions, words like "round" and "erase" are not contained in CAD help manuals, which makes the traditional search engines unable to process them. In order to manage such diverse expressions, a CAD Lexicon List is proposed to support CAD Command Search Engine. Meanwhile, this CAD Lexicon List has another potential to be directly employed in a new innovative CAD system called Voice-Enabled CAD System to understand Users' short utterance as well as complicated expressions (e.g. Tab. 4).

3 CAD COMMAND SEARCH USING CAD LEXICON LIST

Imagine a scenario like this, a newbie CAD user would like to create a rounding of an exterior corner, but he has no knowledge about the very command used in SolidWorks (i.e. the name, the location of the button) to perform this rounding. He could simply input "round this corner" and the Command Search Interface will offer him the intended command with name "FILLET".

3.1 Problem Statement

When a sequence of words is input into the search engine, a set composed of words and phrases is created from this input. This set, denoted by capital letter *W*, is named as *Term Set*, and the words and phrases contained are called *Search Terms*. With this *Term Set W,* the most pertinent CAD command set *C* should be provided to users from the CAD system commands repository C_0.

$$W = \{w_i \mid 0 < i \leq n\} \tag{3-1}$$

$$C = \arg\max_{c \in C_0} g(c) \tag{3-2}$$

Where:

- w_i is a *Search Term* contained in *the Term Set W;*
- *n* is the total number of *Search Terms*;
- *g(c)* is a relevance measurement function which determines strength of the relevance between *Term Set W* and certain command *c*.

The input of "round this corner" in the aforementioned scenario is processed as follows:

$$W = \{round, corner\}\,,\ C = \{"FILLET"\}$$

3.2 CAD Lexicon List

CAD Lexicon List is created based on CAD systems' help manuals and the synonymous words from different sources like WordNet and Wikipedia. The definitions about this List are described as follows:

- ***CAD Lexicon List:*** A list storing different *Lexicon Units* (as shown in Tab. 1).
- ***Lexicon Unit***: A designed unit consists of 4 elements: *Lexicon Word*, *Synonym Set*, *Term Weight* and *Related Command Table*.
- ***Lexicon Word***: A word or a phrase obtained directly from the help manual (totally 3000+), which also uniquely marked its *Lexicon Unit*.
- ***Synonym Set***: A set containing the words and phrases with synonymous meaning to the *Lexicon Word*.
- ***Term Weight***: A numerical parameter used to represent the importance of the *Lexicon Word* when it appears in the *Term Set W*.

- ***Related Command Table***: A table which stores the commands related to the *Lexicon Word* along with a *Relevance Score* quantitatively representing the strength of this relation.
- ***Relevance Score (RS)***: A numerical parameter used to represent the strength of the relation between a *Lexicon Word* and a CAD command.

Remark: In CAD Lexicon List, the total number of Lexicon Units equals the total number of Lexicon Words because Lexicon Word marks a Lexicon Unit uniquely

Lexicon Word: CHAMFER
Synonym Set: {bevel, cant, angled cut, concave corner, oblique cut}
Term Weight: 1.620

Command	**Relevance Score (RS)**
Chamfer	1.615
Sketch Chamfer	1.600
Chamfer Dimension	1.595
Break-Corner/Corner-Trim	0.520
End Cap	0.020
3D Sketch	0.005
…	…

Tab. 1: A Partial Lexicon Unit in CAD Lexicon List.

In CAD System help manuals, the vocabulary is relatively abundant and it seems that all the words and phrases should be added to the proposed *CAD Lexicon List* in order to sustain a robust search engine. However, including all the words and phrases might cause problems. For example, word “the” has relations with almost all CAD commands, of which command “FLEX” has the highest *Relevance Score (RS)*. That is to say, if the search input contains the word “the”, it implies that users are probably looking for the command “FLEX”. In fact, this is not true. For instance, if the input is “the point”, its required commands have nothing to do with “FLEX”. In order to avoid the occurrence of the above problems, not all of the words or phrases in CAD systems’ help manuals are selected as *Lexicon Words*. Some words like “a” and “the” are excluded when referring to the value of its *Term Weight*.

