Study on Behavioral Personality of a Service Robot to make more Convenient to Customer

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Study on Behavioral Personality of a Service Robot to make more Convenient to Customer

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***Abstract*— In recent years, a lot of companies and laboratories start to announce their various prototype service robots. As we could know in that point, the market for intelligent service robots is expected to grow in future. Then it is expected that customers demand more performance to a robot to be fitted for them when a robot is supplied widely. In the present paper we shall see the robot's variation of behavioral personality from the experiments. These results show that by adjusting the parameters related to robot perception, the robot can be varied in its personality for customer. The robot is implemneted by "Cognitive Robotic Engine (CRE)" for the dependable integration of human-robot interaction (HRI) components [1][2].**

I. Introduction

These days, a lot of companies and laboratories start to announce their various prototype service robots. As we could know in that point, the robot market is seeing exponential growth. For example, experts are predicting explosive growth in the Korean robotics market, from a meager W350 billion (about US$350 million) in 2004 to W10 trillion by 2010 and to W100 trillion by 2020 [3]. It does not exist that a killer application of a service robot in a service robot market yet, however it is expected that customers demand more performance to a robot to be fitted for them in future. This research is begun by an idea that if a robot behavior is fitted for customers that how comfortable they are. To make a behavioral personality of the robot, we adjust several parameters in our "Cognitive Robotic Engine (CRE)" program which is proposed by the authors to implement an active service robot [1]. The purpose of CRE is to accomplish ad-hoc mission by eliminating uncertainty that comes when the robot works.

In the most of researches, robot personality is about an emotional expression imitating the human [7][8]. The Kismet from MIT modeled the emotional reaction of 3 years old baby. The study aimed for social interaction of robot. It is able to show its feeling by facial expression with emotion engine [9]. The other researches took the ideas from psychology or biology field. "WE" series from Waseda university also implemented internal emotional model and facial expression based on psychological background like Kismet [8][10]. The researches above enable the robot to coexist and interact with human. However, there has been minimal research regarding a robot behavioral personality. Research on a robot behavioral personality is still in its early stage, we adjust several parameters passively at this time. Nevertheless, experiment results still fairly interesting. Of course, we have need of more research, but we expect that our research to help to make a robot more attractive to customer.

This paper is organized as follows: Section II introduces an overview over the CRE, organization, implementation and control of CRE are described in detail in Sections III, IV. Section V shows that robot behavioral personality system based on CRE. And the result of experimentation about the robot behavioral personality is described in Section VI; Section VII concludes this paper.

II. Cognitive Robotic Engine

In order to introduce the concept of CRE, let us consider how a human identifies a caller, if there is, dependably in a crowded and noisy party environment. Upon hearing a novel but highly uncertain nature of sound that may indicate someone calling, one immediately registers in his/her consciousness an ad-hoc mission of verifying if there is a caller. The mission will remain in his/her consciousness till the verification is done with a sufficient level of confidence an individual set. With the registered mission producing a stress, a flurry of asynchronous and concurrent perceptual processing takes place inside in such a way as to reduce the uncertainty as efficiently as possible.

A sufficient amount of evidences may be quickly assembled from multi-modal sensing cues, including both auditory and visual cues such as calling hand gestures and/or calling facial expressions, generated by an asynchronous and concurrent flow of auditory and visual perception building blocks. The first key issue may be to understand an optimal way of constructing an asynchronous concurrent flow of perceptual building blocks for decision, dynamically to the real-time variation of situations. In addition, human tends to take appropriate actions for gathering a better quality of or a new addition of information instead of depending passively on what is sensed for a decision. The second key issue may be how to choose action blocks to be incorporated into an asynchronous and concurrent flow of perceptual building blocks in such a way as to achieve an optimal overall efficiency in reaching the decision. Summarizing the above, human dependability in perception may be conjectured as the result of the following exercises:

