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**DESIGNING A HAND GESTURE VOCABULARY
FOR HUMAN - ROBOT INTERACTION APPLICATIONS**
THIẾT KẾ TẬP CỬ CHỈ CHO CÁC ỨNG DỤNG TƯƠNG TÁC NGƯỜI - ROBOT

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ABSTRACT

Recently, human - machine interaction (HMI) becomes a hot research topic because of its wide applications, ranging from automatic device control to designing and development of assistant robot or even smart building at sparser scale. One of the most important questions in this research field is finding out an efficient and natural method of HMI. Among several channels of communication, hand gestures have been shown to be an intuitive and efficient mean to express an idea or to control something. In this paper, we propose a framework to study the behavior of Vietnamese in using of hand gesture in communication with robot. This study allows designing a hand gesture vocabulary for human - robot interaction (HRI) applications. In the literature, there are no works similar to ours. This makes our twofold contributions: (1) a general framework of studying and designing an interaction protocol between human and robot; (2) a basic set of hand gestures that can be used in general situation of HRI.

Keywords - Hand gesture, Human robot interaction

TÓM TẮT

Tương tác người - máy đang trở thành một lĩnh vực thu hút sự quan tâm nghiên cứu của các nhà khoa học trong và ngoài nước bởi các ứng dụng rộng rãi của nó trong điều khiển tự động thiết bị, thiết kế và phát triển robot trợ giúp hay ở quy mô lớn hơn là tòa nhà thông minh. Một trong những câu hỏi quan trọng đặt ra trong bài toán tương tác người - máy là phải tìm ra một phương thức tương tác hiệu quả và tự nhiên nhất có thể. Trong số các phương thức tương tác người - máy, cử chỉ bàn tay đã được chứng minh là một phương tiện trao đổi trực quan và hiệu quả. Trong bài báo này, chúng tôi đề xuất một mô hình nghiên cứu thói quen sử dụng cử chỉ của người Việt nam trong khi tương tác với robot. Nghiên cứu này cho phép thiết kế một tập cử chỉ tương tác cơ bản, có khả năng sử dụng trong nhiều ứng dụng tương tác người - máy. Theo như những hiểu biết của chúng tôi, các nghiên cứu trong bài báo này là hoàn toàn mới và không trùng với bất kỳ một công trình nghiên cứu khoa học trong và ngoài nước.

I. INTRODUCTION

Robotics is currently undergoing a major change. In the past, robots have been employed in assembly lines or well structured environments. Nowadays, we can see the presence of robots in many aspects of everyday life for professional as well as personal assistant services.

To assume the communication between human - robot, many researches on HRI have been conducted. An intelligent robot requires natural interaction with human. The interaction could be performed via several perception channels like vision, speech, touch, etc. Although significant advances have been made in speech-based interface research, these interfaces will be sometimes impractical in both

noisy and quiet environment.

Gesture is an intuitive and efficient mean of communication between human and human in order to express information or to interact with environment. In HRI, hand gesture can be an ideal way that a human controls or interacts with a robot. Providing robot with the ability to understand hand gestures will improve the ease and efficiency of interaction.

To be able to interact with human through hand gesture, the robot needs to understand hand gestures. The recognition will be performed by learning examples of gestures of interest and recognize given a new gesture.

For a successful hand gesture based interaction between human and robot, a

vocabulary of hand gestures needs to be defined and a gesture based protocol of communication should be understood by both human and robot.

This paper proposes a framework for designing such a vocabulary of basic hand gestures for HRI. The study and design of a gesture set, commonly used by Vietnamese in interaction with robot, helps for building applications based HRI by hand gestures. Our main contributions are: study the behaviors of Vietnamese in communicating with robot by hand gesture; define a hand gesture vocabulary that can be used for general purpose. To the best of our knowledge, there exists no similar works as ours.

The paper is organized as follows: In section II, we analyze some sets of hand gestures proposed in the literature. In section III, we propose a framework for designing a vocabulary of hand gestures then detail each step to be performed in order to obtain the results (section IV). Conclusions and future works are discussed in section V.

II. RELATED WORKS ON HAND GESTURE VOCABULARY

Since recent several years, a lot of researches in human - computer interaction based on hand gestures have been conducted [1,2]. In general, each work has been evaluated on a common hand gesture database then experimented with another database built by the authors themselves according to the application context. Some of databases are published for research use. But it is necessary to rebuild database for a specific application. In addition, the methodology for designing and building a hand gesture database has not been mentioned yet in all related scientific papers.

