TABLE I
TWELVE GENERATED EMOTIONS

Positive	Negative
Satisfaction, Relief, Joy, Gratification, Pride, Love	Distress, Disappointment, Remorse, Shame, Fear, Hate

Simplification of OCC Model to a certain level that corresponds with the abilities of an agent has been advocated by many researchers, even by its founder Ortony.[12] He proposed to use six positive emotions (joy, hope, relief, pride, gratitude and love) and six negative emotions (distress, fear, disappointment, remorse, anger and hate). Still, these emotions might be too many for an agent that uses only facial expressions, which is usually able to expresses only the Ekman's six basic emotions. Therefore, we modify OCC model in the same manner, and map the generated emotions to expressions.

One interesting thing with the simplified OCC model proposed by Ortony is that the emotional states considering consequences for other agents were excluded (happy-for, gloating, resentment and pity). In the same manner, we got rid of the emotional states that concerns focus on other agents (admiration and reproach), and some other states (gratitude, anger) in the compound category were also removed since they are triggered with praiseworthiness of an agent's action when desirability of a consequence of an event is prospect irrelevant. Our simplified model is shown in Fig. 1.

Twelve emotional states are categorized according to what they are affected. Six states are connected to consequences, four states among them are prospective relevant and two are not. There are two emotional states for each praiseworthiness and appealingness, and finally, two compound emotional states exist. These emotional states in each categories show relatively opposite feelings thus may be put on the opposite sides if they were in a space model. The defined emotional states and classification according to categories are listed in Table 1 and 2 respectively.

B. Stochastic Approach to Deciding an Emotion

When there is a stimulus to a certain agent, it receipts it as an input, and interprets it. Rather than using the interpretation just for one emotion, we assume that one interpretation can cause various emotions. When a person encounters a certain situation a hundred times, he or she might not feel the same emotion each time. Suppose a boy was praised for a certain same action a hundred times, however, the emotion that he feels due to the praise may be satisfaction, gratification, pride or even a negative emotion. This is due to the uncertainty that natural creatures carry, resulting in all kinds of different actions even though they are all the same kind.

Stochastic or probabilistic approach is very helpful in this case. There are several methods such as Bayesian Belief Network, Confabulation and so on that are able to handle uncertainty very powerfully. However, they still require a big database in order to interpret all the situations for conditional probabilities.[7,8]

TABLE II
EMOTION CATEGORIES

Category	Emotions
Desirability – Prospect Relevant	Satisfaction, Relief, Fear, Disappointment
Desirability – Prospect Relevant	Joy, Distress
Praiseworthiness	Pride, Shame
Appealingness	Love, Hate
Compound	Gratification, Remorse

Assuming that sensory inputs are processed and interpreted as a prior step, interpreted stimuli are inputted into the model, each emotional state is influenced by the input. Each stimulus has values defined by a designer or a user for each emotion, consisting a 4x4 matrix S where each column stands for criteria categories, and each element stands for the stimuli value as in (1). These elements are user defined, so that they can generate a unique emotion generation process for each agent. A designer can define an integer from 1 to 10 for each element according to the intensity of emotions that they have in mind for each stimulus. If these elements are not reasonable, such as assigning big values to negative emotions for a positive stimulus, then the emotion model will create a crazy personality.

$$S = \begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{14} \\ s_{21} & s_{22} & s_{23} & s_{24} \\ s_{31} & 0 & 0 & 0 \\ s_{41} & 0 & 0 & 0 \end{bmatrix} \tag{1}$$

$$\mathbf{N} = \left\{ n_{desire\_p} \quad n_{desire\_np} \quad n_{praise} \quad n_{appeal} \right\}$$

$$\begin{aligned} n_{desire\_p} &= \sqrt{\frac{\sum_i s_{i1}}{2}} \\ n_{desire\_np} &= \sqrt{\sum_i s_{i2}} \qquad i = 1,2,3,4 \\ n_{praise} &= \sqrt{\sum_i s_{i3}} \\ n_{appeal} &= \sqrt{\sum_i s_{i4}} \end{aligned} \tag{2}$$

Norms of each column n are then calculated as in (2) in order to find which criteria category has the most effect on the emotion that will be triggered. The norm of desire-prospective category is divided into half in the square root since it has twice higher dimension than others. When an emotion is generated, this norm is defined as the intensity of the emotion, for it was triggered only by the criteria category.