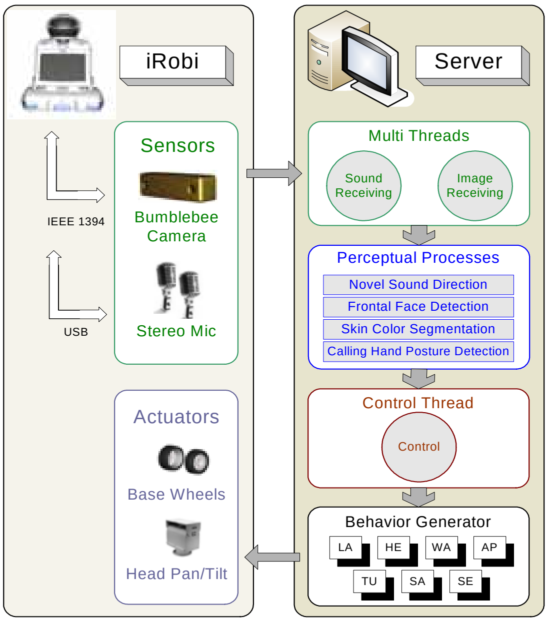

Fig. 1. The architecture design of CRE implementation on iRobi

1) The spontaneous and self-establishment of ad-hoc perceptual missions in connection to particular sensing that drive the subsequent perceptual processes till satisfied.

2) The choice of particular asynchronous and concurrent flow architecture of perceptual building blocks out of a potentially huge number of possible flow architectures as the basis for deriving evidences to be fused together.

3) The incorporation of action blocks into the chosen asynchronous and concurrent flow architecture of perceptual building blocks as a means of proactively collecting sensing data of less uncertainty and of new evidence, which triggers a dynamic reorganization of the asynchronous and concurrent flow architecture of perceptual building blocks.

4) The optimal process control in terms of the choice of a particular asynchronous and concurrent flow architecture of perceptual building blocks to follow as well as of the choice of particular action blocks to be invoked at each sampling time. The environment or toolkit that enables the above asynchronous and concurrent flow of a perceptual process, or, in general, a robotic process, is referred to here as CRE.

III. Organization and Implementation of CRE for Caller Identification Mission

In this paper, we chose the caller identification mission. The reason we chose this mission is that it is positively necessary for a service robot and it is necessary to accomplish other missions, e.g., delivery of information mission.

A. Overall System Architecture

Overall architecture of CRE system is shown in Fig. 1. Generally, hardware dependant procedures are implemented in the robot. On the other hand, hardware independent procedures are implemented in the server to make it better in compatibility. The system operating procedures are as follows: 1) each thread from the server request sensing data to the robot, 2) the sensors transmit external data, 3) the perceptual process analyze the information, 4) the control thread gathers all the information from perceptual processes, and then make a decision, 5) if there is any necessity, the behavior generator make the robot to act.

TABLE I
Description of Perceptual Processes for Caller Identification

NSD	Def.	When the sound volume exceeds the threshold, estimates the direction of source
	Source	Mic Array
	Input	Raw data of sound
	Output	Direction of novel sound Estimated Certainty (CF-E) Present Certainty (CF-R) Expected Certainty(CF-A) Candidate of action (AC) Processing Time (PT)
FFD	Def.	Finds face region by image feature
	Source	Camera
	Input	Raw image from Camera
	Output	Coordinate, and size of detected face CF-E, CF-R, CF-A, AC, PT
SCB	Def.	Distinguishes skin region by RGB condition and makes others black in image
	Source	Camera
	Input	Raw image from Camera
	Output	Image of skin color segmentation Most probable direction that callers exist in. CF-E, CF-R, CF-A, AC, PT
CHP	Def.	Estimates calling hand by skin color in face adjacent area
	Source	FFD, SCB
	Input	Coordinate and size of detected face Skin segmented image
	Output	Direction, and distance of caller CF-E, CF-R, CF-A, AC, PT

B. Perceptual Process and Precedence Relation

Table I represents the specification of four perceptual processes for caller identification mission – Novel Sound Detection (NSD), Frontal Face Detection (FFD), Skin Color Blob (SCB), and Calling Hand Posture (CHP). Commonly, the individual perceptual process has estimated and actual certainty (CF-E, CF-R), action candidates that can improve the certainty factors (AC), expected certainty (CF-A), and processing time for the process (PT).

We say processes A and B are in the precedence relation if the output of A is the input of B. Fig. 2 shows the precedence relation of perceptual processes for caller identification mission.