In the literature, there exists about more than ten public databases of hand gestures (including static and dynamic hand gestures) for different applications (e.g. hand sign language [3], robot controls [4]). In this paper, we do not want to do a survey on hand gesture databases in general but we focus only on hand gestures vocabulary for HRI application.

In [1], six hand gestures have been considered to control a robot: pointing, thumbing, relaxed, raised, arched, halt.

In [5], the authors used both static and dynamic gestures to control a trash-collecting robot: stop (moving arm into the right position for about 1 second), follow (wave-like motion, moving the arm up and down), pointing vertical (move the arm from a position up to a position), pointing low (starting from a position, pointing to an object on the floor, return to the initial position).

In [3], the authors tested with five types of gestures: stop, waving right, waving left, go right, go left. The data are collected from video sequences of five subjects. The subjects are led into a room with constant background and instructed how meaningful the gesture looks. They are further instructed to look at the camera and execute the movement.

In [4], a robot is controlled via five dynamic hand gestures: move forward, move forward then right, move forward then left, move backward then left, move backward then right. These hand gestures are built from one or two hands.

In [6,7], the authors presented a robot Robotinho playing the role of tour guide in museum. Arm and hand gestures are both used for communicating with tourists. The hand gestures that human interact with robots include: waving (one handed gesture), pointing (parametric, one handed gesture), thisbig (two handed gesture to indicate the size of an object), dunno (two handed gesture to express ignorance). A part from using hand gesture, body and head gesture were also considered.

We found that for each specific application, a vocabulary of hand gestures has been proposed by authors. Almost approaches build hand gesture set by predefining hand gesture set and recording videos of the users doing these gestures. Some of these gestures are common among applications (e.g. waving), some others have different meaning even the movement of the hand remains the same. This requires redefining a gesture set for a new application. In addition, this gesture set, as proposed by researchers, is imposed for human without considering if they do this in a comfortable manner or not.

In HRI, some scenarios of

communication remain the same for all applications. For example, before controlling or interacting with the robot, human needs to call the robot coming near to him/her. When human does not have anything else to command, he/she can make a signal to say goodbye or to end the interaction, etc. Therefore, we think that it should be useful to study and to design a common set of hand gestures that could be used for general context.

III. DESIGNING A HAND GESTURE VOCABULARY FOR HRI

Framework of designing hand gesture vocabulary

The designing of a vocabulary of hand gesture needs to satisfy 2 requirements:

- *Toward human in the interaction:* The gestures should be intuitive and comfortable to perform by the human.
- *Toward system (robot):* The gestures should be distinct and recognizable by the system.

In [8], the authors proposed an method for selecting an optimal hand gesture vocabulary. However, this method is quite analytic and psychological. The authors did not indicate a study case to obtain a vocabulary.

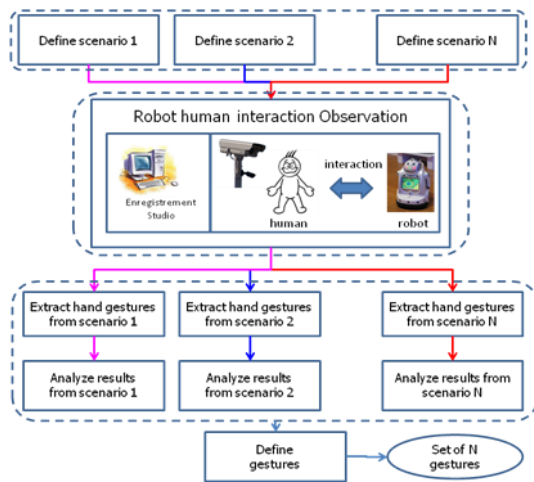


Figure 1. Framework of designing hand gesture vocabulary.

We inspire the idea in this work and propose a framework to design a hand gestures vocabulary in reality (Figure 1). This framework consists of four main blocks: (1)

definition of interaction scenarios; (2) HRI observation in each scenario by camera; (3) hand gestures extraction and analysis; (4) definition of hand gestures set. In the second block, a set of people will be invited to participate into interaction with the robot without knowing that their interaction is registered (we refer to the Wizard of Oz technique - an efficient way to examine user interaction with robot). This allows obtaining the most natural HRI.

