Affective Learning Reaction Model Based on Smartphone and Sensors

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Abstract. As we daily use smartphones as like as televisions and cars, smartphones are usually used to access and communicate with learning contents and lecturers. And through smartphone, various types of multimedia contents can interact with users, since there are many types of sensors equipped with smartphone. Information and sensor technology are very precious that users can be detected their movement, emotion and learning status. Especially, most of learners (above 90% of Korea National Open University students) access to learning contents with their smartphones in the mobile learning environment. But, there is few methods, technology and service model for learners’ learning status tracking, only focusing degree and learning concentration level. In this paper, we propose learning reaction model and criteria for learning state. For simple approach, we propose sensor-based metrics with smartphone and the learning emotional reaction model between learners and learning contents is based on learner’s learning actions and learner’s sage state for a smartphone. Proposed Affective Learning Reaction Model(ALRM) consists of learner’s learning emotional state, learners’ personal environment state and learner’s learning activity patterns. Each state has both mandatory and optional information. Mandatory information is important metrics to decide learners’ learning emotion state. And Optional information is complimentary information. Those metrics have their own value and sum of them decides learner’s learning state. With the ARLM, personalized and modified learning contents can be delivered to a learner.

1. Introduction
On e-learning environment, learning contents are delivered to a learner and the learner should do everything by him/herself. After delivering learning contents to a learner, e-learning system or service does not track the learner’s learning activity and does not feed learning activity results and personalized learning compliments back to the learner. These situation makes learners loss study interest or learning concentration and students drop out of school or university. And, in these kinds of e-learning environment, learning progress and study achievement or assessments totally depend on learners or learners’ self-controls. In order to make up for these weakness, we need agents or tools to track learner’s learning activity and learner’s learning emotional state. If we have learner’s learning emotional state, then we can modify learning contents and make personal learning environment according to personal learning state[1,2].

But, nowadays most learning devices have various kinds of sensors and seamless network communication capability. With these devices, sensors and network communication environment, e-
learning system can track a learner’s learning activity and feed personalized learning contents back to the learner.

And in digital textbooks, sensors can initiate learners’ learning interactions with learning contents and easily track learners’ learning interactions. These kinds of e-learning service are studied and proposed in previous works[2]. But, without learning emotional model, consistency of personalized learning contents and personalized learning environment can not be guaranteed. If a learner studies one learning subject with an e-learning system, he/she can be provided learning contents related the subject and learning environment change makes another types or delivery methods of the learning contents and the modified learning contents are provided with to the learner. In this situation, without learning emotional model, learners’ learning environment could be misunderstood and misestimated, and learning contents modification rules could not be choose consistently. This means that we need consistency learning emotional model that supports learning contents modification rules.

We propose Affective Learning Reaction Model as learning emotional model that considers learner emotion, learner’s learning activity, and smartphone attitude. And we also study on Learning Reaction Analysis Engine to analyze learner’s activity, learner’s smartphone attitude, bio signals and Learner’s attitude, and infer learners’ emotion state. The remainder of paper is organized as follows. In chapter 2, we re-view previous affective computing and emotion analysis research for e-learning learning. The proposed learners’ Affective Learning Reaction Model and learner activity-related information (learner’s activity, learner’s smartphone attitude, bio signals and Learner’s attitude, and infer learners’ emotion state) are described in chapter 3. We introduce the architecture and function modules of Learning Reaction Analysis Engine and Affective Learning Reaction Model are defined and described in chapter 4. Finally, we conclude in chapter 5.

2. Related Works
In [3], various emotion states metrics are proposed and dealt with by intelligent tutoring system. But only bio-signal based information is focused. Behavior of learner is useful to analyze learner’s emotion state. In this paper, we involve those kinds of bio information. In [4], problems of technology usage for the learner’s learning environment is discussed and affective emotion based approach is suggested for programming courses at university students. In [5], affective computing platform for e-learning is proposed and analyze learners’ emotional information. But, emotional information is limited within bio-signal information. In [6], the relationship between learners’ perceptions of affective learning, instructors’ attractiveness and instructor evaluations is revealed and shows positive correlation with task attractiveness, social attractiveness, affective learning and instructor evaluations.