Term Weight is an established practice which indicates users’ preference for search terms (i.e. words or phrases contained in the input) [13]. For example, if the search input is “draw a circle”, “a” is probably not the main user’s concern for retrieving the desired CAD command but “draw” and “circle” are. In other words, words like article ‘a’ bear less CAD specific information and are less important than the words “draw” and “circle” in retrieving the intended CAD commands. In fact, even for “draw” and “circle”, their importance for CAD command retrieval is different either, and these differences are shown by the value of *Term Weight* [13, 14]. Based on the algorithm proposed by Sparck Jones [3], the value of *Term Weight* for a *Lexicon Word l*, denoted as *p(l)*, is obtained by:

$$p(l) = -\log\frac{n_l}{N} \tag{3-3}$$

Where:

- $p(l)$ is the value of *Term Weight*;
- N is the total number of commands in repository C_0;
- n_l is the total number of commands related to *Lexicon Word l*.

In order to exclude the aforementioned words and phrases, a threshold value (e.g. 0.2) could be used to filter out these words. That means, for each *Lexicon Word*, if its *Term Weight* is smaller than threshold value (0.2), it is excluded.

With the proposed *Term Weight*, the overall number of *Lexicon Words* obtained from CAD System help manual is 3000+, and they might not be enough for a robust search engine. This does not mean that the quantity of the words is too small to ensure a good performance, but the diversity of the words and phrases is insufficient for a robust search engine. In CAD help manuals, the sentences seem to be used based on templates with fixed words and phrases inside. For example, the descriptions for

CAD commands in Tab. 2 look as if they are created from one template with the same verb “display”. These templated expressions are very common in CAD system help manuals. If the *CAD Lexicon List* is simply constructed from these materials, it is unable to handle users’ diverse input, especially when users are not experienced with CAD systems. The search engine will fail to process inputs like “smooth the corner” and “erase it”.

CAD Command	Description
swCommands_FourView	Display a four view viewport with 1st or 3rd angle projection.
swCommands_SingleView	Display viewport with a single view.
swCommands_TwoViewVertical	Display viewport with front and right views.
swCommands_TwoViewHorizontal	Display viewport with front and top views.
swCommands_ShadedView	Display a shaded view of the model.
swCommands_Persperctive	Display a perspective view of the model.
swCommands_PrintPreview	Display full pages as they will be printed.

Tab. 2: Descriptions for CAD commands.

In order to eliminate this weakness and provide users with a strong support for diverse expressions as the search input, a *Synonym Set* is enclosed in each *Lexicon Unit* to enable synonymous expressions for a similar CAD command. This enclosed *Synonym Set* is similar to the idea of WordNet [8]. However, it cannot be obtained completely from WordNet. This is mainly caused by the generality of WordNet unable to denote CAD specific synonymous relations [5]. For example, the word “fillet” in WordNet 3.0 [15] has 7 relational entries, but none of them relates to the word “round” or “smooth”. In CAD modeling or engineering design, however, these words are synonymously related with each other.

In the proposed *CAD Lexicon List, Synonym Set* enclosed in each *Lexicon Unit* is partially obtained from WordNet 3.0 and partially obtained from other sources like help manuals of other CAD system (Pro E, UG) and Wikipedia (See an example in Tab. 3). The total number of words contained in each *Synonym Set* is not very large, which ranges from 0 to 7, and most of the words obtained from Wikipedia are added manually.

Lexicon Word: FILLET	
Synonymous Word/Phrase	**Source**
Round	Pro E
Blend	UG
Smooth	Wikipedia
Concave easing	Wikipedia
Convex easing	Wikipedia

Tab. 3: Synonym Set for Lexicon Word "Fillet".

These synonymous words are not treated as the same as or equal to the *Lexicon Word* itself. According to their sources, a Decay Factor is applied to represent this synonymous relation occurred in one search input, which is defined in section 3.3.

Among the four elements in the *Lexicon Unit*, the most important one is the *Related Command Table*. It stores all the commands related to the *Lexicon Word* and together with their *Relevance Scores* to quantitatively represent the strength of the relations. This *Relevance Score* is calculated based on the frequency of *Lexicon Word* occurred in the help manual related to a certain command. In CAD help manual, many different kinds of instructions and explanations are used to describe a command and they will all be considered as the reference of *RS* calculation. However, they are not of equal importance in determining the value of *RS*. For example, the title is the most important text in the whole command introduction page compared with other texts; and the definition for a command is more important than the illustration of its modeling procedures.

