SEMANTIC PROCESSING MECHANISM FOR LISTENING AND COMPREHENSION IN VNSCALENDAR SYSTEM

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ABSTRACT

This paper presents some generalities about the VNSCalendar system, a tool able to understand users' voice commands, would help users with managing and querying their personal calendar by Vietnamese speech. The main feature of this system consists in the fact that it is equipped with a mechanism of analyzing syntax and semantics of Vietnamese commands and questions. The syntactic and semantic processing of Vietnamese sentences is solved by using DCG (Definite Clause Grammar) and the methods of formal semantics. This is the first system in this field of voice application, which is equipped an effective semantic processing mechanism of Vietnamese language. Having been built and tested in PC environment, our system proves its accuracy attaining more than 91%.

KEYWORDS

Speech Recognition, Voice Application, Vietnamese, Natural Language Processing, Formal Semantics.

1. INTRODUCTION

In 2012, Vietnam saw many remarkable publications displayed by groups devoting to spoken Vietnamese recognition researches from Institute of Information Technology (Vietnamese Academy of Science and Technology) and University of Science, VNU-HCM. It is worth mentioning the works of Thang Vu and Mai Luong [13] as well as Quan Vu et al. [1], [3], [5], [9]. The authors crucially concentrated on improving the efficiency of their voice recognition system, such as the Quan Vu et al. 's one which obtained the precision rate of over than 93% and this group successfully built many voice applications on this base. Nevertheless, all the applications have not been accompanied with a efficient semantic processing mechanism yet, which is the important mechanism in view of helping the system with understanding commands.

In this paper, we introduce the VNSCalendar system. It is a tool, as a combination of the spoken language recognition and the written language processing, would help users with managing and querying their personal calendar by Vietnamese speech commands. Our system can recognize many forms of Vietnamese speech commands and questions, convert them into text, resolve their syntax and semantic analysis, then, generate database queries, and finally, return the results to

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user. The work of resolving syntactic parsing and semantic analysis of Vietnamese commands and question is based on using DCG [2], [7] and computational techniques of formal semantics [6], [10], [11].

In this research, we focus on semantic processing of Vietnamese commands and questions. We only deal with a Vietnamese speech recognition task by using HTK (Hidden Markov Model Toolkit) [12] and build a training data as well as testing data for it.

2. SYSTEM ARCHITECTURE

In accordance with Thien Khai Tran [14], our system is designed to carry out these functions as bellow:

1. Add events: add events into the calendar by Vietnamese speech.
2. Delete events: remove events out of the calendar by Vietnamese speech.
3. Edit events: edit events from the calendar by Vietnamese speech.
4. Query events: query events from the calendar by Vietnamese speech.
5.

VNSCalendar fulfills these above functions in observing the further scenario:

The interaction between users and system can be presented in brief as following steps:

Step 0 Listening stage

Step 1 User says to the system by Vietnamese.

Step 2 The speech sentence is converted into the Vietnamese text sentence thanks to the Speech Recognizer.

Step 3 The system analyzes the syntax structure and gets the key information of the text sentence.

(3.1) If the input sentence is a command:

If it is an add command:

- The system adds the associated event to the schedule calendar and confirms the result to user.
- Return Step 0.

If it is a delete command:

- The system deletes the associated event from the schedule calendar and confirms the result to user.
- Return Step 0.

If it is an edit command:

- The system deletes the event needing to edit and adds the associated event to the schedule calendar and then confirms the result to user.
- Return Step 0.

(3.2) If the input sentence is a query

- The system executes the query, searches information in the database and shows the result to user.
- Return Step 0.

(3.3) In case the syntax is incorrect, the system will inform user of it and user can take another command/query.