Definition of HRI scenarios

In order to study the behaviors of Vietnamese in communication with robot and to build a set of hand gestures, we define a series of HRI scenarios in a simulated library context. It needs to be noted that this simulated context is not a special context, so the HRI studied in this context can be used and extended to many others contexts. The scenarios must be basic and simple which allow subjects play them easily and exactly.



Figure 2. An example of scenario in which a human asks the robot to know more about the abstract of a book to which his hand is pointing. The robot will answer the human by synthetic voice using Vietnamese speech synthesis system.

The simulated library is a room of size 3m x 3m in which we equip some tables, chairs, bookshelves. All are similar to a reading room in the library so that the human can feel as in a real library.

To define interaction scenarios, we invent situations and assign roles to a human

and a robot. The scenario can start with a human entering into the library, learnt that there is a service robot, he looks around the room to find the robot, then calls the robot coming near to him to ask some services like looking for a book; asking to know more about the book; looking for a room; etc. During the playing, the human can do anything (by gesture or voice) to explain his demand or his attitude to the robot. Once all demands are responded/refused, the human feels (un)happy to pass the time in the library, he ends the interaction with the robot and goes outside. Figure 2 extracts a frame of a scenario in which a human is interacting with the assistant robot in the library.

Although scenarios are played in the context of a library with library specific operations, we will only study behaviors of human interacting with the robot in the most five common situations: *call the robot; point to something for a service; agree or disagree with the robot's answer, finish the interaction.* The library context helps the human interacting with the robot in a real situation. To summarize, five interaction scenarios will be considered:

- Call the robot to come.
- Point to an object to know more about it.
- Agree with the robot.
- Disagree with the robot.
- Finish the interaction with the robot.

HRI observation

Once scenarios are defined, we start filming the scene with 3 cameras to assure that all in the scene are visible. A microphone is also used to register voice communication. In order to study the hand gesture set of Vietnamese in HRI, a multimodal corpus (video/audio) was built with twenty-two native Vietnamese peoples (eleven males and eleven females) with a mean age of 23. There are fourteen right-handers, and eight left-handers. These people have the same awareness and knowledge level.

Figure 3 illustrates the simulation interaction environment and control room. All people are asked to play two times all the defined scenarios, each at one time in the

simulation environment. To be able to obtain the natural HRI, we say to the human that we would like *to test the robot's abilities, i.e. the performance of speech and gesture recognition system embedded on robot while interacting with human.* He/she does not know that robot is controlled by an anonym technician in the control room. During interaction with the robot, the human is asked to not move a lot such that only hand movement is taken into account.

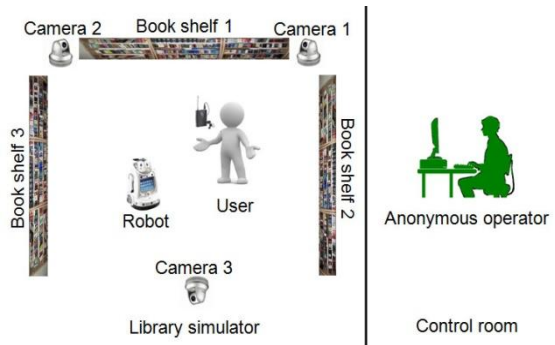


Figure 3. Setup library simulator and control room.

All twenty two peoples play two times all the defined scenarios, yielding 66 video files (22 subjects x 3 cameras). All videos files are recorded in the same format avi, sampled at 25 fps with resolution 352x280. Depending on the relative position of human w.r.t the camera pose, some hand gestures are visible in one camera field, some others do not. After selecting and editing, we have obtained 850 clips (corresponding to 459 scenarios) that only present one hand gesture per one scenario.

Hand gesture analysis

Until know, we have all data for gesture analysis. The analysis step should answer to the following questions:

- Which gestures are used in each scenario?
- How are gestures characterized?

A hand gesture is defined as a sequence of movements of hand postures. In general, a gesture is composed of three phases: preparation; execution; finish. We are interested only in execution phase. We propose to analyze gestures based on hand postures and movement properties during execution phase of hand gesture as movement speed, movement amplitude; performing time of gesture.

