Calibrated Meditation with Sensor Network and Virtual Reality

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ABSTRACT

Chan is a superior mental training methodology derived from Buddhism and absorbed wisdom of religious practitioners, philosophers, and scholars through thousands of years. As the primary way of Chan, meditation has clear effects in bringing practitioners' mind into a tranquil state and promoting both the mental and the physical health. We propose to establish a Chan science by applying modern experimental sciences to the measurement of the effects of meditation. Brain state models can be built to guard meditation practice. In addition, virtual reality can create an environment for the meditators to regulate minds. Through these studies, we believe we will be able to make Chan a beneficial practice to promote human's life in modern society.

Keywords: Chan, Meditation, Mental Health, Brain State Modeling, Machine Learning, Virtual Reality.

1. INTRODUCTION

Chan (Zen), originated as a methodology of spiritual meditation, has played an important role in the history of Eastern countries. In recent centuries, with the fusion of various cultures in modern society, Chan has drawn attention of various ethnic groups for its focus on practice and direct effect on human's lifestyles and health conditions. Chan has shown its religion neutral nature in the modern society.

Chan can be regarded as a philosophy that impacts human's view about the essence of science and relates scientific study to the contemplation of its performer --- human. In recent years, term "life science" has been used to denote studies related to the understanding of human's nature and seeking ways to harmonize human's life with the environments.

Probably the most straightforward way to study meditation is to apply medical technologies to measure the effects of meditation. Such kind of research is suited into the context of medicine research. Generally, two types of research models can be used: statistics models and micro models.

Statistics models are built by applying statistical analysis to collected data from meditation practitioners. Data analysis is done either in the progress of the practice, e.g., comparing the indexes at different points of time during the process; or between different groups, e.g., comparing a group of meditators to a control group.

Current literatures show that both methods are used in the study of complementary and alternative medicine, which includes meditation as one of the methods. In [1], a 20-week contemplative self-healing program was studies. Biologic data were analyzed at the beginning and the end of the program. Research results showed that a contemplative self-healing program can be effective in significantly reducing distress and disability among the testers. In [2], a long-term (5-20 years) project was carried out to investigate the use of complementary and alternative medicine and its effects onto the testers' health.

Comparisons across different groups of people are also found. For example, in a 6-week mindfulness-based stress reduction program, subjects assigned to the program demonstrated significant improvements in psychological status and quality of life compared with usual care [3]. Another comparison is found in [4], where a group of Qigong practitioners were compared to a control group and positive indicators were found in the study.

A survey of the literature on cognitive impairment and cancer presented in [5] suggests that meditation may help to improve cancer-related cognitive dysfunction and alleviate other cancer-related sequelae.

It is well understood that although statistical study can provide evidence for the effectiveness of meditation, it fails to provide a systematic view of human's epistemology and psychology. This addresses the needs for micro models that depict the inter-relationship between human's mind and physical body. We propose that meditation methodologies be utilized to create models for studies on meditation. Such models can be examined during meditation practices to create a calibration system for meditation.

One possibility is to build a system that can collect, store, and process Electroencephalographic (EEG) data, and through the interpretation of EEG signals, the neuron activity inside of the human brain can be characterized, providing a window through which we can better study and understand human brain activities [6]. The combination of EEG data with modeling methods in fields such as data mining and bioinformatics could be used to build brain state models.

For example, the systematic analysis and modeling of subjects' brain activity could be used to prove that subjects in a state of transcendental meditation are in a verifiable and observable state of mind that can be monitored and predicted [7]. Experiments found that cancer patients who practiced meditation experienced higher levels of well-being, improved cognitive function, and lower levels of inflammation than a control group [8].

We propose to build a full-fledged calibration system for meditation practice. This calibration system uses brain state models to guide meditation process and give feedbacks to the meditator when deviation from expected brain state is detected. Moreover, feedbacks in the form of virtual reality can be utilized to regulate mind-body activities. This system can not only calibrate meditation, but also give feedbacks about the healthiness of brain states during daily lives. Such type of full-fledged calibration is congruent to the requirement of Chan methodology.

