A Contextual Emotion Appraisal System Based on a Sentential Cognitive System for Robots

Graphical Abstract

Emotion plays a powerful role in humans' interaction with robots. In order to express more human-friendly emotions, robots need the capability of contextual appraisal that expresses the emotional relevance of various targets in the spatiotemporal situation. In this paper, an emotional appraisal system is proposed in this study to cope with such contexts. Specifically, the Ortony, Clore, and Collins model is abstracted and simplified to approximate an emotional appraisal model in the form of a sentence-based cognitive system. The contextual emotion appraisal is modeled by formulating the emotional relationships among multiple targets and the emotional transition with events and time passing. To verify the proposed robotic system's feasibility, simulations were conducted for scenarios where it emotional interacts with humans manipulating liked or disliked objects on a table. This experiment demonstrated that the robot's emotion can variously change over time like human by using a proposed formula for emotional valence, which is moderated by emotion appraisal of occurring events.

Table 3. The contextual emotion appraisal model with targets and source of emotions.

#	Emotions	Targets			Sources of appraisal		Emotional valence
		Object	Agent	Event	A priori	Contextual	
1	Love-Hate (LH)	○	○	△	○	○	-1.0 ~ 1.0
2	Pride-Shame (PS)			○		○	-1.0 ~ 1.0
3	Gratitude-Anger (GA)		○	△		○	-1.0 ~ 1.0
4	Joy-Distress (JD)			○		○	-1.0 ~ 1.0
5	Hope-Fear (HF)			○		○	-1.0 ~ 1.0

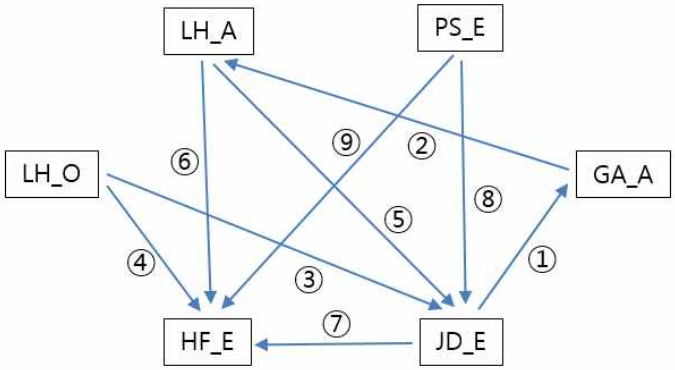

Figure 3. Transition of emotions and their mutual relationships among Love-Hate_Object (LH_O), Love-Hate_Agent (LH_A), Gratitude-Anger_Agent (GA_A), Pride-Shame_Event (PS_E), Joy-Distress_Event (JD_E), and Hope-Fear_Event (HF_E): ① An agent causing JD events, ② LH toward an agent may rise from the GA, ③ target of LH of objects is identified, ④ target of LH of objects is expected, ⑤ target of LH of agents is identified, ⑥ target of LH of agents is expected, and ⑦ HF is generated when JD is expected, ⑧ JD is produced when PS occurs, and ⑨ HF is produced when PS is expected to occur.

Figure 5. Emotion appraisal system implemented in a robot (TUBO) and an agent.

Table 7. The sentences of events and emotional valences stored in the sentential memory.
(V: Vision module, L: Listening module, U: Utterance module)

#	Time (hh:mm:ss)	Module	Sentences of events	Emotional valences of targets		
				A_1 (LH, GA)	A_2 (LH, GA)	Events (PS, JD, HF)
S_1	10:13:02	V	(S (NP A new agent) (VP appeared (PP at (NP the front))))	(0.0, 0.0)	(0.0, 0.0)	(0.0, 0.0, 0.0)
S_2	10:13:05	U	(S What (S (VP is (NP your name))))	(0.0, 0.0)	(0.0, 0.0)	(0.0, 0.0, 0.0)
S_3	10:13:09	L	(S (NP I) (VP am (NP John)))	(0.0, 0.0)	(0.0, 0.0)	(0.0, 0.0, 0.0)
S_4	10:13:25	V	(S (NP An apple) (VP appeared (PP at (NP (173, 296)))))	(0.0, 0.50)	(0.0, 0.0)	(0.0, 0.28, 0.0)
S_5	10:13:28	U	(S (VP Thank (NP you)))	(0.0, 0.50)	(0.0, 0.0)	(0.0, 0.28, 0.0)
S_6	10:14:06	V	(S (NP An orange) (VP appeared (PP at (NP (343, 162)))))	(0.53, 0.76)	(0.0, 0.0)	(0.0, 0.73, 0.0)
S_7	10:14:10	U	(S (VP Thank (NP you)))	(0.53, 0.75)	(0.0, 0.0)	(0.0, 0.73, 0.0)
S_8	10:14:14	U	(S (NP I) (VP love (NP you)))	(0.53, 0.74)	(0.0, 0.0)	(0.0, 0.72, 0.0)
S_9	10:16:03	V	(S (NP A new agent) (VP appeared (PP at (NP the front))))	(0.31, 0.43)	(0.0, 0.0)	(0.0, 0.49, 0.0)
S_{10}	10:16:06	V	(S What (S (VP is (NP your name))))	(0.31, 0.43)	(0.0, 0.0)	(0.0, 0.48, 0.0)
S_{11}	10:16:11	L	(S (NP I) (VP am (NP Tom)))	(0.29, 0.42)	(0.0, 0.0)	(0.0, 0.47, 0.0)
S_{12}	10:17:07	V	(S (NP A banana) (VP appeared (PP at (NP (635, 393)))))	(0.15, 0.35)	(0.0, -0.20)	(0.0, 0.24, 0.0)
S_{13}	10:17:23	V	(S (NP An apple) (VP disappeared))	(0.13, 0.33)	(0.0, -0.69)	(0.0, -0.07, 0.0)
S_{14}	10:17:26	V	(S (NP I) (VP am (ADJP angry)))	(0.12, 0.33)	(0.0, -0.70)	(0.0, -0.07, 0.0)
S_{15}	10:17:32	U	(S (NP An orange) (VP disappeared))	(0.12, 0.32)	(-0.69, -0.99)	(0.0, -0.63, 0.0)
S_{16}	10:17:35	V	(S (NP I) (VP am (ADJP angry)))	(0.11, 0.32)	(-0.69, -0.99)	(0.0, -0.64, 0.0)
S_{17}	10:17:38	U	(S (NP I) (VP hate (NP you)))	(0.11, 0.32)	(-0.69, -0.98)	(0.0, -0.64, 0.0)
S_{18}	10:19:02	V	(S (NP A carrot) (VP appeared (PP at (NP (201, 278)))))	(0.07 0.27)	(-0.82, -0.61)	(0.0, -0.62, 0.0)
S_{19}	10:19:05	U	(S (NP I) (VP am (ADJP angry)))	(0.07, 0.27)	(-0.80, -0.61)	(0.0, -0.61, 0.0)