- *Movement speed* is defined as hand speed, measured by the distance that the hand moves in a time unit (m/s).
- *Movement amplitude* is defined as the maximum distance between to hand postures centers (Figure 4) when doing the gesture.
- *Performing time*: the total time that a human does a gesture (during execution phase), counting from starting point to ending point.

To obtain the movement parameters of hand gesture during execution phase, we need to:

- Detect boundaries between phases of hand gestures in order to extract only video frames at execution phase from whole video clip.
- Determine 3D hand position at each frame then track the movement of the hand during execution phase, in order to compute the amplitude and the speed of hand movement.

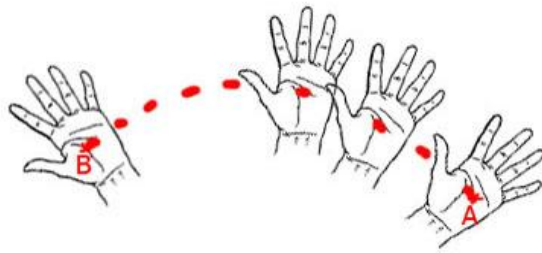


Figure 4: Movement amplitude of a hand gesture is the distance from A (starting point) to B (ending point).

Currently, the boundary detection and hand tracking is done manually. Based on obtained statistic data on movement speed and movement amplitude, we found that to the speed and amplitude could be categorized into three groups:

- *Speed*: Fast ($0.5\text{m/s} < F$), Average ($0.2\text{m/s} < M < 0.5\text{m/s}$), Slow ($0\text{m/s} < S < 0.2\text{m/s}$).
- *Amplitude*: Wide ($15\text{cm} < W$), Average ($5\text{cm} < M < 15\text{cm}$), Narrow ($N < 5\text{cm}$).

The analyzed results show that:

- We observe two interesting differences between human – human interaction and HRI: (1) in order to impress the robot, *when interacting with the robot*, Vietnamese people have trend to move the hand more than when he interacts with human; (2) the performing time for one gesture when human interacts with robot is longer because human seems to keep gestures until obtaining the robot’s response. Therefore, in almost scenarios amplitude and speed of hand movement take a mean value, not a narrow value as we expect.
- For each scenario, several types of hand gestures are used in interaction with the robot.

We will now analyze in more detail the percentage that one gesture is used in each scenario. Table 1 represents two types of hand gestures “**Call1** and **Call2**” when Vietnamese want to call robot. In the scenario definition, the scenario “call robot” is used if human want to start an interaction with robot or he/she needs the robot’s help. The analyzed results show that 92% Vietnamese uses the **Call1** hand gesture (open, wave, hollow of hand down) to call robot and only 8% uses the **Call2** (open, wave, hollow of hand up).





Table 1. Hand gestures used to call the robot.

Type	Illustration	Description	Per.
Call1		hand open, wave, hand hollow down	92%
Call2		hand open, wave, hand hollow up	8%

Table 2. Hand gestures used in pointing scenario.

Type	Illustration	Description	Per.
Point1		open, hand point, not change hand shape	23%
Point2		close, forefinger points, not change hand shape	77%

Table 3. Hand gestures used to explain an agreement with robot.

Type	Illustration	Description	Per.
Agree1		fingers close, but the thumb up	61 %
Agree2		fingers open, but forefinger and thumb close	30 %
Agree3		fingers close, but forefinger and middle finger make the victory symbol	4%
Agree4		hand clap	5%

In the second scenario (human points to an object to ask more information about it), there are also two different hand gestures that are used in which **Point2** type is used more often (77%) than the first one (23%) (**Point1**) (see Table 2).

Table 3 represents the hand gestures used to explain an agreement with robot. In this case, four hand gesture types are carried out, in which the **Agree1** and **Agree2** are used more usually, with 61% and 30%, respectively, than the others.

Hand gestures of Vietnamese for explaining the disagreement with robot and finishing an interaction with robot are represented in Table 4 and Table 5. The disagreement scenario is defined in which human refuses or does not agree with the robot's answer. The finishing scenario will be used if human wants to end the interaction with robot. One important thing needs to be noted that Vietnamese use two different types of hand gestures in each context, but almost people used one hand gesture (with the fingers open, hand

moves left, then right, then left, and shape does not change) to explain two different things (**Dis1** for disagreement scenario, and **Stop1** for finishing the interaction).