This paper will be organized as follows. Section 2 will give a brief description of Chan methodology. In Section 3, we discuss the theoretical base for scientific calibration of meditation. Section 4 will present brain state modeling methods and the virtual reality based meditation guidance system. We will conclude the paper thereafter.

2. CHAN MEDITATION

Chan (or Ch'an), also known as Zen in Japanese, was named "Dhyāna" in Sanskrit, the ancient holly language of India. The Wikipedia definition of Chan is: Chan is a school of Mahāyāna Buddhism, Chan is itself derived from the Sanskrit Dhyāna, which means "meditation". (http://en.wikipedia.org/wiki/Zen) The literal meaning of Chinese character Chan (禅) is transfer of the sovereign power, derived from the story of the three patriarch emperors Yao, Shun, and Yu. In Chan Buddhism, Chan means the transfer of insightful wisdom.

While a lot of spiritual exercises involve meditation, for example, Yoga, Chan meditation differs from the others in that it emphasizes the acquisition of the insight to one's life so as to be out of the control of any earthly desires and emotions such as anger. Since Chan's goal is the attainment of awakening and enlightenment, it deemphasizes any rational creeds or theoretical reasoning. This is indicated in the beginning story of Chan origination, viz., Flower Sermon [9]. Once Śākyamuni Buddha summoned his disciples for a Dharma talk. When they gathered, he was completely silent and holding up a flower. No bodies understood what Buddha was trying to tell while Mahākāśyapa suddenly broke into smile. Buddha acknowledged this special way of understanding and said:

> "I possess the true Dharma eye, the marvelous mind of Nirvana, the true form of the formless, the subtle Dharma Gate that does not rest on words or letters but is a special transmission outside of the scriptures. This I entrust to Mahākāśyapa."

Flower Sermon clearly indicates that Dharma nature (tathata) is ineffable. It is understood in a sudden acquisition of the insight to it. Therefore, Chan emphasizes direct experience rather than theoretical conceptualization and reasoning. Buddha also clearly ordered that the transmission of this wisdom is outside scriptures. Mahākāśyapa then became the first patriarch of Chan school.

This subtle Dharma Gate was transmitted from Mahākāśyapa through 28 patriarchs in India with Bodhidharma being the 28th patriarch. In about the 5th century, Bodhidharma brought Chan to China and became the first patriarch in China. After several single transmissions, the 6th patriarch, Hui Neng, revolutionized the propagation of Chan. He abandoned the passing of the bowl and cloak as a sign to certify the transmission [10]. Since then, Chan began to broadcast widely and a lot of people acquired prajna.

Bodhidharma said that his school used "special transmission outside scriptures" and "did not stand upon words". Hui Neng summarized his way as "no thoughts, no forms, no anchors". All other patriarchs expressed the same teachings through generations. Chan views all names and concepts as crafted terms and requires that the practitioners do not linger with them in their pursuit. Even Buddha itself should be casted away. Their concentration is on the very status of their lives and the surroundings at the very moment. Mahayana Buddhism (Big Vehicle Buddhism) asserts that all sentient beings possess Buddha nature and Buddha nature is nothing else than the essential nature of the mind itself. When Master Chong Hui was asked, "Why I do not see Dharma?" he answered: "Because you don't understand. If you understand, you will see there is not Buddha to pursue."

As the meaning of Dhyana indicates, meditation is an essential part of Chan practice. As a matter of fact, meditation is the primary way to achieve Chan state, although meditation itself is not the goal of Chan. Chan requires that the practitioners watch their thoughts at every moment, which means that meditation should be carried on alone the entire day. As Bodhidharma said in his famous "On Breaking Forms", "The Dharma way of watching minds embraces all Dharma ways." [11] Meditation with no objects, anchors, or content, is the primary form of the Bodhidharma Chan. The meditator strives to be aware of the stream of thoughts, allowing them to arise and pass away without interference.

