DESIGN AND IMPLEMENTATION OF A CLASSROOM ATMOSPHERE MANAGEMENT SYSTEM


Institute for Information Industry (TAIWAN)

Abstract
The classroom atmosphere interplays between students and teachers, which is there by conceived of multiple expectations, consensus, and behaviors. Research has indicated that positive and uplifting learning environments facilitate learning efficacy and vice versa. To specify, when exposed to rage and frustration, learners tend to be fully occupied by negative messages, resulting in dim recollections and poor mindsets. Consequently, once messages fail to be thoroughly delivered to the neo-cortex layer to be carefully and critically processed, instincts take control. To further facilitate learning and teaching efficiency, especially in remote teaching, this study aims to incorporate classroom atmosphere modules into smart classroom establishments, which functions to measure classroom atmosphere, receive instant feedbacks, and do roll calls. Three techniques are explored in this study; they are atmosphere analyses, learning conditions, and roll call modules. This study develops and implements a Kinect-based 3D gesture recognition and body language recognition and face expression recognition technology for a teaching response system for teacher self-efficacy and student performance. The developed system detects and tracks human hands, body skeleton and face landmark from the RGBD images captured by a Kinect sensor and recognizes human behavior. Furthermore, we have explored and developed Real-time Learning Tracking (RTL) techniques and are expecting to adopt big data to provide more teaching and learning friendly environments. The developed system is implemented on a Windows 10 laptop PC using C++ and OpenCV 3.1.0 library and Dlib19.4 library, and tested in ordinary classroom environment. Its performance demonstrates the overall average accuracy of around 90% in recognizing status of body and face behavior commands under various ambient lighting conditions.

Keywords: Classroom atmosphere, facial recognition, Real-time Learning Tracking.

1 INTRODUCTION
For teachers, classroom management is a prominent and longstanding problem in education (Johns, MacNaughton, & Karabinus, 1989). Martin, Yin, and Baldwin (1998) described classroom management as “the behavioral tendencies that teachers utilize to conduct daily instructional activities. These tendencies reflect the teacher's discipline, communication, and instructional styles, as well as the classroom spatial management. All of these manifest in the teacher's preferences and efforts to attain desirable educational goals.” Lippitt and White (1943) categorized classroom management into three styles, specifically, authoritarian, democratic, and laissez-faire. Teachers who adopt a democratic teaching style spend additional time communicating with students in class to establish a favorable interactive model; this encourages them to express their views on the class content and actively participate in class activities. In other words, such teachers focus on fostering students’ enthusiasm for learning. This interactive teaching style facilitates students’ emotional and personal trait development, such as confidence, proactiveness, positivity, friendliness, and willingness to cooperate.

Controlling classroom climates is a crucial factor in classroom management. It influences whether or not teachers are able to create a learning environment to deliver knowledge, techniques, and attitudes associated with education and social development. Classroom climates are affected by students, teachers, and school management. The principal characteristic of positive classroom climate is a "supportive classroom environment," in which students feel supported and respected by the teacher and are able to develop positive relationships with their peers. During classroom activities, teaching information is transferred from teachers to students or between students. Teachers constantly deliver cultural and scientific information to students, who then internalize this information and provide feedback. In this instance, the classroom becomes the most crucial and most active place of learning; it moderates the actions of the teacher and students, where the classroom climate is the most essential factor that affects teaching and learning emotions and performance.
A “climate” refers to the mood and atmosphere of an environment. Classroom climates can be described as the atmosphere created during classroom teaching. It is the overall reflection of a psychological environment created amidst the emotional interactions between the teacher and students in a classroom. A classroom climate embodies the teaching content and significantly or implicitly affects the lesson. It directly influences the teachers’ teaching behaviors and teaching quality and students’ academic development. In addition, it is controlled by teachers and affects students and external environments.

A relaxing and pleasant classroom climate provides students with a stress-free environment for learning. Such environments not only help students focus but also impel their interest, positivity, and proactiveness, thereby improving their learning outcomes. For teachers, a favorable classroom climate encourages positive student cooperation, making lectures easier and more enjoyable and promoting teachers' enthusiasm. A classroom climate in which teachers and students actively engage in teaching and learning implies that the classroom scenario satisfies students’ curiosity and meets their psychological characteristics. Such a climate reflects ideal and harmonious teacher–student and student–student relationships, creating a beneficial scenario for both the teachers and students. Practical results show that students commonly achieve better grades when learning in a relaxing and pleasant atmosphere. By comparison, students performed less favorably under stress and inhibition. Therefore, it is crucial that teachers create a favorable atmosphere in the classroom.

Classroom climates are typically evaluated through site observations, wherein evaluators record their observations using a seating chart. The chart details students’ gender and other characteristics. A graph is used to illustrate students' behaviors. The verbal interactions and movement in the classroom are documented in a predetermined timeframe (3-4 min).