To realize the functions in observing the above scenario, the system must be composed of following components:

1. *Automatic speech recognizer (ASR)*: identify words that user speaks, then convert them into written text.
2. *Vietnamese language processor*: resolve the syntax and semantic representations of all the command sentences or query sentences of user.
3. *Central processor*:
   - Transform the semantic representations of the command / query sentences into the SQL commands and execute it.
   - Filter, organize, and return the results to user.
4. *Database*: store schedule information

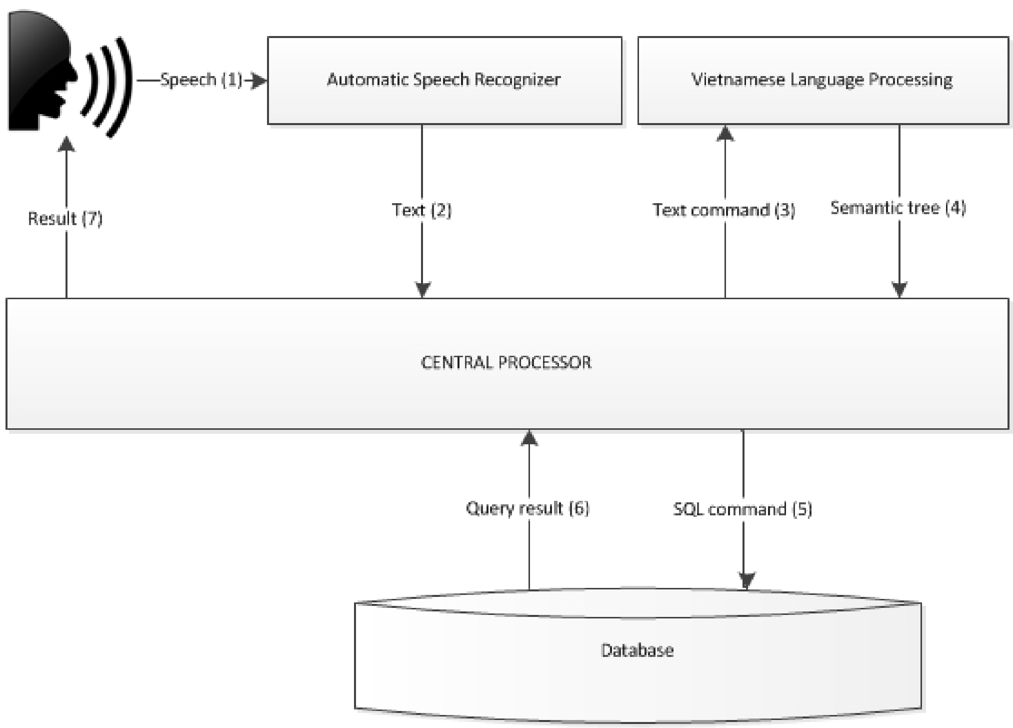

Figure 1. Architecture of VNSCalendar (Source in [Thien Khai Tran 2013])

3. AUTOMATIC SPEECH RECOGNIZER

In VNSCalendar system, we have used HTK [12] to build the Automatic Speech Recognition component. According to the approach of Quan Vu et al. [9], we have applied the context-dependent model based on triphone [12] to recognize keywords and grammar terms.

3.1 Training Data

The speech corpus has 1,045 sentences. Total audio training covers 77 minutes. All speech was sampled at 16000Hz, 16bit by PCM format in a relatively quiet environment with a single speaker.

The lexical comprises of 96 keywords and 19 grammar terms as shown in Table 1 and Table 2. There are some compound words that we cannot translate their extracted single word meaning.

Table 1. List of keywords (*Source*: Thien Khai Tran [14])

ăn (eat)	ba (three)	bài (lesson)	bạn (friend)	bảy (seven)	báo (newspaper)	bốn (four)	buổi (session)
cà	cáo	chiều (evening)	chín (nine)	chồng (husband)	chủ	con (child)	công
cơm (rice)	cùng (with)	cuối (end)	dạy (teach)	đầu (early)	đề	đi (go)	điện
đọc (read)	đồng	đón (get)	du	dự (attend)	gặp (visit)	giờ (hour)	hàng (goods)
hai (two)	học (study)	họp (meeting)	hội	hôm	khách	làm (do)	lịch (calendar)
lớp (class)	mai (tomorrow)	mẹ (mother)	một (one)	mốt (the day after tomorrow)	mười (ten)	mươi	này (this)
năm (year)	nay (this)	ngày (day)	nghe (listen)	nghiệp	người (person)	nhận (receive)	nhật
nhậu (drinking)	nhà (home)	nhạc (music)	ở (in)	phê	phim (film)	phút (minute)	quận (district)
sách (book)	sáng (morning)	sáu (six)	sau (next)	sếp (boss)	tập (do)	tài	tại (at)
tác	tám (eight)	thầu (bid)	thầy (teacher)	thân (relative)	thao	thảo	tháng (month)
thể	thi (exam)	thứ	tiệc (party)	tối (night)	tới (next)	trưa (afternoon)	trường (school)
tuần (week)	tư (fourth)	ty	uống (drink)	văn	vợ (wife)	với (with)	xem (watch)

