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**Invited Paper:**

# Relationship Between Human and Robot in Nonverbal Communication

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**The function of the robot living together converges on the problem of communication. We focus on nonverbal communication and relationship between service robots and human. We show nonverbal communication experiments of robot to build relationship between human. We described some ideal fiction robots to live with. We got experience such as; Relationship based on touch communication is managed three elements, appearance, motion and predictable behavior. As the result, these elements are based on embodiment. Human touches robot after feeling safe and natural motion. Motivation to build relationship with robots is decided above three elements in physically but appearance and motion are important. Evaluation of relationship is complicated because relationship grows up depending on spending time and motivation to relate. These experiences were shown by life sized humanoid robot and robot arm in exhibition. Based on these results, evaluation method to understand relationship between robot and human are considered in near future robot development.**

**Keywords:** nonverbal communication, humanoid robot, robot arm, work with robots, life with robots

## 1. Introduction

The function of the robot living together converges on the problem of communication. Users make relationship with robot through performance as the result of recognition of robot. Communication of robots is one of functions to build relationship between users to share experience of recognition and performance of robot. Communication can be divided linguistically and nonverbally. Robot interaction research were also important. First of all, we are not researchers but developer of robots. It is practical approach to nonverbal communication.

We think that relationship between humans(user) and robots is the most important evaluation for robots living with humans. Relationships are perceived by the user by physical appearance, that is, appearance and physical existence including touch feeling such as surface and behavior style using the body. Add to say, intelligence of robot is found out from users through the performance. Design of appearance is also designed considering relationship [1].


**Fig. 1.** One scene of Doraemon [2].

Safety of robot must be required to live with human. Because humans desire safety and smiles in their daily lives. Let's think about an ideal safety and smile robot to live with. We can remember Baymax (Movie, "Big Hero 6," 2014), Doraemon (Comics and TV animation, "Doraemon" since 1970) in **Fig. 1** etc., in fiction. You can see both robots touch users directly. In past experiments, Robovie, the humanoid robot, worked with visitors including children in museum [3] to interact each other. Their evaluation is based on questionnaire.

An ideal robot, Doraemon, to live with human in fiction is the cat type bipedal robot traveled back from the 22nd century and is created by Fujiko F. Fujio, a renowned Japanese cartoonist. From the view point of the interface, Doraemon has perfect natural interactive communication such as conversation, common sense and touch communication. You can read Doraemon forecasts to fight with Nobita about numbers of rice cakes through the conversation. It can be inferred that Doraemon has a function to understand common sense such as "human wants more than others," "children of this age have no mind to avoid fight to keep their wants," and "to fight with the boy at this age is good to foster social sense." However, these functions are hard to realize current technology.

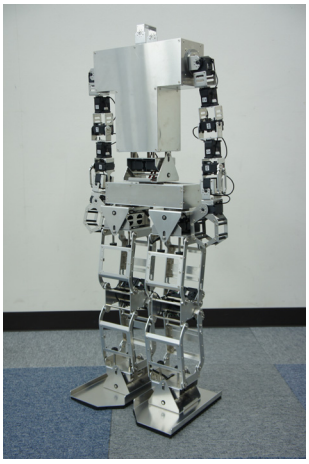

**Fig. 2.** RIC 90 (Robot inside character).

**Fig. 3.** Nekotencho.

Either way, we are paying attention to touch communication, the body control technologies of Doraemon as a robot. When you think about such numbers carefully, you do not find any way that Doraemon may fight against Nobita without the management of power and whole body balance. And also, Doraemon keeps attention to Nobita's punch to avoid damage itself. It is natural performance of animal but robot. Natural performance of robot gives an important impression of the safety to users. In fact, Nobita's mother feels Doraemon to be safe and positive for her child because she allows Doraemon to live together. Thus, predictable behavior with common sense and culture and power adjustment suggests it to be safe. It is hard to share safety and smiles each other. Add to say, robot has many users position, mother (owner/operator) and child (end-user) and so on.