Table 4. Hand gestures used to explain a disagreement with robot.



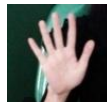

Type	Illustration	Description	Per.
Dis1		Fingers open, hand moves left, then right, then left, not change hand shape	82 %
Dis2		close, forefinger points down, not change hand shape	18 %

Table 5. Hand gestures used to finish the interaction with robot.

Type	Illustration	Description	Per.
Stop1		Fingers open, hand moves left, then right, then left, not change hand shape	94 %
Stop2		fingers close, but forefinger and middle finger make the victory symbol	6%

In order to distinguish these two types of hand gesture (**Dis1** and **Stop1**), we carried out some analysis on movement speed, movement amplitude, hand type (right or left), and performing time of gestures.

Table 6 shows that all most Vietnamese carry out the both hand gestures (**Dis1** and **Stop1**) with medium and narrow moving amplitude (44% and 49%, respectively) and medium speed (61% and 58%, respectively). There are 82% and 73% human who use right hand for **Dis1** and **Stop1**, respectively, gestures.

Table 6. The analyzed results (speech, amplitude, hand type, performing time of gesture) of **Dis1** and **Stop1** in two scenarios: disagreement and finish interaction.

Gesture	Speed %			Amplitude %			Hand %		Time (s)	
	Fast	Medium	Slow	Wide	Medium	Narrow	Left	Right	Mean	Sd.
Dis1	30	61	9	18	44	38	18	82	1.56	0.61
Stop1	31	58	11	13	38	49	27	73	2.27	1.86

This can be explained because there fourteen right-handers (64%) among twenty-two people in our corpus. So it can be noted that the both two types of hand gesture (**Dis1** and **Stop1**) present many similar characteristics, it can make a difficulty to robot for recognizing.

IV. HAND GESTURE VOCALBURARY DEFINITION

As previous speaking, the designing of a hand gesture vocabulary needs to satisfy two following criteria: (1) the *comfortableness* for human when doing it; (2) the *recognisability* for system when observing it.


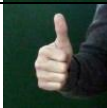
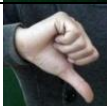
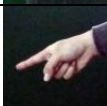
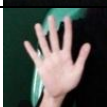
The first criterion is assured by choosing hand gestures that are mostly used by human when interacts with the robot. As analysis above, five following hand gestures will be selected: **Call1** (92%), **Point2** (77%), **Agree1** (61%), **Dis1** (82%), **Stop1** (94%).

We can see that following this criterion, Vietnamese people use the similar hand gesture to express two different things: *disagree with robot* (Dis1) and *end the interaction* (Stop1). As analyzed previously, two types of hand gesture (**Dis1** and **Stop1**) present many similar characteristics. To assure the recognisability of the system, hand gestures need to be distinct. We found that in “*disagree with the robot*” scenario, two gestures have been used (Dis1, Dis2). We then decide to choose the remaining gesture **Dis2** that is different from the gesture **Stop1** used in “*finish the interaction*”, even the number of using **Dis2** takes only 18%. In conclusion, the hand gesture set that assures two criteria is designed as in the Table 7. This set contains five hand gestures commonly used in five scenarios usually concerned in HRI context.

ACKNOWLEDGEMENT:

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Table 7. Proposed Hand gesture vocabulary. In the table **S**: hand movement speed, **A**: hand movement amplitude, **H**: hand type; **T**: performing time in average. **M**: medium, **R**: right.

Gesture	Illustration	S	A	H	T
Call		M	M	R	3s
Agree		M	M	R	2s
Disagree		M	M	R	2.5s
Point		M	M	R	10.5s
Stop		M	M	R	2s

V. CONCLUSIONS

This paper studied the behavior of Vietnamese in using of hand gesture in communication with robot. The study has been carried out through a framework of four steps. The proposed framework is general and could be used for all other studies aiming finding out other interaction methods (e.g. using speech). Results obtained from this study are a set of hand gestures (five gestures) commonly used in five scenarios that all HRI applications should concern. These five hand gestures have been designed satisfying *comfortableness* and *recognisability* criteria. Researchers in the domain can reuse this set of gestures without requiring redesigning it.

In the future, we will validate quantitatively this set of hand gestures based on HCI usability measures as well as hand gesture recognition rate.

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