Table 2. List of grammar terms (*Source*: Thien Khai Tran [14])

ai (who)	có	gì	hay	khi
không (yes or not)	lúc (at/ in/ on)	đâu	nào	nhỉ
sửa (edit)	tạo (create)	thành (become)	thay (edit)	thể
thêm (add)	vào (to)	vô (into)	xóa (delete)	

3.2. Steps to build the Automatic Speech Recognizer

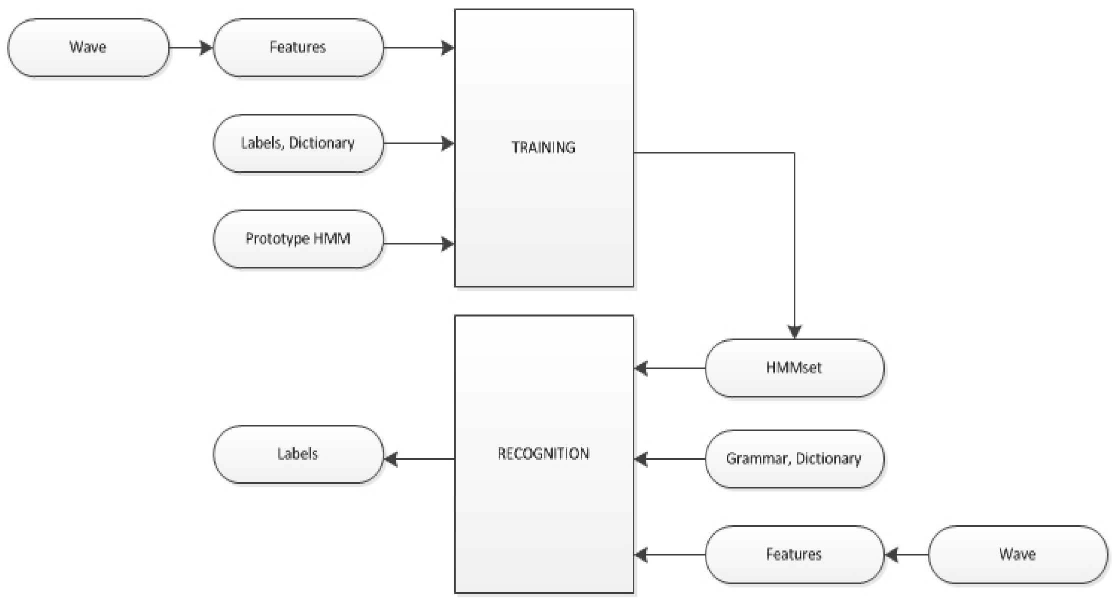

Figure 2. Steps to build the Automatic Speech Recognizer. (Source: Thien Khai Tran [14])

4. VIETNAMESE LANGUAGE PROCESSING

The Vietnamese language processing component analyzes syntax and semantics of Vietnamese commands and questions. Semantic processing aims at computing the semantic structures of the commands or questions. These semantic structures are presented by FOL (First-Order Logic) [2], [7]. In this research, we use techniques of computational semantics [6], [10], [11].

4.1. Commands

The semantic structures of Add, Del, Edit commands are listed in Table 3, Table 4, Table 5.