Excellent classroom observations should address problems relating to observation protocols and tools. Beach and Reinhartz (2000) proposed six principals that should be followed during classroom observations, specifically (1) emphasize student behavior; (2) set limiting and specific teaching variables (e.g., students at work, classroom climate, students’ learning attitude) as the key factors of observation; (3) avoid disrupting the lesson; (4) ensure observation integrity, clarity, and accuracy; (5) analyze observation data extensively; and (6) provide observation data to the teachers as feedback. Therefore, classroom evaluators are responsible for “supervision and observation,” applying various tools to collect data concerning “knowledge delivery by teachers, learning by students, teacher–student interactions, and classroom situations and context.” By comparison, teachers are responsible for “teaching.”

The Flanders Interaction Analysis System (FIAS) is a technique for quantifying classroom observations. It contains two features, namely, (1) verbal interaction categorization and (2) timeline coding. Verbal interaction categories comprise indirect styles of teaching, direct styles of teaching, and neutral styles of teaching. Generally, an indirect teaching style is associated with promoting proactive learning and enhancing performance. However, certain circumstances call for direct teaching styles, such as introducing new content or providing guidance (Acheson & Gall, 1997). Timeline coding is employed to record teacher–student interactions.

Classroom climates can be observed and analyzed using the aforementioned method. However, in the current education system, only in rare circumstances do evaluators comprehensively observe teaching activities and provide feedback, because the number of professional education evaluators is simply insufficient to meet the prevalence and requirements of evaluation activities. Therefore, this study combined a human behavior signal processing technique with artificial intelligence technology to develop a reliability, repeatable, and scalable classroom climate management system that automates people’s subjective perception mechanisms. The system features facial recognition, face emotion recognition, and body gesture recognition functions to analyze teacher–student and student–student interactions in the classroom and quantify group and individual emotion levels for statistical analysis, providing teachers and school managers with objective classroom climate observation statistics. This system helps teachers become aware of their teaching behaviors and highlights problems in their teaching activities, thereby improving their teaching performance.

2 METHODOLOGY

The proposed system caters for two groups of users: those that teach remotely over the Internet and those that teach in a physical venue (Fig. 1). The system uses a camera to capture the face information and physical gestures of students during a teaching activity. Subsequently, the group
The proposed system analyzes images to detect students' behaviors in the classroom. Image data can be characterized by color image data and depth image data. The functions of the dlib C++ library were used to process information such as students' facial features and head poses. The Histograms of Oriented Gradients (HOG) Feature Extraction, image pyramid creation, and sliding-window detection methods were applied to plot facial feature points. Once facial quadrants are established, a machine-learning algorithm was applied to train the data and create a recognition model containing 68 facial feature and profile (characteristic) tags (Fig. 4). The system projected the users' faces onto vector spaces containing 128 dimensions. The distances of users' faces in a feature space were compared to sample images from a database to detect the nearest user for face identity recognition (Fig. 4). A support vector machine learning algorithm was employed to train face emotion recognition data and create a model that distinguishes between happy and neutral expressions (Fig. 5). Several facial feature points (nose tip, chin, outer corner of left eye, outer corner of right eye, left corner of the mouth, and right corner of the mouth) were matched with those of a universal 3D face model to determine head positions in real-time (Fig. 6). The proposed system is equipped with a Kinetic in-depth image sensor to map the body gestures of users. The k-th nearest neighbor (KNN) algorithm was employed to classify users' gestures and distinguish between upper body (raised arms) and lower body (standing or sitting) gestures (Fig. 7).
Figure 3. Facial Feature Points.

Figure 4. Facial Recognition Test.

Figure 5. Head Pose Recognition Test (Left: Facing right; Right: Facing forward).

Figure 6. Head Pose Recognition Test (Left: Facing right; Right: Facing forward).

Figure 7. Body Gesture Recognition Test.
3 RESULTS

The proposed system was tested on a group of self-study students in the Taitung Morning Light Academy. The intervention was delivered remotely from the Digital Education Institute of the Institute for Information Industry. The teacher, who was based in Taipei, taught an interactive teaching activity to a class of students in Taitung remotely by streaming video over the Internet (Fig. 8).

Figure 8. Test Environment (Left: Screenshot of the teacher as seen by the students in Taichung; Right: Screenshot of the students as seen by the teacher in Taipei).

Figure 9. Test Environment Layout.

The test environment was a remote, live-broadcast classroom (Fig. 9). The students were placed in a horseshoe configuration facing the projection screen. A camera was installed above the projection screen to monitor the students during the lesson. The system detected students’ facial features in real-time. As shown in Figs. 10 and 11, the system could accurately identify the students and detect their face emotions and head poses (normal face vectors) when they were facing the screen. Video footages of the class were used to evaluate the classroom climate. Evaluators can review the analysis indicators recorded by the proposed system after the lesson. Their observations serve as a reference for teachers for assessing classroom management performance. The classroom climate analysis indicators employed in the proposed system was based on the FIAS.
The system recorded and analyzed the personal atmosphere and group atmosphere in the classroom. In the personal atmosphere analysis, the face identity recognition and face/head pose recognition results were consolidated to determine the behaviors of each student over time. The system classified two types of face emotion by detecting students’ facial profiles and facial lines: A student with a serious expression shows tightened facial muscles and does not smile, demonstrating a neutral expression (Indicator A). A student slightly raises his or her corners of the mouth and shows relaxed facial muscles, demonstrating a happy expression (Indicator B).