Sitting meditation is the most important part of Chan practice before one acquires the prajna, since it is the most effective way to regulate one's mind. The Wikipedia definition of sitting meditation is: "core aspect of Zen practice, during which practitioners usually assume a position such as the lotus position." (as shown in Figure 1) Various methods were used to regulate the mind. For example, awareness can be directed towards counting or watching the breath; awareness can be put in the energy center below the navel; awareness can be fixed at a picture such as the image of a Buddha or a scene; awareness can also be directed to muttering a Buddha's name, either in voice or silently; etc.

Figure 1. Lotus Position

3. SCIENTIFIC STUDY ON MEDITATION

Measurement of meditation effects can be done by analyzing mental health indicators, e.g., lust, anger, fear, ability of cautioning oneself, balance in personality, etc. Existing psychological measurements can be applied to Chan practitioners against psychological indicators. One example of existing metrics that include psychological indexes is Functional Assessment of Cancer Therapy --- General (FACT-G) [12], which consists of four subscales assessing physical well-being, social well-being, emotional well-being, and functional well-

being. Another metric is Profile of Mood State, which measures mood. [13]

Famous Zen scholar, Daisetz Teitaro Suzuki (铃木大拙), wrote a book [14] about Zen and psychoanalysis, which gives a Buddhist analysis of the mind, its levels, and the methodology of extending awareness beyond the merely discursive level of thought. In producing this analysis, Suzuki gives a theoretical explanation for many of the swordsmanship teaching stories in "Zen and Japanese Culture" [15] that otherwise would seem to involve mental telepathy, extrasensory perception, etc.

A recent work in Zen and psychotherapy can be found in [16], where the therapeutic value of meditation is analyzed. There are six Zen principles of psychotherapeutic value: acceptance (suffering), fearlessness (courage), truth (enlightenment), compassion (toward self and others), attachment (desire), impermanence (letting go). In addition, Zen is analyzed against the phenomenology of traditional psychotherapy in the biological approach, the learning theories, the cognitive approach, the psychodynamic perspective, and the humanistic approach.

As a matter of fact, models can be built from the procedures of meditation itself. Such a model will no longer be suitable for clinical purposes but aiming to be guidance for meditation practice.

The well known four Dhyanas (catvari-dhyanani) theory clearly depicts the procedure of meditation in four series of stages, viz., the first Dhyana through the fourth Dhyana, as described in the following.

1) First Dhyana: Bliss Born of Separation
2) Second Dhyana: Bliss Born of Samadhi (proper concentration and proper reception)
3) Third Dhyana: Wonderful Happiness of Being Apart from Bliss
4) Fourth Dhyana: Clear Purity of Casting Away Thought

(http://www.bhaisajyaguru.com/buddhist-ayurveda-encylopedia/four_dhyanas_sz-chan_sz-jing-chu_catvari-dhyanani_jhana.htm)

Each stage has specific state of mind, the realm of sensory perspectives, possible interaction with spiritual beings, and methods to avoid deviations from the right path. In Sui Dynasty of China, Patriarch Zhi Kai (智凯, AC 523-597), the first patriarch of the Tiantai School (one of the eight primary Buddhism schools), specified the detailed methods of Dharma practice for each Dhyana stage [17] and his methods have been used as the primary methods and/or guidance for meditation ever since.

Detailed descriptions of the four Dhyanas are:

- In the First Dhyana (The Ground of Bliss Born of Separation), one's pulse stops, but this doesn't mean one is dead. This brings a particular happiness which is unknown to those in the world.
- The Second Dhyana is called the Ground of Bliss Born of Samadhi. . . . In the Second Dhyana, one's breath stops. There is no detectible breathing in and out, but at that time an inner breathing takes over.
- The Third Dhyana is the Ground of the Wonderful Happiness of Being Apart from Bliss. One renounces the *dhyana*-bliss as food and the happiness of the Dharma that occurs in initial samadhi. One goes beyond that kind of happiness and reaches a sense of wonderful joy. It is something that one has never known before, that is inexpressible in its subtlety, and that is inconceivable.
- The Fourth Dhyana is called the Ground of the Clear Purity of Casting Away Thought. In the Third Dhyana thoughts were stopped--held at bay--but they still had not been renounced altogether. In the heavens of the Fourth Dhyana, not only are thoughts stopped, they are done away with completely. There basically are no more cognitive considerations. This state is extremely pure, subtly wonderful, and particularly blissful.