Considering the differences mentioned above, information in CAD help manuals are divided into different categories (In the prototype system, they are divided into 6 categories). Each category is assigned with a specific weight *m* (*0<m<1*), the more important the information is, the larger value *m* is assigned. It is similar to the weight system used by Google's PageRank [6], of which Page Title, Link Text, Heading Tags and so on are treated differently. With this weight *m*, *Relevance Score* (*RS*) between a *Lexicon Word* w_0 and a command *c* is obtained by:

$$RS(w_0, c) = \frac{\sum_{i=1}^{K} m_i r_i}{\sum_{i=1}^{K} r_i} \tag{3-4}$$

Where:

- m_i is the total number of occurrences of w_0 in a specific information material for a command *c*;
- r_i is the weight associated with a certain category of information;
- *K* is the total number of information categories.

3.3 CAD Command Search

When a sequence of words is input into the search engine, the first thing to do is to create a *Term Set W* from it, which contains both single words and compound phrases. This process does not mean splitting the input into several segments; instead it is to obtain the maximum number of words and phrases for this input. For example, if the input is "create a corner rectangle", the *Term Set W* should be {"create", "corner", "rectangle", "corner rectangle"}, which is different from directly splitting the input. In fact, if directly splitting the above example input, it is difficult to determine whether the *Term Set* is {"create", "corner rectangle"} or {"create", "corner", "rectangle"}. And, it is also difficult to judge which one of these two sets is more representational for the input. Based on this consideration, all of the possible words and phrases are proposed to be included into the *Term Set W*. And it has two main advantages:

- It is easier than directly splitting the sentence into segments.
- It can get more words and phrases, offering more information for a similar input.

The process of generating *Term Set W* consists of the following three steps:

I) Get all compound phrases from the input based on the CAD Lexicon List,

II) Get all the single words from the input based on the CAD Lexicon List,

III) Group phrases from step I and words from step II into one set (i.e. *Term Set W*)

With the *Term Set W*, the final output of the search engine should be a candidate command list with the most likely command on top of the list. And all these candidate commands related with the *Term Set W* is selected and sorted by a Cumulative *Relevance Score (CRS).* This *CRS* is used to quantitatively represent the degree that a certain command *c* is related to the *Term Set W*. Based on the *Relevance Score* (*RS*) in the *Related Command Table*, the *CRS* between a *Term Set W* and a command *c* is obtained by:

$$CRS(W, c) = \frac{\sum_{i=1}^{n} p(w_i) RS'(w_i, c)}{\sum_{i=1}^{n} p(w_i)} \bullet \prod_{j=1}^{m} f(j) \quad (0 < f(j) < 1) \tag{3-5}$$

Where:

- *RS'* is the modified *RS* (as explained in the following paragraph);
- *n* is the total number of elements in *Term Set W*;

- *f(j)* is called Decay Factor for condition *j*;
- *m* is the total number of categories for Decay Factors;

As mentioned before, words and phrases contained in the Synonym Set are not equivalent to the *Lexicon Word* owing to the nature of human language that one word or phrase might bear multiple meanings. For instance, even if the word "round" exists in the phrase "a round curve", it does not have a close meaning to the word "fillet". In order to represent unequal synonymous relations, a factor *f*, called Decay Factor ($0 < f < 1$) is used to modify the *RS* when a word or phrase in *Term Set W* belongs to the *Synonym Set* of a *Lexicon Word*. This modified *RS* is obtained by:

$$RS'(w_i, c) = RS(w_i, c) \bullet f^{\alpha(w_i)}(j) \le RS(w_i, c) \tag{3-6}$$

$$\alpha(w_i) = \begin{cases} 1 & (w_i \in Synonym \quad Set) \\ 0 & (w_i = Lexicon \quad Word : w_0) \end{cases} \tag{3-7}$$

These Decay Factors are defined according to the sources where the synonym words and phrases are obtained (Tab. 3). The idea of Decay Factors is not only useful in determining the *Relevance Score (RS)* for an item in synonym set. It can also be used to help measure the overall *CRS* of a search input. For example, if five elements are included in a *Term Set W*, but only four of them are related with command *c*, the *CRS* of the search input for command *c* is multiplied by a Decay Factor *f* (0.8 for example) as a penalty. In the prototype system, the Decay Factor *f* for this circumstance is obtained by:

$$f = \frac{n'}{n} \tag{3-8}$$

Where:

- *n'* is the total number of *Search Terms* related to command *c*;
- *n* is the total number of *Search Terms* in the *Term Set W*.