By normalizing these norms, we calculate the probability of each category being chosen p^c as in (3).

$$p^c{}_i = n_i / \sum_i n_i \qquad (3)$$
$$i = desire\_p, desire\_np, praise, appeal$$

Sums of elements in each column, Sum, are also calculated as in (4) in order to go through another normalization process.

$$\begin{aligned} Sum_{desire\_p} &= \sum_i s_{i1} \\ Sum_{desire\_np} &= \sum_i s_{i2} \\ Sum_{praise} &= \sum_i s_{i3} \\ Sum_{appeal} &= \sum_i s_{i4} \end{aligned} \qquad i = 1,2,3,4 \qquad (4)$$

The normalization process creates probability vectors p^e as shown in (5).

$$\mathbf{P}^e = \begin{bmatrix} \mathbf{p}^e{}_{desire\_p} & \mathbf{p}^e{}_{desire\_np} & \mathbf{p}^e{}_{praise} & \mathbf{p}^e{}_{appeal} \end{bmatrix}$$

$$\mathbf{p}^e{}_{desire\_p} = \frac{1}{Sum_{desire\_p}} \begin{bmatrix} s_{11} \\ s_{21} \\ s_{31} \\ s_{41} \end{bmatrix} = \begin{bmatrix} p_{11} \\ p_{21} \\ p_{31} \\ p_{41} \end{bmatrix}$$

$$\mathbf{p}^e{}_{desire\_np} = \frac{1}{Sum_{desire\_np}} \begin{bmatrix} s_{12} \\ s_{22} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} p_{12} \\ p_{22} \\ 0 \\ 0 \end{bmatrix}$$

$$\mathbf{p}^e{}_{praise} = \frac{1}{Sum_{praise}} \begin{bmatrix} s_{13} \\ s_{23} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} p_{13} \\ p_{23} \\ 0 \\ 0 \end{bmatrix}$$

$$\mathbf{p}^e{}_{appeal} = \frac{1}{Sum_{appeal}} \begin{bmatrix} s_{14} \\ s_{24} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} p_{14} \\ p_{24} \\ 0 \\ 0 \end{bmatrix}$$

(5)

When a user defines the stimuli values, his or her intention is to determine which emotional states are more frequently to be triggered according to the stimuli. In order to fulfill this intention, we put a mask on the probability values. This process makes the probability values close to 0 smaller and leaves the ones close 1 by multiplying the mask to each probability value. We chose the inverse of Epanechnikov kernel for mask M_{ij} as in (6) where p_{ij} is the probability value, since we want only slight changes of the probability values, not eliminating those close to 0. The final probability for each emotion categories to be determined by going through (4)~(5) again.

TABLE III

CATEGORIZATION OF EMOTIONAL STATES ON EXPRESSION

Emotional State	Expression
Satisfaction, Relief, Joy, Gratification, Pride, Love	Happiness
Distress	Anger
Disappointment, Remorse, Shame	Sadness
Fear	Fear
Hate	Disgust

$$M_{ij}(p_{ij}) = \frac{1}{1 - p_{ij}{}^2} \qquad i, j = 1,2,3,4 \qquad (6)$$

With the norms and probability values given from above, we are now ready to decide which emotional state an agent will have. We use the roulette method to choose both criteria and emotion categories. When a stimulus is inputted, it calculates all the norms and probabilities using the user defined intensity values, and runs the roulette method to choose a criteria category, and runs it again to choose a proper emotion. When the criteria category is 'praiseworthiness' and norm of 'desire-nonprospective' is above a certain threshold, an emotion in the compound category is selected with the probabilities of those in praiseworthiness category. [3]