It is easily seem that each Dhyana has specific bodily manifestations. For example, one's pulse stops in the first Dhyana and the breath stops in the second Dhyana, and one can anchor his thoughts in the third Dhyana and totally stop thoughts in the fourth Dhyana. With the advancement of modern technology, we can well go beyond these obvious bodily manifestations and give more detailed accounts of bodily manifestations in terms of modern medical terminologies, such as those used in electrocardiogram, electroencephalogram, and magnetic resonance imaging (MRI).

There are not so many meditators with such high achievements in the four Dhyana levels. As a matter of fact, most of the meditators are even under the lowest level of heaven with desires. It might be more meaningful and cost-effective to test one's proficiency level of meditation using more direct indicators.

With the advancement of communication technologies, modern societies are getting more and more cyber-fused. Instantaneous information propagation creates a flow of information around each person. Abundance in material supplies has enriched people's lives. While this abundance allows for more choices for people, it brings hardships in that more and more things must be obtained by effort instead of be given as before. Therefore, people are leading busier and busier lives. Span of attentions is getting shorter. More and more problems have been created because of the exposure to all sorts of media.

Scholar Zizhu Dong used the mesh of Mouni pearls to describe the phenomena of this cyber-fused world. [18] The mesh of Mouni pearls is described in Buddhism scriptures. A Mouni pearl reflects the lights of all other Mouni pearls in the mesh. In the modern society, any individuals are no longer isolable from the group. Modern communication technologies, such as TV, Internet, and portable phones, connect people such that each individual of the society can instantly sense every change in the surrounding world.

With this mode of society and the advanced sensing technologies, we can think of developing a computing system that can calibrate the procedures of meditation such that meditation can be achieved as a pragmatic in people's daily lives.

4. MEDITATION CALIBRATION AND VIRTUAL REALITY

According to the channel theory of Chinese medicine, the circulation of energy in the channel system of a human body is cyclic on daily basis, with each channel being active in a specific two-hour period, as shown in Table 1. Therefore, the channel model is actually a time-space system. If a meditator is aware of this, he can better arrange his practice in order to have

a better control of his body, as well as to avoid negative effects caused by improper timing of the practice. This is congruent to Chan's principle that inner reflection of minds has to be a continuous activity.

Table 1. Cyclic circulation of energy in channels

Lungs	3 AM to 5 AM
Large Intestine	5 AM to 7 AM
Stomach	7 AM to 9 AM
Spleen	9 AM to 11 AM
Heart	11 AM to 1 PM
Small Intestine	1 PM to 3 PM
Bladder	3 PM to 5 PM
Kidney	5 PM to 7 PM
Pericardium	7 PM to 9 PM
San Jiao	9 PM to 11 PM
Gall Bladder	11 PM to 1 AM
Liver	1 AM to 3 AM

How to calibrate meditation with scientific means? In the following, we propose two technical schema, viz., passive calibration, and active calibration.

Passive calibration uses physiological measuring devices to monitor mind-body states of the meditator and give feedbacks to the meditator to help keeping him/her in the right route of the meditation process. This method employs data analytics algorithms to model mind-body states so that the calibration system can detect deviated activities from the meditator during meditation. In the following, we give a brief description of an ongoing project that uses brain waves signals to classify brain states.