In the calculation of this *CRS*, other Decay factors could also be employed. For example, the total number of synonymous words or phrases (e.g. if there are five of them), compared with the overall number of *Search Terms* (e.g. if there are six of them) in the *Term Set W*, can also serve as a factor to determine the final *CRS*. In the prototype Command Search Interface introduced in **Section 4.1**, no other factors except for the one defined in Eqn. (3-8) are used for simplicity purpose. That is to say, in Eqn. (3-5), m=1.

After *CRS* is obtained, different subsequent procedures might be taken for different systems. For the Command Search Interface in a CAD system, a list of candidate commands will be displayed, of which all candidates are sorted in descending order according to their *CRS* values. For a Voice-Enabled interface in CAD system, the most pertinent command or command set is obtained by Eqn. (3-9), if only one command is included in this command set, it will be directly executed and if more than one command is included, a list for these commands with the same highest *CRS* values is prompted for users to select from.

$$C = \arg\max_{c \in C_0} CRS(W, c) \tag{3-9}$$

4 IMPLEMENTATION AND EVALUATION

4.1 Command Search Interface of CAD System

This proposed Command Search Interface is implemented in SolidWorks 2008. The command search process is structured as shown in Fig. 2. Users' search input is first split into an item set containing phrases and words, which will be further processed based on the proposed CAD Lexicon List. After this, the related commands will be sorted based on their CRS score and finally the commands with the highest CRS are highlighted for the user. In order to offer users with a more flexible choice, a list of commands with lower CRS will also be provided to the users in case the command with the highest command is not the right one wanted by the users. Users can directly click on the icon shown in the result list to do modeling. The system interface is shown in Fig. 3, where users are trying to find the exact CAD command with a sequence of words "fillet this edge". The required command button is correctly prompted in the Command Search Interface with its definition, name and button.

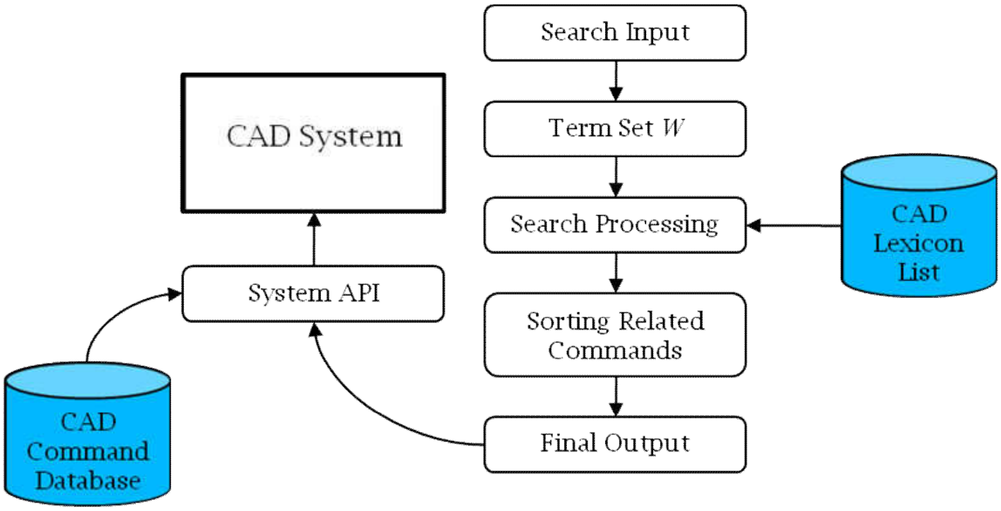
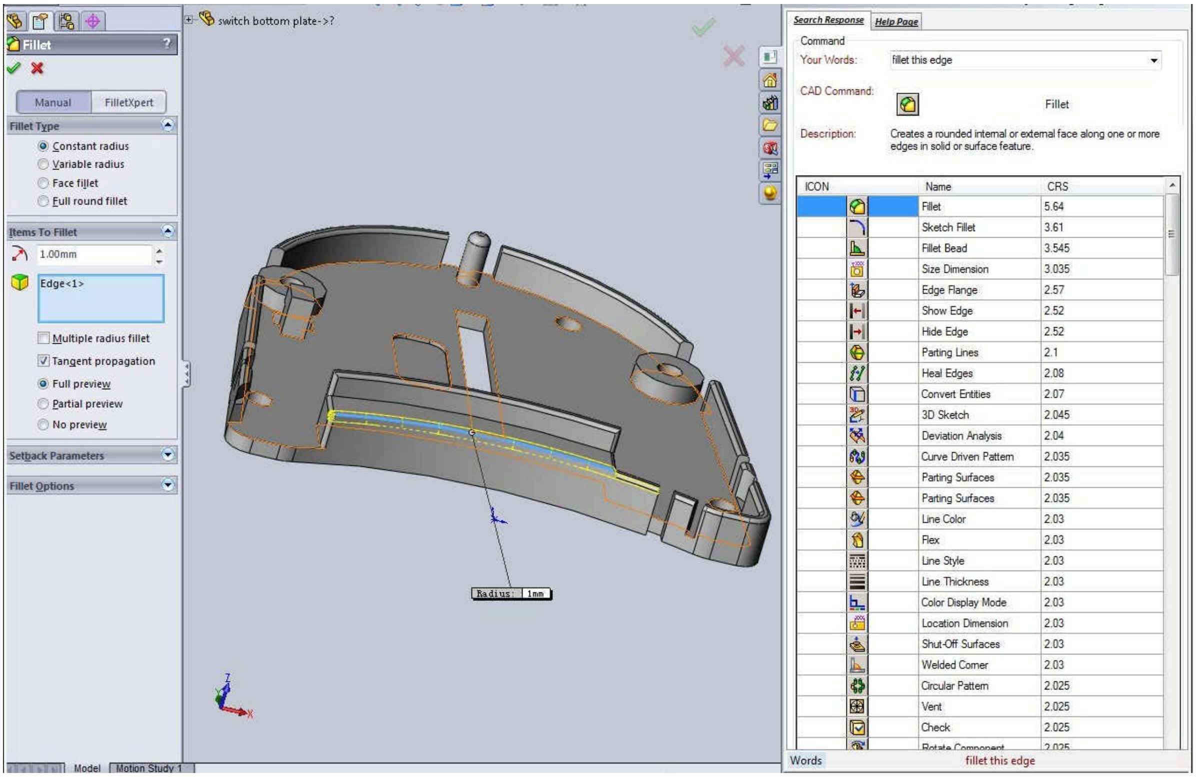