Based on these idea, we introduce 2 robots, humanoid and robot arm focused on development of robots to watch nonverbal communication. A humanoid robot with cat suit "Nekotencho" is introduced to show hug with mainly children. "Nekonote" is the robot arm with force command to work with human. You can see in following sections. Appearance of robot, natural motion and touch communication are the powerful tools (skills?) to make relationship.

## 2. Nekotencho, the Life-Sized Humanoid

### 2.1. Life-Sized Humanoid

First, confirm that you have the correct template for your robot image. In **Fig. 2**, the base robot RIC90 is 28DOF, 90 cm height and 9 kg. RIC90 is named from Robot Inside Character with 90 cm height. Nekotencho has 120 cm height and 13 kg weight with a cat suits in **Fig. 3**. It can walk slowly. Motors are position controlled with compliance. Raspberry Pi 2 with speakers is onboard to Nekotencho to speak. Camera is also put inside of eyeball to watch through web (not to recognize).

### 2.2. Safety and Motion of This Robot

Light body is the one of solution for the safety. In robot development, there is no perfect safety but to show safe. Light weight realizes to bring easy even if child brought. Nekotencho has 13 kg weight that 5 years old children can support the body if it falls.

Keeping away from pinching accident is important these complicated articulated robots. Cat suit is made by synthetic bore fabric to feel smooth. It helps to avoid pinching by each limb.

Human misunderstand it is safe if it has cute appearance. Cute appearance connotes safety but it covers dangerous body. Cute motion is also danger to loosen attention to robot but leads smile. Of course, enough attention is paid to design the robot to be safe. For example, to avoid fire, we paid attention to put cables not to cut, motor unit RS405CB Futaba having cut off function of overload, safety board for lithium battery and so on.

The motion is just implemented shop staff motion in front of shop to watch visitors such as "look around" "say welcome," "waving hand," "shake hand," "hug," and "bowing." These motions are implemented by hand to show randomly. Clearly, these motions are predictable in exhibition scene. **Fig. 4** is the one of scene in exhibition.

### 2.3. Evaluation

Evaluation is smile of children and mother doesn't stop them to hug. We put Nekotencho in iREX2015.

Many children and parents feel Nekotencho to be safe and fun from appearance. In fact, they gathered around the robot. Their parents recommended their children to go and gave hug. Some of boys lifted Nekotencho. They took photo with smile.

In comparison, robot engineer never touch robot and lift it up. Because they know the robot to be danger in their nature.

These results show as;

1. Parents feel safe enough to the robot which their children touched. They might judge from the robot appearance and predictable motion sets.

**Fig. 4.** Nekotencho and children in iREX2015.

2. Children close to robot from themselves after they felt safe and fun. Some of children feel fear to the robot because they were smaller than the robot. "Safe" criteria seem to be based on personal feeling, body size and so on.

3. Professional engineers are trained not to touch the robot before feeling to avoid accidents. They don't touch even if staff urged.

### 2.4. Intelligence Without Conversation

Relationships between robots and human leads required intelligence per spending time together. We show short time relationship intelligence veiling patterns. In other words, long time observation gives discomfort to aware no intelligence in pattern series of motion. Because human performs to the robot to make relationship through giving task. In short time relationship, robot can make users misunderstand it having intelligence. We tried several experiments as follows.

Nekotencho has function to speak without intelligence. We put it in front of our shop to evaluate human can feel intelligence in short time. The experiment continued almost 2 years. During the operation of 2 years, we gave hug sometimes by hand operation and it speaks automatically using TTS with random motion. As the result, customer can't aware it can speak. Because touch communication has impact comparing with conversation with no intelligence.

For comparison, We put the robot in exhibition in conference of Robomech, SI20xx, JSAI and RSJ in Japan. Almost vision engineer misunderstood natural robot motion performed by face tracking. Sometimes they outline how the function performs in this robot. They were surprised if we showed there was no vision system inside of robot. These motion is just hand implemented.

We got experience to show intelligence as follows.