The brain emits electrical signals can be measured by placing an electrode in contact with the scalp. The resulting electroencephalogram (EEG) readings initially consist of a voltage measurement, on which a spectral analysis is then performed in order to observe the signal in the frequency domain. Electrical activity in the brain can therefore be analyzed in terms of the frequency ranges in which neural oscillations are observed and recorded. Measurements that are concentrated within each of these frequency bands are associated with certain mental states, and thus by analyzing the spectral content of the electrical impulses in the brain, a highly educated guess can be made as to what mental state a subject is in. This is the basic idea behind the categorical classification of brainwave data. A model is first constructed based on a pre-classified set of training data. This model can then be used to classify newly collected data.

We built a web-based EEG data storage and analysis system that provides onsite EEG data modeling and testing services. Once the EEG data has been collected and stored in a standard format, it can be analyzed and modeled. The inclusion of data analysis methods is central to the overall system, because they allow the user to analyze and test data from various subjects and collection times through a centralized interface. The current version of our toolkit includes the following classification algorithms: K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Boosting, Randomized Aggregated Decision Trees (Random Forest), as well as a Naïve Bayesian Classifier.

Figure 2 shows a portion of the web interface that prompts the user to select one of the available algorithms.

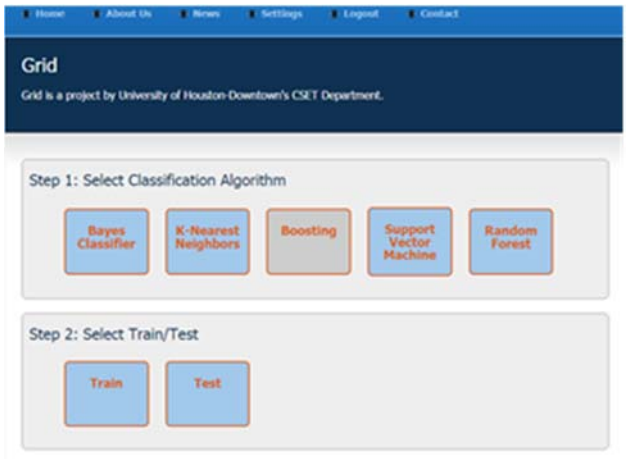

Figure 2. Algorithm Selection Pane

Quite generally, each of these Machine Learning algorithms works by gleaning distinguishing features from a set of pre-classified training data that is fed into the algorithm, upon which a statistical model is constructed. Based on this model, any new data can then be analyzed, compared to the model, and assigned to a particular class. Thus we can see that this process involves two discrete phases, which are: (1) data modeling and (2) data classification.

Each of these algorithms works in a different way, so we can expect that some will perform better than others when given the task of classifying EEG data. The inclusion of all of these algorithms benefits the user by providing the ability to compare the operation and the results of multiple modeling and classification methods.

Figure 3 shows the results of a sample test using the Random Forest algorithm. The results show that for data set containing a total of 154,247 rows, only 7168 of them were classified as class 1, while the remainder was assigned to class 0. In this case, we can conclude that the data set that was tested probably came from a subject engaged in a similar activity as the data assigned to class 0 in the trained model. Here, Class 0 and 1 refer to two different brain states under testing.

With such a system, we can build models of meditation for a certain subject against certain meditation method, and then use this model to monitor the meditator's brain state while meditation. A feedback can be sent to the meditator when the brain state is deviated from the "correct" routine according to the brain state model.

With the availability of wearable EEG devices, this system can also be used to monitor brain states in daily life to give feedbacks to the meditator when his/her brain state is deviated from "healthy" states according to Chan standards. Needless to say, other physiological signals, such as ECG, EMG, pulse, and temperature, can also be used in such a calibration system.