Fig. 2: System Structure of Command Search Interface.



Fillet

Manual | FilletXpert

Fillet Type

● Constant radius
○ Variable radius
○ Face fillet
○ Full round fillet

Items To Fillet

1.00mm

Edge<1>

□ Multiple radius fillet
☑ Tangent propagation
● Full preview
○ Partial preview
○ No preview

Setback Parameters

Fillet Options

Command

Your Words: fillet this edge

CAD Command: Fillet

Description: Creates a rounded internal or external face along one or more edges in solid or surface feature.

ICON	Name	CRS
	Fillet	5.64
	Sketch Fillet	3.61
	Fillet Bead	3.545
	Size Dimension	3.035
	Edge Flange	2.57
	Show Edge	2.52
	Hide Edge	2.52
	Parting Lines	2.1
	Heal Edges	2.08
	Convert Entities	2.07
	3D Sketch	2.045
	Deviation Analysis	2.04
	Curve Driven Pattern	2.035
	Parting Surfaces	2.035
	Parting Surfaces	2.035
	Line Color	2.03
	Flex	2.03
	Line Style	2.03
	Line Thickness	2.03
	Color Display Mode	2.03
	Location Dimension	2.03
	Shut-Off Surfaces	2.03
	Welded Corner	2.03
	Circular Pattern	2.025
	Vent	2.025
	Check	2.025
	Rotate Component	2.025

Words fillet this edge

Fig. 3: Command Search Interface Integrated in SolidWorks 2008.

4.2 Voice-Enabled Interface of CAD System using CAD Lexicon List

This prototype system is wholly based on the proposed CAD Lexicon List in understanding the utterances of CAD users. The general structure of this system is presented in **Fig. 4**.