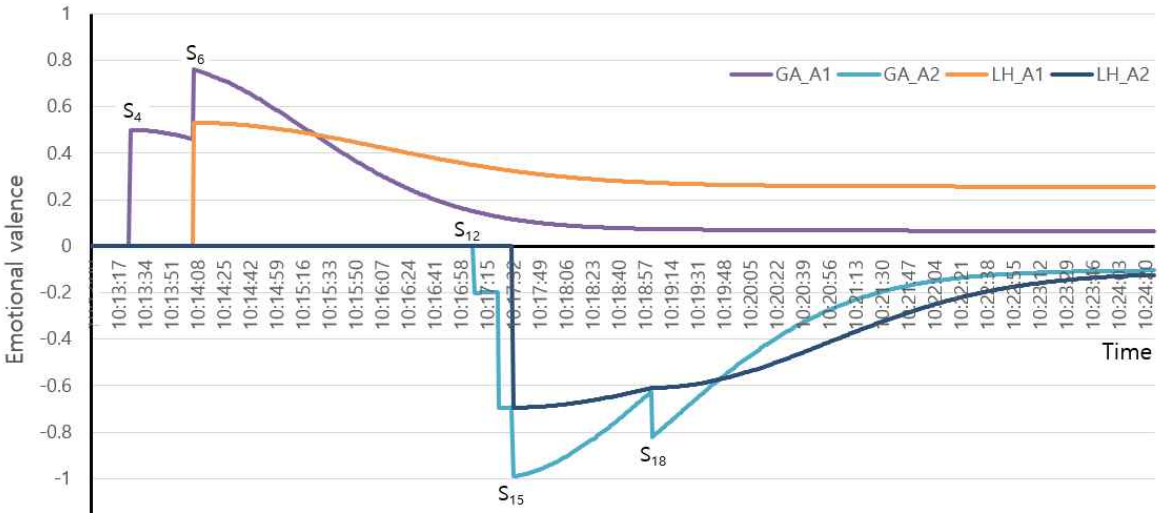

Figure 9. The variation of emotion appraisal toward the agents (A_1 and A_2).

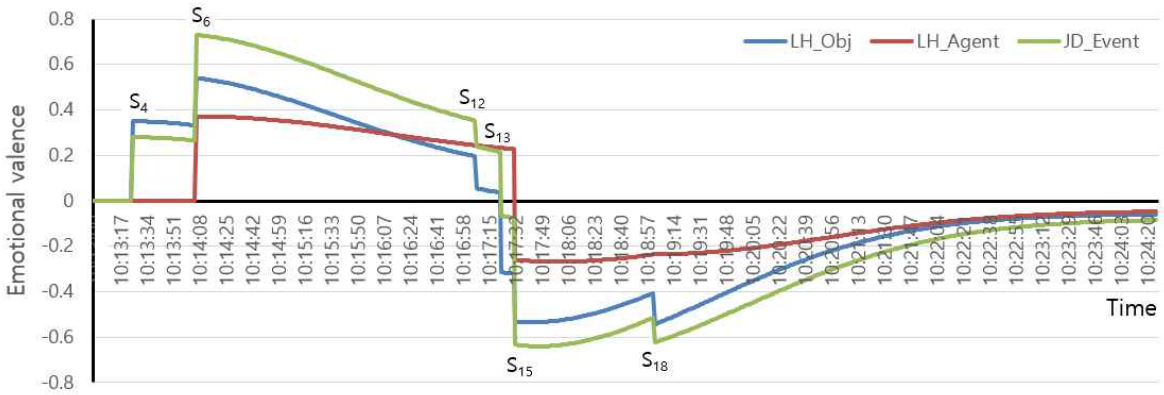

Figure 10. The variation of emotion appraisal toward the events.