C. Behavior Generator with Action Process

The robot action for collecting better evidences can be organized in terms of simple actions that are mutually exclusive, such as head and base motion based actions and verbally oriented actions, and of compound actions as a combination of simple actions. Similar to our previous approach [1], we define Look Around (LA) and Heading (HE) as head motion based actions, Wandering (WA), Approaching (AP), Turning (TU) as base motion based actions, and Verbal Inquiry (VI) as a verbally oriented action.

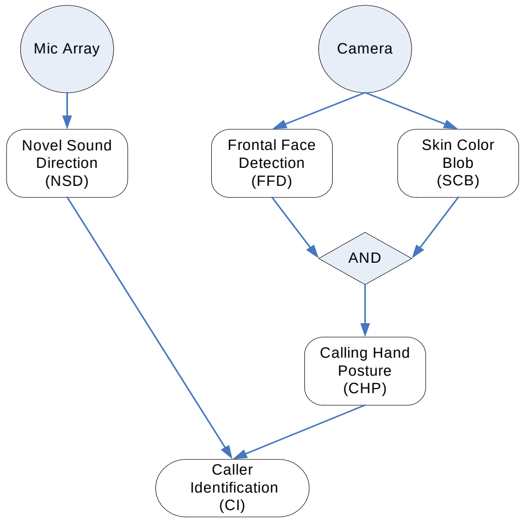

Fig. 2. The precedence relation of perceptual processes for caller identification mission – All the relations without AND mean OR

As for a compound action, we define a Searching (SE) action as a random combination of LA and WA. This is illustrated by Table II. Note that we simplified the number of actions so as to observe their effect on actual robot behaviors more clearly. For more details of the definition of each action in Table II, refer to [1]. Note that the actions defined here are connected to individual perceptual processes in which the candidate actions for improving the certainty factor of the corresponding evidences are defined.

IV. Control for Optimal Accomplish of Mission

A. Evidence Structure for Caller Identification

CRE aims at combining or fusing multiple evidences in time for dependable decision. The evidences to be fused are chosen from the list of evidences that can be offered by the individual perceptual processes with/without taking the actions for collecting better certainty of evidences into consideration. In order for the system to automatically determine the processes and/or actions that supply the evidences to be fused, we need to know how individual evidences and their certainty factors contribute to the certainty factor of the decision for the given mission. For this purpose, we define an evidence structure describing the logical relations of individual evidences. For instance, for the caller identification mission, the evidences provided by individual processes can be structured based on the following causal relationships:

$$\begin{aligned}
&FrontalFaceDetection -> CallerIdentification\\
&SkinColorBlob -> CallerIdentification\\
&NovelSoundDirection -> CallerIdentification\\
&FrontalFaceDetection \wedge Hand\ at\ side\ of\ FrontalFace(Using\ SkinColorBlob)\\
&\rightarrow CallingHandPosture\\
&CallingHandPosture \rightarrow CallerIdentification
\end{aligned} \quad (1)$$

Fig. 2 illustrates the above logical relationships among evidences in a graphical form.

TABLE II
List of Candidate Actions for Caller Identification

Action Classes	Unit Actions
Head Action	Look around (LA) Heading (HE)
Base Action	Wandering (WA) Approaching (AP) Turning (TU)
Verbal Action	Verbal Inquiry (VI)
Compound Action	Searching (SE)

The evidence structure described by (1) and Fig. 3 is equivalent to a Bayesian net, except that we consider explicitly the conjunctions of evidences that becomes sufficient for proving the truth of another evidence and represent them with AND operations. This is to make it easier to define the joint conditional probabilities required for the computation of certainties based on the Bayesian probability theorem. The actual implementation of computing certainty update is based on the Bayesian net update procedure. [2]

B. Certainty Factor Associated with the Mission

The certainty factor associated with the mission should be updated in time as evidences are accumulated. E.g., a novel sound may increase the certainty factor of the caller ID over a threshold and invoke the caller ID mission. To verify the truth of the mission, CRE may seek for such additional evidences as Frontal Face in the direction of Novel Sound, Calling Hand Gesture, etc. with or without actions like Approaching to Novel Sound Direction, Verbal Inquiry, and etc. to update the certainty factor of the mission. The update of the certainty factor can be done by applying the Bayesian posterior probability theorem to the evidence structure for evidence fusion and the filtering in time for evidence accumulation:

$$\begin{aligned}
&\mathrm{Mission_Certainty}(CallerID) =\\
&P(CallerID \mid Evidences) = \frac{1}{1+\dfrac{P(Evidences \mid \overline{CallerID})P(\overline{CallerID})}{P(Evidences \mid CallerID)P(CallerID)}}\\
&\therefore P(CallerID \mid Evidences) =\\
&\frac{1}{1+\dfrac{P(FFD \mid \overline{CallerID})P(SCB \mid \overline{CallerID})P(NSD \mid \overline{CallerID})P(CHP \mid \overline{CallerID})P(\overline{CallerID})}{P(FFD \mid CallerID)P(SCB \mid CallerID)P(NSD \mid CallerID)P(CHP \mid CallerID)}}
\end{aligned} \quad (2)$$

(2) shows that the probability of Caller ID, represented as the certainty factor of Caller ID, given a set of evidences can be computed by estimating the probabilities of a set of evidences when caller ID is and is not assumed as well as the prior probabilities of caller ID and no caller ID. Note that at time *t*, the certainty factor of evidence, represented as the probability that the evidence is true for the given sensing, propagates through the evidence structure defined previously to update other evidences. This can be done by using the Bayesian net update procedure by interpreting the evidence structure in terms of a Bayesian net. However, each evidence is subject to a certain degradation of its certainty factor as time passes, where the degradation is determined by the temporal correlation of evidence.

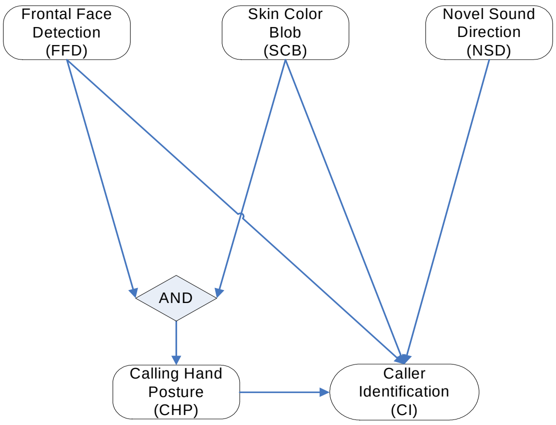

Fig. 3. Evidence structure for caller identification mission

For instance, assuming Frontal Face is detected at time t with a certain certainty factor, the certainty factor of Frontal Face at time *t+1* may be degraded from that of time t according to the tracking uncertainty if tracking is applied or degraded significantly if no tracking is applied, etc.

C. Selection of Action for Accomplishment of Mission

The action should be selected to eliminate uncertainty of mission, not uncertainty of individual process. This means that the selected action has to improve the mission certainty best. Let $B = \{b_1, b_2, \ldots, b_n\}$ is a set of proposed actions by a set of perceptual processes $P = \{p_1, p_2, \ldots p_n\}$, at time *t*. From the perceptual process, we can estimate the variation of certainty when the robot takes an action below.

$$b_1 \rightarrow \Delta C_{(b1)} = \{\Delta c_{1(b1)}, \Delta c_{2(b1)}, \ldots, \Delta c_{k(b1)}, \ldots, \Delta c_{n(b1)}\}$$
$$b_2 \rightarrow \Delta C_{(b2)} = \{\Delta c_{1(b2)}, \Delta c_{2(b2)}, \ldots, \Delta c_{k(b2)}, \ldots, \Delta c_{n(b2)}\}$$
$$\ldots$$
$$b_k \rightarrow \Delta C_{(bk)} = \{\Delta c_{1(bk)}, \Delta c_{2(bk)}, \ldots, \Delta c_{k(bk)}, \ldots, \Delta c_{n(bk)}\}$$
$$\ldots$$
$$b_n \rightarrow \Delta C_{(bn)} = \{\Delta c_{1(bn)}, \Delta c_{2(bn)}, \ldots, \Delta c_{k(bn)}, \ldots, \Delta c_{n(bn)}\}$$

where $\Delta c_{k(bk)}$ is expected certainty variation of p_k when the action is selected. $\Delta C_{(bk)}$ is a set of variation values. Now we can select an action using (2).

$$Selection\ of\ action = b_{\max}\{P(callerID \mid Evidences + \Delta C_{b1}), \ldots, P(callerID \mid Evidences + \Delta C_{bn})\} \quad (3)$$

The selected action will increase the mission certainty best.