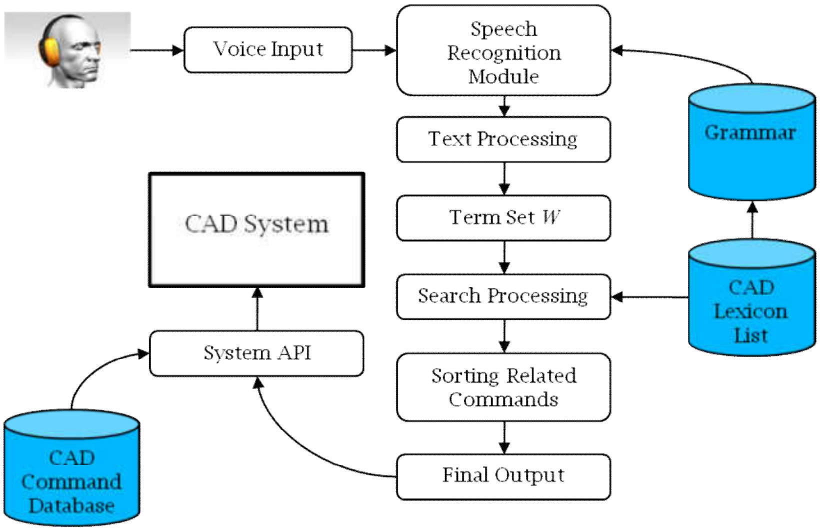


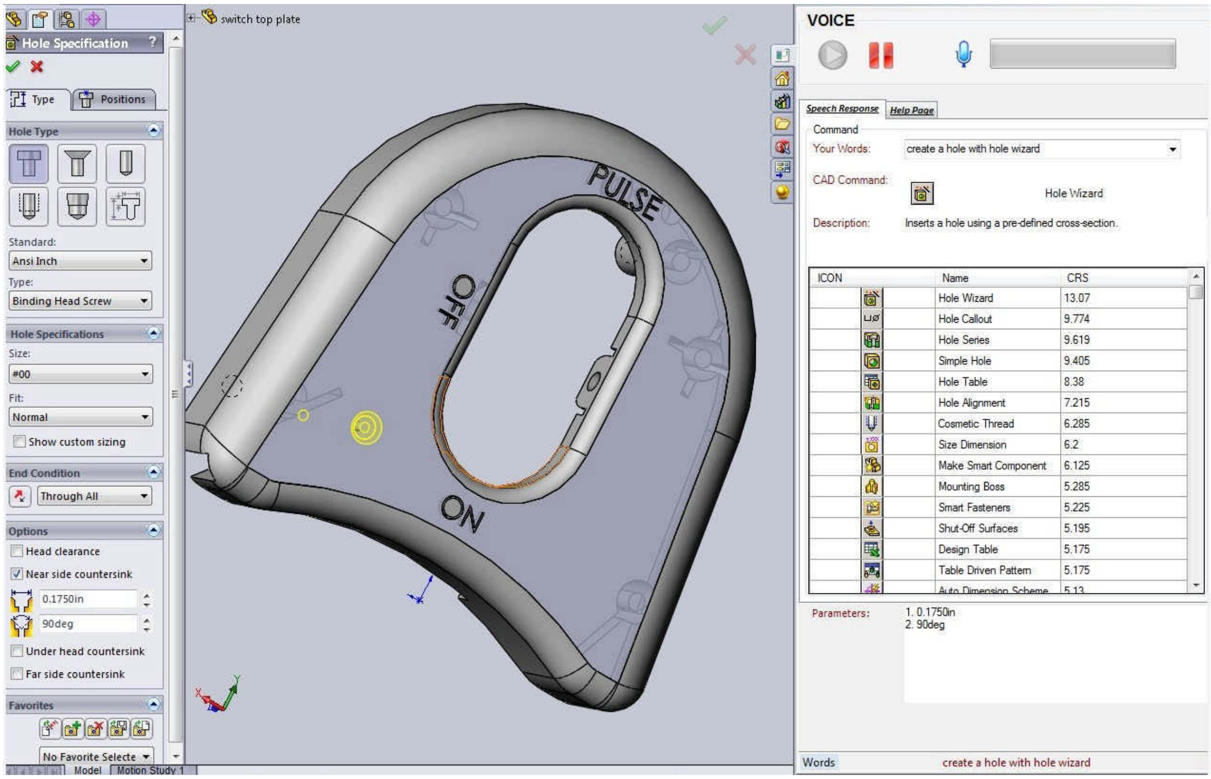
Fig. 4: System Structure for Voice-Enabled CAD Based on CAD Lexicon List.

Users' voices are recognized by the speech recognition module (Windows Speech Recognition Engine). After that, the recognized sequence of words will be further processed by a procedure similar to the processing method in Command Search Interface. And within the final command set, the command with highest score will be executed or alternatively a few commands candidates with the same highest score will be prompted for users to choose from.