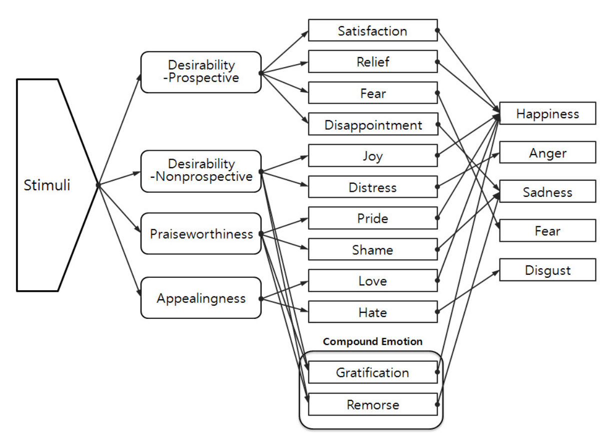


Fig. 2. Overall Structure of the Proposed Emotion Generation Model

C. *Emotion to Expression*

Even though there are many emotional states that an emotion generation model can create, the expression of the emotion is limited to expression abilities of each agent. We used a 3D simulator of Doldori, a facial expression robot developed by Robot Research Lab. at KAIST. It is able to express Ekman's six basic expressions not only with its face, but also using gestures, LEDs and so on. There are total of twelve emotional states generated by the proposed model, and only six expressions exist to be shown. Therefore, mapping emotional states to emotion expression is necessary.

Among the six basic expressions, there is only one positive expression, happiness, while anger, sadness, fear are considered as negative. Surprise and disgust are generated through rather reactive than cognitive process; therefore they are not included in the OCC model. Consequently, we map the twelve emotional states into five emotion expression categories including disgust. In addition, expressions are shown only when the norm of the chosen criteria category is above a certain threshold value. Our expression categorization is shown in the Table 3. The overall structure of the emotion generation model is drawn in Fig. 2.

D. *Linear Dynamic Affection-Expression Model*

The expression model used for the proposed emotion generation model is based on LDAEM (Linear Dynamic Affect-Expression Model). This model consists of two different models, the linear affect-expression space model and the dynamic emotion model[9]. The linear affect-expression space model is proposed to express robot's emotional states efficiently with reduced complexity of the system[10,11,12]. Dynamic emotion model is proposed to make changes of facial expressions continuous and natural by applying different dynamic properties to the each basis of the affect space[13]. We thus make a robot's facial expressions more similar to those of humans efficiently.

The benefit of using this model is that even though the simplified OCC model is deterministic in choosing an emotion, the emotion can be expressed dynamically and lively using the space model when there is a change between emotions.

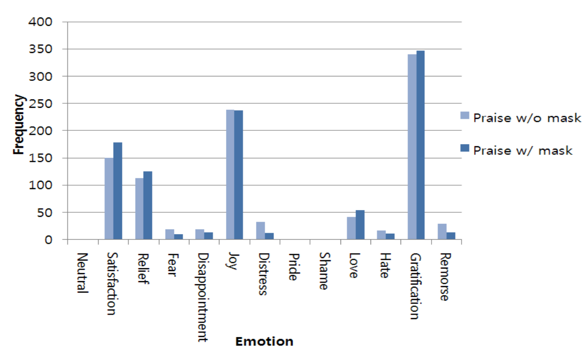
Fig. 3. A picture of the 3D Doldori simulator

III. Experiment Result

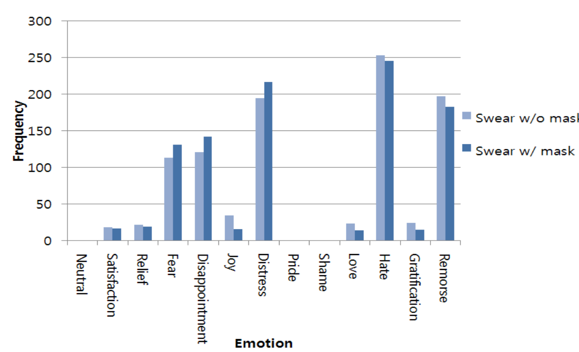
Experiment was carried with a 3D simulator using SimStudio(http://www.simlab.co.kr), a real-time dynamic simulation software platform. The simulator can express the Ekmans's six basic expressions using its facial expressions, gestures and LEDs on both ears. The picture of the simulator is given in Fig. 3.

In order to demonstrate the proposed model, we ran the model a thousand times for each defined stimuli, and some of the results are shown as graphs. Fig. 4 shows the graphs of frequency of emotions triggered when stimuli comes in. When a robot is praised a thousand times, it generates various and distinctive emotions each time. Considering that it a positive stimulus, positive emotions such as joy, gratification, satisfaction and so on are mainly triggered. There are also a few negative emotions, proving the uncertainty from this model. When a mask is imported, there are some changes in the frequency of all emotions, especially giving decreases to all the negative emotions. Similar result is derived when it is sworn, only that it generates negative emotions most of the times. The believability is more obvious when the emotions are expressed as in Fig. 5.