D. Sampling Time of Control based on Forgetting Curve

Among the several approaches for sampling time, we got the idea from psychology field [18][19][20]. Fig. 4 shows forgetting curve for human short-term memory. Based on that, the sampling time is determined as 600ms approximately.

V. ROBOT PERSONALITY SYSTEM BASED ON CRE

For the service/mobile robot, the adjustment of parameters is to find an optimal solution of robot behavior or perception.

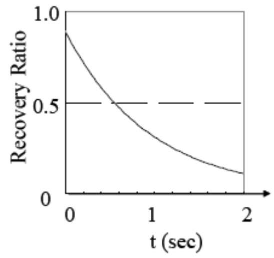

Fig. 4. Forgetting curve of Brown Peterson paradigm

In the most of previous researches, the robot personality is regard as an emotional expression of robot that imitates a human [7][8]. However, the adjustment of parameters in this study is not for the optimal solution of service/mobile robot as general, but only for the behavioral robot personality. The architecture of behavior personality system is shown in Fig. 5. In this paper, we assumed that all parameters of a robot are fitted for customer's taste when a robot is taken goods out of the warehouse. The information of external environment is the input for CRE and the "Personality Generate Function (PGF)." According to this system, the PGF regulates some parameters of the CRE. It is necessary to adapt a robot to new circumstances. However, in present research, the PGF has not been completed yet. Hence we adjust several parameters passively. All adjusted parameters and the influence of the change on the robot's behavior are as follows.

A. Adjusted Parameters and The Influence of them

- Threshold level of each perceptual process:
  This parameter affects sensitivity of each perceptual process.
- The control interval:
  This parameter affects the robot's decision time.
- The condition of mission invocation:
  This condition affects the level of each mission invocation. A robot could select the mission more quickly or more slowly according to this parameter.
- The threshold level of mission success:
  A robot decided that a time of mission's completion since this parameter.
- Forgetting function:
  This function decreases an evaluated certainty gradually. So that change of this parameter decided how long a robot should maintain certainty of the mission.

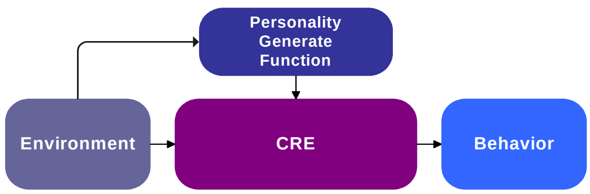

Fig. 5. The architecture of behavior personality system for CRE

TABLE III

LIST OF PARAMETERS

Main Parts	Parameters
Perceptual Part	threshold level of perceptual process
Control Part	control interval condition of mission invocation threshold level of mission success forgetting function

VI. EXPERIMENT RESULTS

In this chapter, we analyzed the behaviors of robot during its execution of caller identification mission. In Fig. 6, 7, and 8, X-axis represents a time sequence, and Y-axis represents the sorts of actions. The diamond features in the line of figures mean the time when the control gave the order to the behavior generator. The Fig. 6, 7, and 8 show that the caller identification mission is invoked at time 0, and then the mission is changed to caller following with successful accomplishment of caller identification mission.

A. Experiment Condition

The experiment scenario is as follows. First, the caller calls the robot so the robot starts the caller identification mission. After the robot took the actions, in order to find the caller, the robot found and identified the caller. At this moment the caller disappears for a while. A few seconds later, the caller repeats same action but this time the caller does not disappear.

All experimentations are proceeded with the same scenario and the same place. The caller was one and there were no any obstacles in testing facility.

B. Action- Transition Diagram

This action is displayed as follows: CF) Caller Following, AP) Approaching, HE) Heading, TU) Turning, LU) Look Around, WA) Wandering, SE) Searching, VI) Voice Inquiring.

Fig. 6 shows the action-transition diagram of the caller identification mission. In this experiment, the robot tried to find a caller without any parameters change. All parameters were held standard values which were obtained through many experiments. After the robot was powered on, an evidence of skin color blob invoked the caller identification mission. Next, the robot was turning at more confident evidence. Missing the candidate of caller, robot tended to search a caller again. And then the robot approached to a found face to reduce the uncertainty of caller. A few seconds later, however, robot was searching again since he/she was not a caller. Next time, the robot found a human face with the evidences of skin color blob. From the fusion of data, the robot identified a caller, and in a moment the robot was approaching to the caller. Since the identification mission was succeeded, following mission is started. This result tells the mission is dependably completed even the caller often disappeared from the sight of robot.