Tab. 4 shows the results of this Voice-Enabled Interface (See Fig. 5) in mapping users' utterance to the CAD executable commands based on the CAD Lexicon List. In order to further improve this system, some other mechanisms such as parameter understanding, can be added into this system to make it more natural and effective.

No.	Users' Utterance	Command with Highest *CRS*
1	Create a new part document	swCommands_NewPart
2	A new sketch please	swCommand_Sketch
3	Insert Line	swCommands_Line
4	Sketch a fillet	swCommands_SketchFillet
6	Cancel	swCommands_PmCancel
7	Show me the normal view	swCommands_NormalTo
8	View Normal	swCommands_NormalTo
9	round this edge	swCommands_Fillet
10	Create a hole with hole wizard	swCommands_HoleWizard
11	Zoom it to fit the screen	swCommands_ZoomToFit
12	Display hidden lines	swCommands_HiddenLinesVisible
13	Display it in isometric view	swCommands_Isometric

Tab. 4: Some users' utterances and processing result.



Standard: Ansi Inch

Type: Binding Head Screw

Size: #00

Fit: Normal

□ Show custom sizing

Through All

□ Head clearance

☑ Near side countersink

0.1750in

90deg

□ Under head countersink

□ Far side countersink

No Favorite Selecte

Your Words: create a hole with hole wizard

CAD Command: Hole Wizard

Description: Inserts a hole using a pre-defined cross-section.

ICON	Name	CRS
	Hole Wizard	13.07
	Hole Callout	9.774
	Hole Series	9.619
	Simple Hole	9.405
	Hole Table	8.38
	Hole Alignment	7.215
	Cosmetic Thread	6.285
	Size Dimension	6.2
	Make Smart Component	6.125
	Mounting Boss	5.285
	Smart Fasteners	5.225
	Shut-Off Surfaces	5.195
	Design Table	5.175
	Table Driven Pattern	5.175
	Auto Dimension Scheme	5.13

Parameters: 1. 0.1750in
2. 90deg

Words create a hole with hole wizard

Fig. 5: Voice-Enabled Interface Integrated in SolidWorks 2008.

A demonstrating video of modeling with this proposed Voice-Enabled CAD System can be viewed on YouTube via http://www.youtube.com/watch?v=PtuuET1xka4 .

4.3 Evaluation

As a search engine, speed and accuracy are two important factors for its final performance. This search engine can process the search inputs of diverse structures (see the examples in **Tab. 4**) with a good accuracy and robustness. Meanwhile, the respond time is good, which is primarily below 5 ms (See **Tab. 5**).

No.	Search Input	Respond Time (ms)
1	Line	0.4
2	Sketch a line	2.8
3	Sketch a circle with radius	4.1
4	Draw a hole with hole wizard	3.5
5	Normal view please	0.6
6	Zoom it to fit the screen	5.0
7	Display it in isometric view	3.3

Tab. 5: Respond Time of the Search Engine.

Once the proposed search engine is integrated together with speech recognition technology, the respond time for the proposed Voice-Enabled Search Interface is shown in Tab. 6.

No.	Search Input	Respond Time (ms)
1	Line	37.7
2	Sketch a line	110.3
3	Sketch a circle with radius	192.6
4	Draw a hole with hole wizard	179.3
5	Normal view please	54.6
6	Zoom it to fit the screen	207.3
7	Display it in isometric view	180.1

Tab. 6: Response time of the proposed voice-enabled CAD interface.

Apart from the speed and accuracy, an evaluation method [4] is proposed to quantitatively represent the performance enhancement when using a Voice-Enabled Interface for CAD system, which compares the mouse movements with and without using voice as an input method. By studying the construction process of three selected models, it is found that the mouse movement is reduced by about 50% when using the Voice-Enabled CAD system compared with the tradition system.

5 CONCLUSIONS AND DISCUSSIONS

The paper presents a CAD Command Search Interface to help users find the CAD command and finally execute it to assist modeling. Users can rely on their knowledge about the command (e.g. command name, parameter name, synonymous expressions) when using this interface. With the proposed CAD Lexicon List, users can still navigate through other highly related commands in the candidate command list and familiarize themselves with these listed commands by referring to the “Help Page” to get a more precise explanation and operation guide from CAD system help.