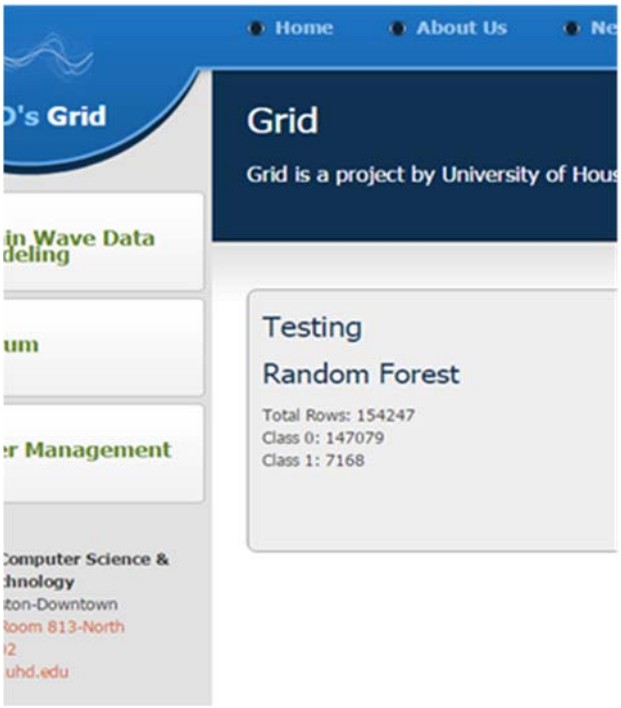

Figure 3. Classification Results

Active calibration involves an inducive system that can guide the meditator into the meditating state. This method requires precise understanding of the meditation procedure. In the following, we discuss the possibility of using virtual reality to help the reflection in mantrayala meditation.

Mantrayala Buddhism uses immersing imaginations as part of the meditation procedure. The immersing imagination normally involves a figure of Buddha called Yidam. The imagination must be able to visualize the figure in every detail so that the Yidam appears to the meditator in effect. The procedure may include imagination of the meditator's transforming into Yidam and eventually the Yidam merges into a realm of emptiness.

Traditionally, meditators use Mandala, a terrace with sculptures of Buddha figures, as the place for the meditation rituals. Such a Mandala is not available to most of the lay Mantrayala meditators, especially those living in urban areas. Virtual reality, however, will be able to visualize Mandalas for those meditators. In addition, various sensors can be used to regulate the meditating activities during the process.

We present several virtual reality based systems we plan to design as the followings. The first three systems will be designed for meditation in a quiet environment, applicable for sitting meditation. The fourth system will be designed for meditation in between of normal daily activities, with continuous monitoring of attention, using augmented reality technologies.

In the last paragraph of Section 2, we mentioned that various methods were used to regulate the mind. We will design the first system with sensors including breath tracking sensors and EEG brain activity monitoring sensors. The system includes a software based visual feedback with a number showing the counting of the breath. The breath tracking sensors track the individual's breath in real-time, and compute out the breath counting numbers from a beginning point of time. The number of breath then triggers a visual feedback system to show the number of breath in a form with number characters. The EEG sensors continue to monitor the individual's brain activities. The data analysis module analyses the activities and triggers a module to change the frequency of the feedbacks. For example, at the beginning, the display of the visual feedback is once per breath. When the EEG sensors determines that the individual is in deeper meditation, the display of the visual feedback is one per two breathes.

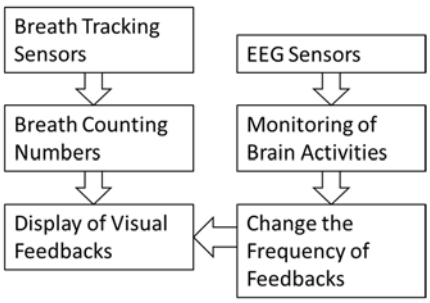

Figure 4. Diagram of System One for Body Sensor Network and Feedback System.

We will design the second system with sensors including EMG - Electromyography sensors tracking muscle tension index, EEG sensors tracking brain activity and a voice feedback of Buddha's name.

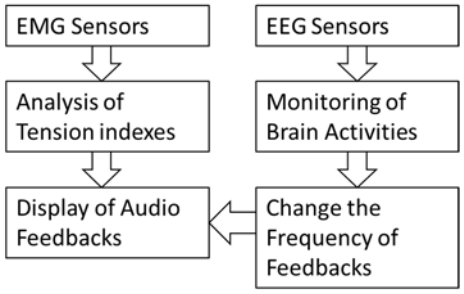

Figure 5. Diagram of System Two Body Sensor Network and Feedback System.