Among the thousand stimuli, the positive expression, happiness, is dominant when the robot is praised, however,

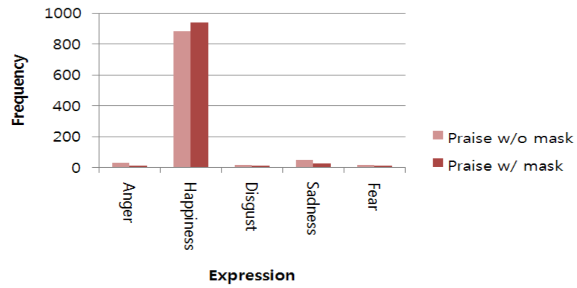


(a) When Praised

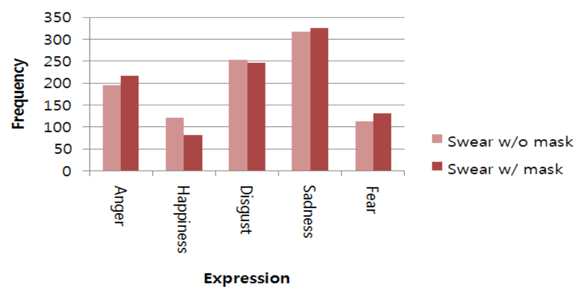


(b) When sworn

Fig. 4. Graphs of frequency of emotions triggered by stimuli. (a) shows the case when the robot was praised a thousand times, and (b) shows the case when the robot was sworn a thousand times.



(a) When Praised

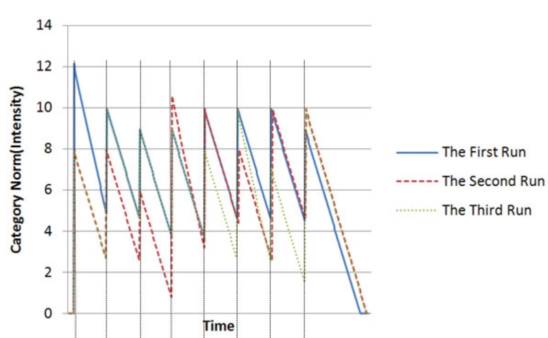


(b) When Sworn

Fig. 5. Graphs of frequency of expressions shown. (a) shows the case when the robot was praised a thousand times, and (b) shows the case when the robot was sworn a thousand times.

others are still shown from time to time. In the other case, the robot is sworn a thousand times, showing rare happiness but expressing various negative emotional expressions, not just a single one. This means that there are many emotions available with this model when a stimulus comes in, and they are expressed with different expressions maintaining the uncertainty that natural creatures have.

Next, we ran the model three times in a specific order of stimuli. The robot was praised twice at first, was scolded twice, saw its user twice and saw its hostile twice. These



	Emotions							
Stimuli	Praise		Scold		User		Enemy	
1st Run	F	G	R	R	L	L	H	D
2nd Run	J	J	H	F	L	J	H	H
3rd Run	J	G	R	R	J	S	D	L

Fig. 6. Graphs of category norm(intensity) in timeline. F, G, R, L, H, D, J, S each deontes to fear, gratification, remorse, love, hate, disapointment, joy and sat isfaction.

stimuli were inputted with intervals of six seconds. Even though they were the same stimuli in the same sequence, it showed different response with different intensities each time. Two emotions out of thirty-two responses seem unreasonable, one fear when praised and one love seeing a hostile, showing 93.75% of appropriateness, meaning the uncertainty was preserved.

IV. Conclusion

In this paper, we proposed a simple emotion generation model with uncertainty of human nature but preserving believability. The OCC model was simplified at first, and stochastic approach was applied to the model with a theory that a stimulus has effects on all emotions. Implementation and demonstration was carried in order to show the properness of this model. Since human relies a lot on the context information when communicating, having proper emotion and expressing it is enough for a person to interpret the situation. Considering this it was successful in a way that it proved its uncertainty and believability by showing various emotions generated with a same stimulus and avoiding deterministic property.

Even though the proposed model is originated from the OCC model, it is rather reactive than being cognitive. Moreover, it lacks of homeostasis and still has the problem of missing interaction between emotional states that is already inherited in the OCC model. Importing the concept of mood or personality will help solve the problem mentioned above.

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