Table 3. Semantic structures of Add-command (*Source*: Thien Khai Tran [14])

1	add(time,work(action,obj))
2	add(time,work(action,obj),place)
3	add(time,work(action,obj),person)
4	add(time,work(action,obj),person,place)

Example 1: Thêm sự kiện dự thầu tại công ty lúc chín giờ thứ ba tuần sau. *(Add event of bidding at the company at 9 am next Tuesday)*

The syntactic and semantic rules in DCG are defined as below:

```
command(P) --> add_34(P), pp_time(PP), {arg(3, P, PP)}.
add_34(P) --> w_add_3(P), w_calendar, vp(VP), np_place(Place), {arg(1, P, VP)},
{arg(2, P, Place)}.
w_add_3(add(X, Y, Z)) --> [thêm].
w_calendar --> [sự, kiện].
vp(work(Action, Obj)) --> verb(Action), noun_comp(Obj).
verb(action(dự)) --> [dự].
noun_comp(obj(thầu)) --> [thầu].
pp_time(time(Gio, Thu, Tuan)) --> pp_hour(Gio), pp_wday(Thu), pp_week(Tuan).
pp_hour(Gio) --> w_at, whathour(Gio), w_hour.
w_at --> [lúc].
whathour(hhour(chín)) --> [chín].
w_hour --> [giờ].
pp_wday(Thu) --> w_on, w_wday, whatwday(Thu).
w_on --> [].
w_wday --> [thứ].
whatwday(wday(ba)) --> [ba].
pp_week(Tuan) --> w_on, w_week, whatweek(Tuan).
w_week --> [tuần].
whatweek(week(sau)) --> [sau].
np_place(Place) --> w_at, whatplace(Place).
w_at --> [tại].
whatplace(place(công, ty)) --> [công, ty].
```

These syntactic and semantic rules determine the semantic structure of this command as below:

```
add(time(hour(chín), wday(ba), week(sau)), work(action(dự), obj(thầu)), place(công ty)).
```

This semantic structure is the structure 2 in Table 3.

Table 4. Semantic structures of Del-command (*Source*: Thien Khai Tran [14])

5	del(time,work(action,obj))
6	del(time,work(action,obj),place)
7	del(time,work(action,obj),person)
8	del(time,work(action,obj),person,place)

Example 2: Loại bỏ khỏi lịch mười ba giờ ngày hai tám tháng mười hai báo cáo đề tài.
(Delete event of reporting topic at 13 o'clock on December 28th)

The syntactic & semantic rules in DCG are defined as below:

```
command(P) --> del_21(P), vp(VP), {arg(2, P, VP)}.
del_21(P) --> w_del(P), calendar_d, pp(PP), {arg(1, P, PP)}.
vp(work(Action, Obj)) --> v_work(Action), n_work(Obj).
v_work(action(báo, cáo)) --> [báo, cáo].
n_work(obj(đề, tài)) --> [đề, tài].
w_del(del(X, Y)) --> [loại, bỏ].
calendar_d --> [khỏi, lịch].
pp(time(Gio, Ngay, Thang)) --> hour(Gio), day(Ngay), month(Thang).
hour(Gio) --> w_at, what_hour(Gio), w_hour.
what_hour(hour(mười, ba)) --> [mười, ba].
day(Ngay) --> w_at, w_day, what_day(Ngay).
what_day(mday(hai, tám)) --> [hai, tám].
month(Thang) --> w_at, w_month, what_month(Thang).
what_month(mmonth(mười, hai)) --> [mười, hai].
w_at --> [].
w_hour --> [giờ].
w_day --> [ngày].
w_month --> [tháng].
```

These syntactic and semantic rules determine the semantic structure of this command as below:

```
del(time(hour(mười, ba), mday(hai, tám), mmonth(mười, hai)), work(action(báo, cáo),
obj(đề, tài)))
```

This semantic structure is the structure 5 in Table 4.