We will design the third system with the EEG sensors tracking the attention status, and virtual 3D images of natural sceneries or images of Buddha. We will use OpenGL computer graphical software for the construction and animation of the virtual scenes. We will acquire the head-mounted display for the display of the 3D sceneries. For on the head-mounted display, there usually is a gyroscope and magnetometer to track the head's position. The viewpoint of the scenery will be changed accordingly to enhance the user's experiences.

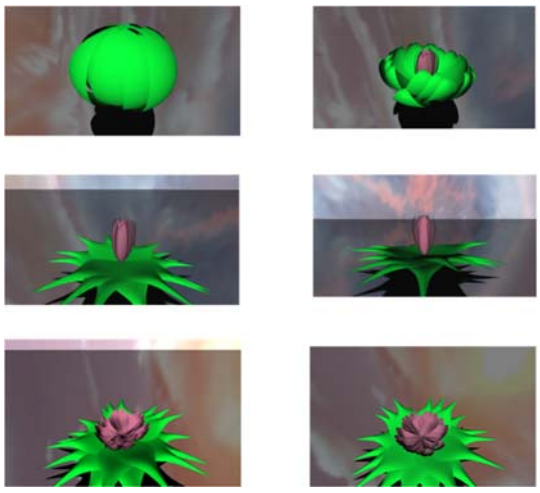

Figure 6. Examples of Virtual Scenes in System Three with Body Sensor Network and Feedback System.

Meditation can be embedded into daily activities by one's continuous monitoring of attention and awareness. Therefore, we propose a system continuously tracking one's attention. The sensory system tracking one's attention can include breath-tracking sensors, EMG sensors and EEG sensors. The system also involves an augmented reality glass. The augmented reality glass enables the user to perform normal daily activities, and at the same time, can show particular augmented reality images, or audio feedbacks. Whenever there are certain scenarios in which the individual is in a status that is not peaceful, with stress and tension, the system provides the feedback.

Figure 7. Illustration of Continuous Monitoring of Individual's Awareness with Augmented Reality Biofeedback

5. CONCLUSIONS

With modern sensor and virtual reality technologies, meditation can be performed with the help of intelligent systems. In this paper, we proposed two calibration strategies. One is passive calibration strategy. We implemented the EEG web server and web interface to be a good starting foundation to visually see the EEG data capture and display from start to finish. Additionally, we built the classification interface which can provide a way for users to test out various algorithms using different combinations of data to construct training models. It is possible to capture EEG data from anywhere, while on the move, and be able to immediately see results, as well as delve deeper by performing analysis remotely. In the active calibration, we proposed four systems with body sensor network and visual and audio feedbacks for enhancing the meditation experience. The first three systems utilize sensors include breath tracking sensors, EMG and ECG sensors. The biofeedback includes visual and audio feedback in various forms. The fourth system we propose is an augmented reality application. With the state of the art augmented technology, the system can continuously monitor the individual's awareness while giving feedbacks whenever it is proper. Although much more refinement is required in increasing the performance of existed systems and implementing the proposed systems, the article provides a vision of meditation with the state of the art technologies in computer science and engineering.

6. FUTURE WORK

We are working on building a group of sensor systems to automatically track people's body health signals. The goal of the design of systems, is to make them light weight, easy to wear, energy efficient and low cost for individual purchases. We are researching on the state of the art data preprocessing and machine learning algorithms to better understand meditation states. We will build the various visual and audio biofeedback modules to provide the user with enhanced user experience. Furthermore, we are working on collaboration with meditation experts to enhance the design and performance of the systems. Based on the work of an efficient and predictable brain wave modeling system, with the proposed sensor and virtual reality systems, we aim at achieve potential applications in hospitality and the clinical industry for self-controlled deep brain relaxation and early diagnosis of various brain abnormalities respectively.

7. ACKNOWLEDGEMENTS

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