The proposed CAD Lexicon List is the core of Command Search Interface, which contains the relations between a certain word or phrase and a certain CAD command. More importantly, the strength of these relations are also quantitatively represented which offers a reference in studying and using these relations. The characteristics of the CAD Lexicon List make it practical to be employed in a Voice-Enabled CAD system especially in understanding very concise phrases like “create a circle”, “round this edge” and “insert a line”. By combining with other mechanisms, it can be further employed to help understand more complicated expressions in CAD modeling like “extrude the sketch with length 50”.

This interface is still a preliminary start in exploring the improvement of the traditional interface in CAD System. It can be further improved and extended in many aspects. Here are a few possible directions that could be further studied:

1) Make the search engine accept both traditional key-word based input and natural language input (Semantic Search)

Semantic Search [7] is a kind of search which makes use of the advantages brought about by Semantic Web, which is an extension of current Web. It is innovated to search by understanding the meaning of the search input instead of calculating the cumulative frequency of words/phrases. If the CAD system help manual can be re-structured in a way like Semantic Web does, a more intelligent search interface can be implemented based on this re-structured help manual. More importantly, owing to the cross-application reuse of the information in Semantic Web, the online information can be integrated together with the CAD Lexicon List to help disambiguate the meanings of the words/phrases contained in the search input. For example, make the Command Search engine understand different meanings of the word “round” in “a round curve” and “round this edge” respectively.

2) Offer users with more specialized advise on modeling (For example, the difference between the two similar CAD commands)

In a CAD system, there are a lot of similar commands, for example, “center-point arc”, “3-point arc”; and these similar commands can create the same geometric entity but the procedures are totally different. If the difference among these similar commands and the unique procedures behind them can all be structured into CAD Lexicon List, this Command Search Interface can do much more than search. It can help users choose and determine the modeling procedures by providing aforementioned specialized information for modeling.

6 ACKNOWLEDGEMENT

This project is supported by Research Grant Council (RGC) of HKSAR government. We would like to thank RGC as well as Department of Mechanical Engineering, the University of Hong Kong for supporting this research work.

REFERENCES:

[1] Bland, W.; Naughton, T.; Vallee, G.; Scott, S.: Design and implementation of a menu based oscar command line interface, 21st International Syposium on High Performance Computing Systems and Applications (HPCS'07), 2007.

[2] Enso. http://www.humanized.com/enso/.

[3] Jones, K.: A statistical interpretation of term specificity and its application in retrieval, Journal of documentation, 60, 2004, 493-502.

[4] Kou, X. Y.; Liu, X. C.; Tan, S. T.: Quadtree based mouse trajectory analysis for efficacy evaluation of voice-enabled CAD, International Conference on Virtual Environment, Human-Computer Interfaces, and Measurements Systems (VECIMS), 2009.

[5] Kou, X. Y.; Xue, S.;Tan, S. T.: Knowledge-guided inference for voice-enabled CAD, Computer Aided Design, 2010.

[6] Langville, A.; Meyer, C.; FernAndez, P.: Google's PageRank and beyond: the science of search engine rankings, The Mathematical Intelligencer, 30(1), 2008, 68-69.

[7] Lei, Y.; Uren, V.; Motta, E.: Semsearch: A search engine for the semantic web, Lecture Notes in Computer Science, 4248, 2006, 238-245.

[8] Miller, G.: WordNet: a lexical database for English, Communications of the ACM, 38(11), 1995, 39-41.

[9] Norman, D.: The next UI breakthrough: command lines, Interactions, 14 (3), 2007, 44-45.

[10] Piegl, L.: Ten challenges in computer-aided design, Computer-Aided Design, 37(4), 2005, 461-470.

[11] Raskin, A.: FEATURE: The linguistic command line, Interactions, 15 (1), 2008, 19-22.

[12] Robertson, D.; Ulrich, K.; Filerman, M.: CAD systems and cognitive complexity: beyond the drafting board metaphor, Design Theory and Methodology, 1991, 77-83.

[13] Robertson, S.; Jones, K.: Relevance weighting of search terms, Journal of the American Society for Information Science and Technology, 27 (3), 1976, 129-146.

[14] Salton, G.; Buckley, C.: Term-weighting approaches in automatic text retrieval, Information processing & management, 24(5), 1988, 513-523.

[15] WordNet Search - 3.0. http://wordnetweb.princeton.edu/perl/webwn.

[16] Xue, S.; Kou, X. Y.; Tan, S. T.: Natural Voice-Enabled CAD: Modeling via Natural Discourse, Computer-Aided Design and Applications, 6(1), 2009, 125-136.