Table 5. Semantic structures of Edit-command (*Source*: Thien Khai Tran [14])

9	edit(del (time, work(action, obj)), add(time, work(action, obj)))
10	edit(del(time, work(action, obj)), add(time, work(action, obj), person))
11	edit(del(time, work(action, obj)), add(time, work(action, obj), place))
12	edit(del(time,work(action, obj)), add(time, work(action, obj), person, place))
13	edit(del(time,work(action, obj), person), add(time, work(action, obj))
14	edit(del(time,work(action, obj), person), add(time, work(action, obj), person)
15	edit(del(time,work(action, obj), person), add(time, work(action, obj), place)
16	edit(del(time,work(action, obj), person), add(time, work(action, obj), person, place)
17	edit(del(time,work(action, obj), place), add(time, work(action, obj))
18	edit(del(time,work(action, obj), place), add(time, work(action, obj), person)
19	edit(del(time,work(action, obj), place), add(time, work(action, obj), place)
20	edit(del(time,work(action, obj), place), add(time, work(action, obj), place)
21	edit(del(time,work(action, obj), person, place), add(time, work(action, obj))
22	edit(del(time,work(action, obj), person, place), add(time, work(action, obj), person)
23	edit(del(time, work(action, obj), person, place), add(time, work(action, obj), place)
24	edit(del(time, work(action, obj), person, place), add(time, work(action, obj), person, place)

Example 3: Chỉnh lại dự thầu tại công ty ngày mười tám tháng chín thành đi công tác ngày mười tám tháng chín. *(Adjust bidding at the company on September 18th by business traveling on September 18th)*

The syntactic and semantic rules determine the semantic structure of this command as below:

del(time(hour(mười, ba), mday(hai, tám), mmonth(mười, hai)), work(action(báo, cáo), obj(đề, tài)))

This semantic structure is the structure 17 in Table 5.

4.2. Questions

The semantic structures of questions forms are listed in Table 6, Table 7, Table 8, Table 9, Table 10, Table 11, Table 12.

Table 6. Semantic structures of Yes/No question (*Source*: Thien Khai Tran [14])

1	yesno(time, action, obj)
2	yesno(time, action, obj, place)
3	yesno(time, action, obj, person)
4	yesno(time, action, obj, person, place)

Example 4: Mai có đi học không? *(Going to school tomorrow or not?)*

The syntactic and semantic rules determine the semantic structure of this question as below:

yesno(time(dday(mai)), action(đi), obj(học)).

This semantic structure is structure 1 in Table 6.

Table 7. Semantic structures of WHAT question (*Source*: Thien Khai Tran [14])

5	workQuery(query(action), query(obj), time)

Example 5: Cuối tuần sau có làm gì không? *(Any job for next weekend?)*

The syntactic & semantic rules in DCG are defined as below:

```
query(workQuery(Action, Obj, Time)) --> pp_time(Time), interrogative1, verb_ query
(Action), noun_ query (Obj), interrogative2.
pp_time(time(Tuan)) --> pp_week(Tuan).
pp_week(week(Prep, Tuan)) --> w_at, pp_prep(Prep), w_week, whatweek(Tuan).
pp_prep(prep(cuối)) --> [cuối].
w_week --> [tuần].
whatweek(week(sau)) --> [sau].
interrogative1 --> [có].
interrogative2 --> [không].
verb_query(query(action)) --> w_do.
noun_query(query(obj)) --> w_what.
w_do --> [làm].
w_what --> [gì].
```

These syntactic and semantic rules determine the semantic structure of this question as below:

workQuery(query(action), query(obj),time(prep(cuối),week(sau))).

This semantic structure is the structure 5 in Table 7.

Table 8. Semantic structures of Go_WHERE question (*Source*: Thien Khai Tran [14])

6	gowhereQuery(query(obj), verb_go, time)
7	gowhereQuery(query(obj), verb_go, person, time)
8	gowhereQuery(query(obj), verb_go, place, time)
9	gowhereQuery(query(obj), verb_go, person, place, time)

Example 6: Tháng mười đi đâu nhỉ? *(Where to go in October?)*

The syntactic and semantic rules determine the semantic structure of this question as below:

gowhereQuery(query(obj), verb_go(đi), time(mmonth(mười))).

This semantic structure is the structure 6 in Table 8.

Table 9. Semantic structures of Visit_WHOM question (*Source*: Thien Khai Tran [14])

10	visitwhomQuery(query(obj), verb_visit, time)
11	visitwhomQuery(query(obj), verb_visit, person, time)
12	visitwhomQuery(query(obj), verb_visit, place, time)
13	visitwhomQuery(query(obj), verb_visit, person, place, time)

Example 7: Tuần sau có gặp ai không nhỉ? *(Whom to meet next week?)*

The syntactic and semantic rules determine the semantic structure of this question as below:

visitwhomQuery(query(obj),verb_visit(gặp),time(week(sau)))

This semantic structure is the structure 10 in Table 9.