These kinds of information metrics are useful to broaden emotional model for learners, teachers and learning contents. In [7], emotion is defined as a critical role in the learning activity and learner’s emotion analysis researches and studies are reviewed, since learning emotion impacts on learners’ motivation and learning achievement. But, there is no way or methods to measure and collect the related data (sensed learner’s activity or environment). In [8], Path model of emotions and learning analytics behavior and cognition is proposed. In Path model of emotions and learning analytics behavior and cognition, the detailed analysis model is proposed only for learner’s behaviors. Except for learner’s behavior, the other data or situation data could be used for analysis of learner’s learning emotion.

Most of the previous works have focused on bio-signal information or learner’s actions or activity, and simple emotion models are used to analyze and to track for learner’s emotion state with only one or two sensors within smartphone. This paper tries to collect various learning emotional information with various sensors and use broad emotion model for a learner. Especially, various sensed data from smartphone would be collected and analyzed. In order to propose the analysis methods, learner’s emotional model and emotional metrics criteria are proposed.

3. Affective Learning Reaction Model and Learner Activity Analysis System
Proposed Affective Learning Reaction Model has various information about a learner. Some information is directly related with a learner or learning activity. And some information is not directly related with a learner nor learning activity. We define information directly related with a learner as Direct Affective Learning Reaction Information (DALRI) and information indirectly related with a learner as Indirect Affective Learning Reaction Information (IALRI). DALRI can be directly analyzed and used for a learner state, learning interest level and learning concentration level. But, an indirect learner state will be inferred from IALRI analysis. Combination of a learner state and an indirect learner decides affective learning reaction state of the learner. According to the affective learning reaction state, appropriate learning contents delivery strategy for a learner can be provided to Automated Tutoring Engine [2].

3.1. Affective Learning Reaction Model

Learning Reaction Analysis Engine needs three types of learner’s learning information that can be classified into personal environment state information, learning activity pattern information and learning emotional state information. Learning Reaction Analysis Engine decides learners’ learning emotional state with personal environment state information, learning activity pattern information and learning emotional state information.

Personal environment state information, learning activity pattern information and learning emotional state information are stored in format of XML at learners’ e-portfolio DB and periodically changed. Personal environment state information, learning activity pattern information and learning emotional state are like as bellows;

- Learner’s activity
  - learning activity time (LAT): activity level of learning duration time (learning activities time per one session of learning contents)
  - learning interaction (LI): initiative level of interaction with learning contents (learning interaction numbers time per one session of learning contents)

- Learner’s smartphone attitude
  - smartphone declined angle (SDA): decline angle detected by gyroscope sensor in smartphone
  - learner’s face shape of smartphone camera (FSC): learner’s concentration level on learning contents
  - display touch frequency (DTF): number of smart phone touch according to learning contents (basic touch number predefined by contents designers)
  - learning sector stay time (SST): time to concentrate on learning contents (basic duration time predefined by contents designers)
  - shaking frequency (SF): time to make irrelevant learning (basic touch number predefined by contents designers)
  - smartphone movement velocity (SMV): learner’s movement velocity
  - smartphone location (SL): learner’s location (in-building, in-car, in-class room, etc.)
  - illumination changes ratio (ICR): illuminations of learners’ environment and illumination change state
  - environment noise with microphone sensor (ENM): learner’s environment state for learning

- Bio signals
  - heart bit (HB): emotional data
  - temperature (TP): emotional data
  - hands movement and shaking frequency (HMS): emotional data

- Learner’s attitude
  - another APP launching types and execution time (AET): number and execution time of other Apps launched on smartphone
  - activity tracking information (ATI): learner’s smartphone usage type