**Fig. 5.** NEKONOTE Green.

1. Short time, almost within 10 mins, users can believe robot has intelligent motion based on implemented high technology.

2. Long time, 1 hour over, users can find out discomfort of performance from series of motion sets.

We should aim to realize intelligence to make long time relationship in performance with recognition and intent to make relation with human. In conversation, there are several test to evaluate relationship to think by Turing test and so on. In nonverbal communication, we have less clear evaluation method by representation.

## 3. Appearance and Design of Robot

Appearance is powerful motivation to touch robots for humans. Cute appearance is not meaning of humanoid and animal. Robot arm shows these differences with good design shells and no shells to watch the same motion.

### 3.1. Life-Sized Robot Arm NEKONOTE

There are two types of robots which has the same function. NEKONOTE is the robot arm torque command to perform smart behavior to work with human. In **Fig. 5**, NEKONOTE Green is 5DOF robot with designed cute body appearance. Designer gave the concept vivid color in kitchen green. In **Fig. 6**., NEKONOTE 6DOF for academic was used for smart factory. In **Fig. 7**, NEKONOTE Chicken Nugget Server robot (here after NEKONOTE CNS[4]) is 6 DOF robot with no shells to work in the factory kitchen. In other words, all of them are developed to help human in kitchen and factory.

### 3.2. Motion of NEKONOTE

They have gravity compensation mode to support to keep position its self but if other force comes it to move. This motion is looked static behavior. It shows natural motion like animal does nothing but in active. It means motion is predictable in this situation for both robots. You can touch robot and keeps position in your style. Based on experience of Nekotencho, we thought we can get almost same result, but we couldn't. NEKONOTE


**Fig. 6.** NEKONOTE 6DOF for academic in smart factory.

**Fig. 7.** NEKONOTE Chicken Nugget Server ver.

Green was popular in exhibition as the same to our experience. On the other hand, NEKONOTE 6DOF (academic / CNS) were not in popular. We asked to visitors to touch, but they hold back from touching on robots even if staff asked to try and touch them. Unfortunately, we are not researcher, therefore we don't have result of questionnaire. But we could know-how from these experiences. In **Fig. 6**., Nekotencho was popular in this exhibition.

### 3.3. Appearance and Shape Show Safety

People expect and predict different motion depending on appearance. We got results in comparison of NEKONOTE Green and NEKONOTE CNS in same motion "gravity compensation" as follows.

1. NEKONOTE Green has many visitors to touch long time in exhibition even if engineer said nothing. Visitors replied "it isn't active." (Robot was active.)
2. NEKONOTE 6DOF academic/CNS have no users to touch. When staff urged, visitor touched the robot. Visitors replied "it shows dangerous."
3. Difference between them is designed shell.

The both robots show the same motion, "gravity compensation" in the same way. Situation is the same food sample. Even if NEKONOTE CNS shows performance to pick the recognized nugget correctly with TensorFlow. It uses intelligent vision system. However, result shows difference. We can conclude aggressively feeling safe and smile depending on appearance and motion. Therefore, we can see effectiveness has no meaning to build the relationship to touch communication. We should learn more and more through experiments what human makes to work or live with robots in daily life.

## 4. Conclusion

In this paper, we described an ideal fiction robot to live with. We show nonverbal communication robot to build relationship between human based on above idea. We got experience such as;

1. Relationship based on touch communication is managed three elements, appearance, motion and predictable behavior. As the result, these elements are based on embodiment.
2. Human touches robot after feeling safe and natural motion.
3. Motivation to build relationship with robots is decided above three elements in physically but appearance and motion are important. Evaluation of relationship is complicated because relationship grows up depending on spending time and motivation to relate.

We've not tried to use conversation to build relationship because of voice recognition and speech understanding context are immature technologies. Speech/text with context have been proposed as Turing test and so on. However, we don't have test for nonverbal one. Therefore, we have to find new evaluation method for verbal and nonverbal mixed communication aided by AI in each steps of relationship between robot and human in near future.

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