Table 10. Semantic structures of With_WHOM question (*Source*: Thien Khai Tran [14])

14	personQuery(query(person),action,obj,time)
15	personQuery(query(person),action,obj,place,time)

Example 8: Mốt báo cáo đề tài với ai?

The syntactic and semantic rules determine the semantic structure of this question as below:

personQuery(query(person),action(báo, cáo),obj(đề, tài),time(dday(mốt))).

This semantic structure is the structure 14 in Table 10.

Table 11. Semantic structures of WHERE question (*Source*: Thien Khai Tran [14])

16	placeQuery(query(place),action,obj,time)
17	placeQuery(query(place),action,obj,person,time)

Example 9: Mốt báo cáo đề tài với bạn ở đâu?

The syntactic and semantic rules determine the semantic structure of this question as below:

placeQuery(query(place),action(báo, cáo),obj(đề, tài), person(bạn), time(dday(mốt))).

This semantic structure is the structure 17 in Table 11.

Table 12. Semantic structures of WHEN question (*Source*: Thien Khai Tran [14])

18	timeQuery(query(time),action,obj)
19	timeQuery(query(time),action,obj,person)
20	timeQuery(query(time),action,obj,person,place)

Example 10: Đi du lịch khi nào? *(When to travel?)*

The syntactic and semantic rules determine the semantic structure of this question as below:

timeQuery(query(time),action(đi),obj(du lịch)).

This semantic structure is the structure 18 in Table 12.

4.3. Pragmatic Semantics Processing

This research also carries out timing situations in relation to pragmatic semantics in sentences. All of timing units will be formatted in a standard timing structure: "yyyy:mm:dd hh:mm".

Table 13. Hypothesis for pragmatic semantics of timing

Keyword	**Context**	**Pragmatic Semantics**
Đầu *(beginning of)*	đầu tuần *(beginning of week)*	Monday → Tuesday
	đầu tháng *(beginning of month)*	day 1 → day 10 of month
	đầu năm *(beginning of year)*	January → March

Cuối *(end of)*	cuối tuần *(end of week)*	Saturday → Sunday
	cuối tháng *(end of month)*	day 20 → day 31 of month
	cuối năm *(end of year)*	month 10 → 12 of year
Sau = Tới *(next)*	tuần sau *(next week)*	next Monday → next Sunday
	tháng sau *(next month)*	current month (recording time) + 1
	năm sau *(next year)*	current year (recording time) + 1
Sáng *(morning)*		4 am → 10 am
Trưa *(noon)*		10 am → 15 pm
Chiều *(evening)*		15 pm →18 pm
Tối *(night)*		18 pm → 24 am
Mai *(tomorrow)*	ngày mai *(tomorrow)*	current day + 1
Mốt *(the day after tomorrow)*	Ngày mốt *(the day after tomorrow)*	current day + 2

Table 14. Examples of schedule time prediction (*Source*: Thien Khai Tran [14])

Recording time	**Timing phrase**					**Prediction time**
	prep	session	day	week	month	
Thứ 5, Ngày 13-9-2012 *(Sep.13, 2012)*		sáng *(morning)*	mai *(tomorrow)*			4h → 10h 14/9/2012 *(4am-10am Sep. 14, 2012)*
				sau *(next)*		từ 17/9 → 23/9 (Sep. 17 → Sep.19)
	cuối *(end of)*				tới *(next)*	từ 20/10 → 31/10 (Oct. 20 → Oct. 31)
				này *(this)*		10/9 →16/9 (Sep. 10 → Sep. 16)

Table 15. Examples of timing part of commands and questions (*Source*: Thien Khai Tran [14])