Learner’s learning activity patterns means learner’s concentration about smartphone contents.
Without other information, smartphone contents may be game application, video, or digital textbook for learning. Learner’s learning activity patterns consist of Learner's activity(learning activity time, learning interaction, Learner's smartphone attitude, display Touch frequency, sector stay time, shaking frequency, smartphone location, illumination changes ratio change state, environment noise with microphone sensor), Learner's attitude(activity tracking information). Learner’s personal environment state information means learner’s environment that makes learning emotion accuracy of the learner. Learner’s personal environment state information consists of Learner's smartphone attitude(smartphone declined angle, smartphone movement velocity, smartphone location, illumination changes ratio change state, environment noise with microphone sensor). Lastly, learner's learning emotional state information consists of Learner's activity(learning activity time, learning interaction), Learner's smartphone attitude(smartphone declined angle, display Touch frequency, sector stay time, learner's face shape of smartphone camera), Bio signals(Heart bit, Temperature, Hands movement and shaking), Learner's attitude(another APP launching types and execution time). Learner’s learning emotional state information decides learner’s learning emotion that resent learning difficulty, learning interests, and learning achievement. In Table 1, each information has their own value and, according to the value sum, learner emotion state can be decided.

**Table 1. Learner’s Information of LRAE Model.**

| Learner’s Info. | Learner’s Information                       | Value                                                                 |
|-----------------|---------------------------------------------|----------------------------------------------------------------------|
| Learner's activity | learning activity time | appropriate time(specified by learning content designer)/ below Appropriate time |
|                  | learning interaction | appropriate frequency(specified by learning content designer)/ below frequency |
| Learner's smartphone attitude | smartphone declined angle | between 30° ~ 75°/ not-between 30° ~ 75° degree |
|                  | learner's face shape of smartphone camera | 60 % ~ 100 % of face/ not-[60%~100%] of face |
|                  | smartphone movement velocity | not-move or above-10km per hour/ 1~10km per hour |
|                  | smartphone location | on the street/ in a vehicle/ in a building |
|                  | illumination changes ratio change state | frequently/ occasionally/ not-change-dark/ not-change-light |
|                  | environment noise with microphone sensor | below 40 dB/ between 40 dB ~60 dB/ above 60 dB |
|                  | display touch frequency | appropriate frequency(specified by learning content designer)/ below appropriate frequency/ above appropriate frequency |
|                  | sector stay time | appropriate frequency(specified by learning content lecturer)/ below appropriate frequency/ above appropriate frequency |
|                  | shaking frequency | frequently (decided by learning content designer)/ occasionally/ not-change-dark/ not-change-light |
| Bio signals | Heart bit | 70–90 bits per min/ above normal heart bit |
|                  | Temperature | 35~37°C/ above normal temperature |
|                  | Hands movement and shaking | appropriate movement/ frequent movement |
| Learner's attitude | another APP launching types and execution time | loner than digital textbook launching time/ shorter than digital textbook launching time |
|                  | activity tracking information | appropriate digital textbook foreground running time(designed by learning contents designer)/ bellow digital textbook foreground running time |
3.2. Affective Learning Reaction Information Processing Module

In order to process affective learning reaction information (ALRI) and decide learner’s emotion state, three stages of process are defined. The first process stage analyzes learner’s learning emotional state information. From the analysis of learner’s learning emotional state information, Learning Reaction Analysis System knows whether a learner is studying or not. At the second stage, Learners’ personal environment state information are analyzed and Learning Reaction Analysis System knows whether a learner concentrate on the subject of digital textbook or not. At the last stage, learner’s learning activity patterns information (module) are analyzed and Learning Reaction Analysis System decides whether a learner’s environment is appropriate for a learning activity or not.

At the first stage, mandatory information of learning emotional state information is smartphone declined angle, learner's face shape of smartphone camera, and another APP launching types and execution time. And optional information is learning activity time, learning interaction, display touch frequency and sector stay time. The mandatory information must satisfy the defined level. If mandatory information of learning emotional state information dose not satisfy the defined level, the learner would not learn or concentrate on the other subject or the other activity. If the defined level of mandatory information of learning emotional state information satisfies all three conditions, then the learner would be learning the subject of digital textbook application. The three conditions are as follows;

- Condition 1 of learning emotional state: smartphone declined angle is between 30° ~ 75°,
- Condition 2 of learning emotional state: learner's face shape of smartphone camera is between 60 % ~ 100 % of face,
- Condition 3 of learning emotional state: another APP launching types and execution time is shorter than digital textbook launching time,