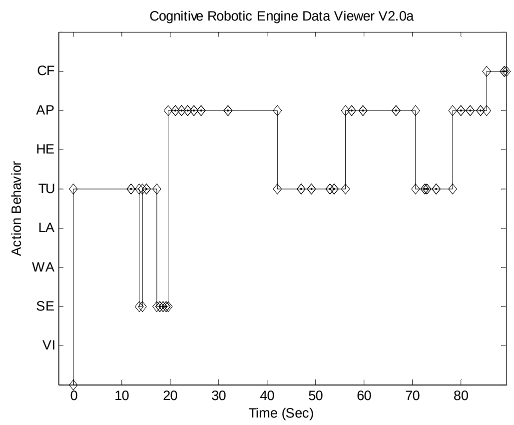

Fig. 6. Action transition diagram of the caller identification mission

The next, Fig. 7 shows the action-transition diagram of circumspect robot. Several parameters were changed higher than standard values. The parameters are condition of mission invocation, and threshold level of perceptual process. The parameters of condition for action selection and forgetting curve were heightened. The diagram shows a monotonous pattern that means the robot selected action very carefully. So the robot tended to act more accurately. Red box 'A' indicates a time when the robot realized the caller disappeared. And Red box 'B' indicates a time of mission success.

Fig. 8 shows the action-transition diagram of impatient robot. This time, the parameters mentioned above are lowered. The diagram displays drastic patterns, which means the robot selected action very quickly. Especially, Red box 'A' shows the robot realized that the caller disappeared more quickly than before. And we see that a time of mission success is also very rapidly from red box 'B'. But the behaviors of the robot did not show accurate actions.

These results show the robot is able to have a behavioral personality using some parameters change.

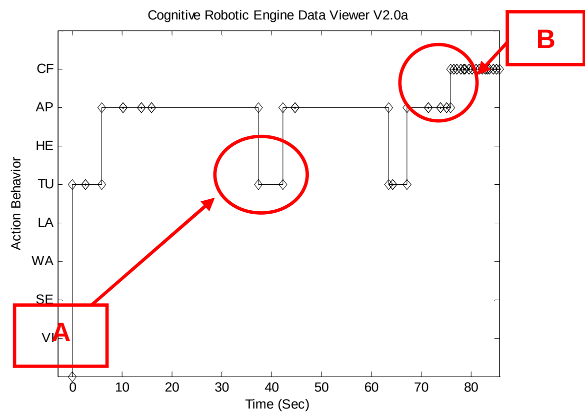

Fig. 7. Action transition diagram of circumspect robot.

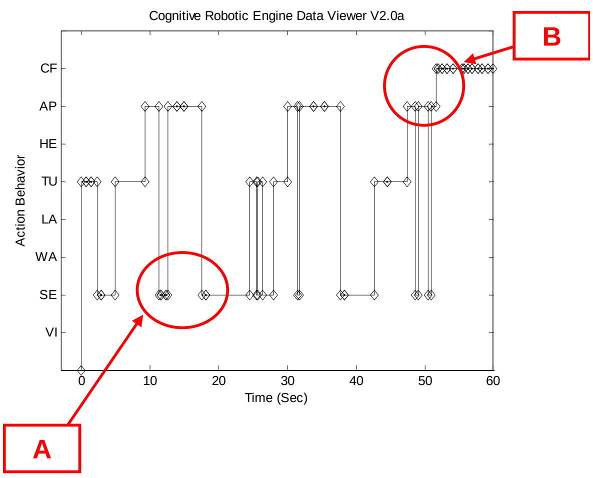

Fig. 8. Action transition diagram of impatient robot

VII. Conclusion

In summary, our proposed CRE is implemented in real robot platform and we gave the experiment results which are displayed in the caller identification mission. As a result, we observed that behavioral personality of robot was varied at the adjustment of parameters.

As a future work, CRE should be improved in mission management and control. For the behavioral personality of robot, the personality generation function needs to be studied more.

Acknowledgment

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