Command sentence	**Schedule time**	**Query sentence**
8g sáng thứ 3 tuần sau đi học *(8am next Tuesday, going to school)*	8h ngày 18/9/2012 *(8am Sep. 18, 2012)*	Ngày 18-9 có đi học không? (Going to school on Sept. 18, or not?)
Gặp khách hàng 15g30 ngày mốt *(visiting partner at 15.30pm the day after tomorrow)*	15h ngày 15/9/2012 *(15am Sep. 15, 2012)*	Chiều ngày 15 có làm gì không? *(Any job for the evening of 15?)*
Ngày 28-10 đi du lịch với nhà (On Oct, 28 travelling with family)	Ngày 28-10 *(Oct. 28)*	Cuối tháng sau có đi đâu không? *(Going anywhere by the end of next month?)*

Example 11a: Thêm sự kiện dự thầu tại công ty lúc chín giờ thứ ba tuần sau. *(Add event of bidding at the company at 9 am next Tuesday)*

The semantic structure: add(time("2012:09:25 09:00"), action(dự), obj(thầu), place(công ty)).
Example 11b: Cuối tuần sau có làm gì không? *(Any job for next weekend?)*

The semantic structure: workQuery(query(action), query(obj), time("2012:09:29 00:00" – "2012:09:30 00:00"))

The SQL command generated by above semantic structure will query all records in database with "time" field satisfying: "2012:09:29 00:00" ≤ time ≤ "2012:09:30 00:00".

5. EXPERIMENTS AND EVALUATION

As mentioned in Thien Khai Tran [14], we have separately carried out tests the two components: Automatic Speech Recognizer and Vietnamese Language Processing. Afterwards, the synthetic experimental step of whole system has achieved

.

5.1. Speech Recognizer

5.1.1. Evaluation Score

The speech recognition performance is typically evaluated in terms of Word Error Rate (WER), which can then be computed as: WER= (S + D + I) / N x 100% [12], where N is the total number of words in the testing data, S denotes the total number of substitution errors, D is the total number of deletion errors and I is the total number of insertion errors.

We make use of Word Accuracy (WA) [12] instead, which is computed as WA = (1 – (S + D + I) / N) x 100%, to report performance of the speech recognizer.

5.1.2. Performance

We have valued the accuracy of the Vietnamese speech recognizer component with 60 sentences, a single speaker in a relatively quiet environment. The results prove that WA can reach 98,09% and average time processing is 1.4 seconds/ sentence.
There are two main reasons explaining that high score: 1- This is a single speaker-dependent speech recognition, 2- We have used context-dependent model based on triphone for speech recognizer component, and made a strict grammar rules for the recognizer.

5.2. Vietnamese Language Processing

We have done manual tests including 60 sentences for evaluating the performance of the Vietnamese processing component. They are pattern sentences found in 48 semantic structures which have built in view of the system. The latter is capable of handling all the pattern sentences.

5.3. System Experiments

The system has been built as a PC-based application by MS Visual C# 2010 and SWI-Prolog version 6.2.1 for Windows NT/2000/XP/Vista/7.

Table 16. Experimental Environments

Number of Commands	38
Number of Questions	22
Environment	in-door
Sampling rate	16 kHz
Quantization	16 bits
Format	PCM

The system correctly analyzes and executes 55/60 of the spoken commands in Vietnamese language. The fault cases must be remained at the speech recognition step. So, our system demonstrates its accuracy attaining more than 91%. About 2.8 seconds for a command is spent as the average feedback time of the system.

We have also evaluated the capacity of handling the semantic commands of the system by using other approaches - keyword matching, phrase matching, such as longest matching algorithm used by Quan Vu et al. [9].

The results showed the 39 tested sentences out of 60 incorrect (65%). That proves the considerable improvement of the correctness of VNSpeechCalender system in handling the semantic commands and questions.

6. CONCLUSION

This paper has presented the architectural model of VNSCalendar system as well as our approach to build it. The Vietnamese Laguaguage Processing component, which can analyze syntax and semantics of some Vietnamese speech commands and questions forms, is centered on this system. With this research, we have provided evidence of the importance of syntax and semantics processing in voice applications, specially Vietnamese speech applications. In next steps, our jobs to be accomplished have essential characters in executing an independent speech recognition and widen vocabulary to realize the application as well as to develop simillar applications based on this research background.

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