At the second stage, mandatory information of learners’ personal environment state information is smartphone movement velocity, illumination changes change ratio state, environment noise with microphone sensor. The mandatory information must satisfy the defined level. If mandatory information of learners’ personal environment state information dose not satisfy the defined level and mandatory information of learning emotional state information would satisfy the defined level, the learner would not concentrate on subject. If mandatory information of learning emotional state information would satisfy the defined level and mandatory information of learners’ personal environment state information would satisfy all three conditions, then the learner would be learning the subject of digital textbook application. The three conditions are as follows;

- Condition 1 of learners’ personal environment state: smartphone velocity is between 0 km ~ 2 km,
- Condition 2 of learners’ personal environment state: illumination changes change ratio is between 0 times/min. ~ 10 times/min.,
- Condition 3 of learners’ personal environment state: another APP launching types and execution time is below 40 dB

At the third stage, mandatory information of learner’s learning activity patterns information is learning activity time, learning interaction, display touch frequency, shaking frequency and sector stay time. And optional information is smartphone location, illumination changes change ratio change state, environment noise with microphone sensor, and activity tracking information. The mandatory information of learner’s learning activity patterns must satisfy the defined level. If mandatory information of learner’s learning activity patterns dose not satisfy the defined level and mandatory information of learning emotional state information would satisfy the defined level, the learner would not concentrate on subject. If mandatory information of learning emotional state information would satisfy the defined level and mandatory information of learner’s learning activity patterns information would satisfy all fours conditions, then the concentration of the learner would be high and the learner would be learning the subject of digital textbook application. The four conditions are as follows;
• Condition 1 of learner’s learning activity patterns: learning activity time is appropriate time (specified by learning content designer),
• Condition 2 of learner’s learning activity patterns: learning interaction appropriate frequency (specified by learning content designer),
• Condition 3 of learner’s learning activity patterns: display touch frequency is appropriate frequency (specified by learning content designer),
• Condition 4 of learner’s learning activity patterns: shaking frequency and sector stay time is appropriate frequency (specified by learning content lecturer).

4. Conclusion
We propose Affective Learning Reaction Model (ALRM). ALRM consists of learner’s learning emotional state, learners’ personal environment state and learner’s learning activity patterns. Each state is inferred by Learning Reaction Analysis Engine. Learner’s learning emotional state is defined as learner’s emotional state for learning contents and environment. Learner’s learning emotional state information consists of learning activity time, learning interaction, smartphone declined angle, display touch frequency, sector stay time, learner’s face shape of smartphone camera, Heart bit, Temperature and Hands movement and shaking. Learners’ personal environment state is defined as learners’ environment information for learning. Learners’ personal environment state information consists of smartphone declined angle, smartphone movement velocity, smartphone location, illumination changes ratio change state and environment noise with microphone sensor. Learner’s learning activity patterns is defined as learners’ learning activity. Learner’s learning activity patterns information consists of learning activity time, learning interaction, display Touch frequency, sector stay time, shaking frequency, smartphone location, illumination changes ratio change state, environment noise with microphone sensor and activity tracking information.

All of the information are produced by smartphone or mobile devices equipped with various sensors. Various sensors collect learner’s learning activities information and learner’s environment information. With those information, learner’s learning emotional state is decided and sent to ATE. ATE decides new learning scenario and reconstructs strategy according to ALRM. In order to decide learner’s learning emotional state, ATE applies conditions of three analysis stage. First stage for learning emotional state information, mandatory information is defined as smartphone declined angle, learner’s face shape of smartphone camera, and another APP launching types and execution time. Second analysis stage for learners’ personal environment state information, mandatory information is defined as smartphone movement velocity, illumination changes ratio change state, environment noise with microphone sensor. Third analysis stage for learner’s learning activity patterns information, mandatory information is defined as learning activity time, learning interaction, display touch frequency, shaking frequency and sector stay time. And threshold value is defined for each mandatory information and threshold value satisfaction condition means learning positive state of a learner. These kinds of information from various aspects of a learner increases accuracy of estimation for learner’s learning emotional state. We have a plan to define and design XML rule for ALRM.

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