Users’ head poses, or normal face vectors, can be calculated by matching the facial features detected by the system with those of the universal 3D face model. If the angle between a student's normal face vector and the direction of which the student faces (i.e., the face angle) is less than 15°, he or she is classified as facing directly toward the projector screen at the front of the classroom (Indicator C). If a student’s face angle is between 15° and 45°, he or she is classified as largely facing the projector screen at the front of the classroom (Indicator D). If a student’s face angle is between 45° and 75°, he or she is classified as barely facing the projector screen at the front of the classroom (Indicator E). If a student’s face angle is greater than 75°, he or she is classified as facing away from the projector screen at the front of the classroom (Indicator F).

The group atmosphere was determined by consolidating the personal atmosphere statistics of all the students in the test environment. Indicator G denotes that over 80% of the face emotions in the classroom are smiles. Indicator H denotes that between 60% and 80% of the face emotions in the classroom are smiles. Indicator I denotes that between 40% and 60% of the face emotions in the classroom are smiles. Indicator J denotes that between 20% and 40% of the face emotions in the classroom are smiles. Indicator K denotes that less than 20% of the face emotions in the classroom are smiles. Indicator L denotes that over 80% of the face angles in the classroom are smaller than 45°. Indicator M represents that between 60% and 80% of the face angles in the classroom are smaller than 45°. Indicator N denotes that between 40% and 60% of the face angles in the classroom are smaller than 45°. Indicator O denotes that between 20% and 40% of the face angles in the classroom are smaller than 45°.
are smaller than 45°. Indicator P denotes that less than 20% of the face angles in the classroom are smaller than 45°.

**Table 1. Atmosphere Analysis Indicators.**

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<th>Personal Atmosphere Analysis</th>
<th>Facial Emotion Analysis</th>
<th>Head Pose Analysis</th>
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<tr>
<td>A. Students exhibit a serious, neutral expression and contracted facial muscles.</td>
<td>Head Pose Analysis</td>
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<tr>
<td>B. Students exhibit a happy expression and slightly raise the corners of the mouth.</td>
<td>C. Students are directly facing the projector screen at the front of the classroom when their face angle is 15°.</td>
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<td></td>
<td>D. Students are largely facing the projector screen at the front of the classroom when their face angle is between 15° and 45°.</td>
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<td></td>
<td>E. Students are slightly facing the projector screen at the front of the classroom when their face angle is between 45° and 75°.</td>
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<td></td>
<td>F. Students are not facing the projector screen at the front of the classroom when their face angle is greater than 75°.</td>
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<tr>
<th>Group Atmosphere Analysis</th>
<th>Facial Emotion Analysis</th>
<th>Head Pose Analysis</th>
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<tr>
<td>G. Over 80% of the face emotions in the classroom are smiles.</td>
<td>Head Pose Analysis</td>
<td></td>
</tr>
<tr>
<td>H. Between 60% and 80% of the face emotions in the classroom are smiles.</td>
<td>L. Over 80% of the face angles in the classroom are smaller than 45°.</td>
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<tr>
<td>I. Between 40% and 60% of the face emotions in the classroom are smiles.</td>
<td>M. Between 60% and 80% of the face angles in the classroom are smaller than 45°.</td>
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<tr>
<td>J. Between 20% and 40% of the face emotions in the classroom are smiles.</td>
<td>N. Between 40% and 60% of the face angles in the classroom are smaller than 45°.</td>
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<tr>
<td>K. Less than 20% of the face emotions in the classroom are smiles.</td>
<td>O. Between 20% and 40% of the face angles in the classroom are smaller than 45°.</td>
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<td></td>
<td>P. Less than 20% of the face angles in the classroom are smaller than 45°.</td>
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During the teaching intervention, the system recorded the atmosphere analysis results on a timeline. The personal and group atmosphere analysis results for a remote lesson delivered on April 18, 2017 (Tues.) are respectively illustrated in Fig. 12 and Fig. 13. The timeline consisted of 39 blocks, each representing a 30-s period. Therefore, 39 observations were made in a total period of 1170 s.

The proposed system recorded the atmosphere and behaviors of the students during the teaching intervention. These data were compared with the class content and teaching methods employed by the teacher in the same period to identify the positive and negative factors concerning learning atmosphere. Accordingly, a reference can be provided for teachers to improve their teaching performance and, by extension, improve students’ learning performance.
4 CONCLUSIONS

In this study, we combined computer vision and behavioral recognition technologies to develop a system that can instantaneously provide feedback concerning students’ personal atmosphere and group atmosphere conditions during teaching activities. The system adapts the teacher–student verbal interaction categorization of the FIAS model and incorporates students’ expressions and head poses as in-class observation items, in conjunction with an information system for feature detection and
This enables providing accurate, comprehensive, and objective analysis and evaluation reports to teachers and managers of education institutions.

The proposed system manifests three distinct advantages. Specifically, it prevents interrupting a lesson, keeps extensive and concise observation records, and enables a comprehensive analysis of observation data. The proposed observation model is highly replicable for widespread applications.

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REFERENCES


