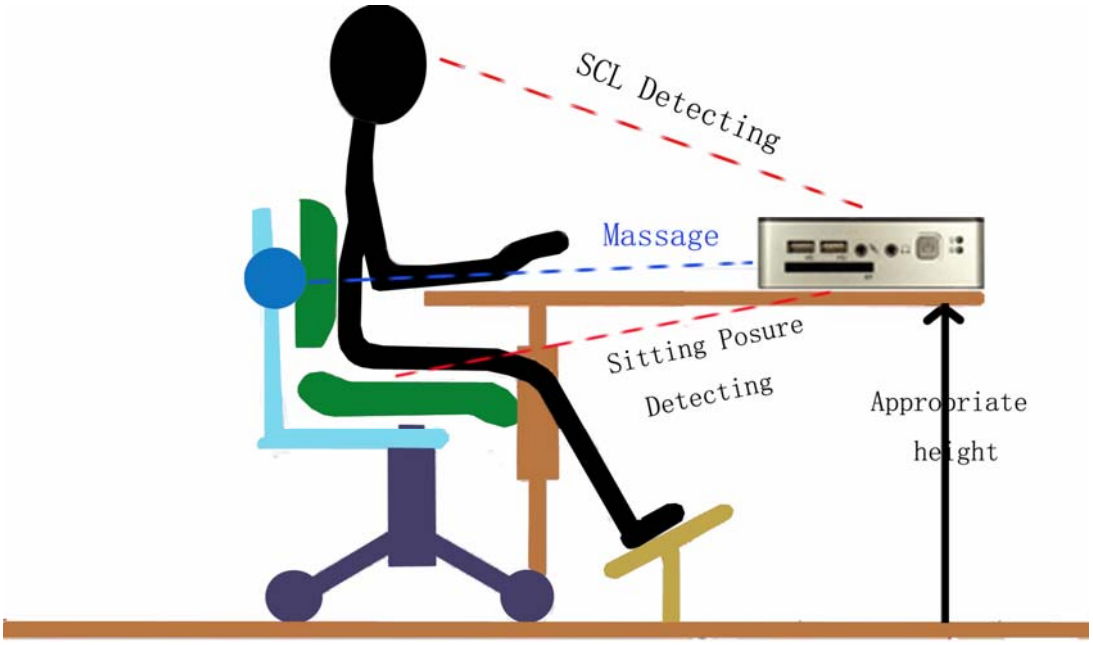
See-Saw

an intelligent study accessorial system for improving study efficiency



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1. Abstract

1.1 Background

It is widely accepted that the process of education is lifelong. However, One's individual development and the capacity to fulfill one's own purposes can largely depend on an adequate preparation in childhood. Therefore a well-grounded Childhood Education, including primary education and secondary education, can help to provide a firm foundation for the fulfillment of personal achievement.

Teaching and learning research indicates that children who are more effective in concentrating on homework or self-study tasks, on average, have better performance in school, and thus are more likely to achieve their academic pursuit when they move onto upper grades.

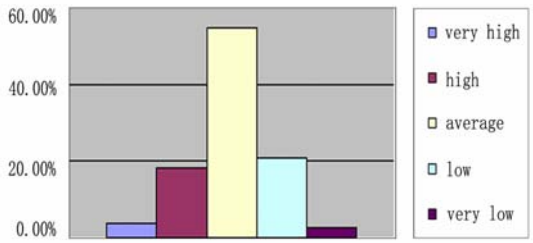

Figure 1 The self-evaluation of study efficiency for secondary students

According to the survey and the statistics, for most of the primary and secondary students, the biggest obstacle lying in their studies is not the grasp of the knowledge itself, but how to cultivate a concentrative, effective and healthy learning habit. Various factors, such as the lack of comfortable study environment, lack of parents' supervision, and especially the unscientific or inappropriate study schedule influence the efficiency in study. The health problems such as Myopia and Spinal Disease will also result from the unhealthy study habits.

In view of the situation above, we came up with the idea of designing an intelligent study accessorial system called "**See-Saw**" which aims at improving the users' learning performance, preparing them the ability of highly efficient self-study and helping cultivate healthy study habit by monitoring users' concentration level, sitting posture and giving feedbacks on them. We hope it would tilt the education as a see-saw by our technology. We also believe this project will provide a brand new way of improving users' study performance especially for the young, thus enables a better education for all.

1.2 Innovation

- **We let users to see their own concentration status.** We have developed a practical algorithm to detect user's concentration level. We used video camera to capture user's face image and then process it in the DSP. The neutral network based on concentration detection module in Ebox will calculate the concentration level and then display it to the user. This process will let the users know their current study status without disturbing them.
- **Our system provides a more intelligent sitting posture monitor mechanism.** By the pressure and infrared distance sensors, Ebox can calculate user's current sitting posture and warn user when he/she is in wrong sitting posture. This intelligent monitor mechanism stands out from the hidebound products in the market.
- **Massage the user with music.** We have developed brand new massage device which can change its massage intensity with the music. By this music massage, user can reduce fatigue quickly.
- **Easy to know the child study status.** With the help of wireless network, we enable the parents know their children's study status easily and effectively without breaking in on them. The PDA devices can receive the information from our system through WLAN, thus parents or guardians can reach their children at any moment.
- **Specific suggestion of study.** By introducing the statistical method to analyze the students' study status and improvement, we could provide a more comprehensive and specific advice. Our system will collect the data when user is using this system. The data collected in this process will indicate user's study habit and user's improvement, thus the system can provide unique suggestion for the user.

2. Market Overview

2.1 Introduction

Education has always been the focus of the society. It is meaningful for the whole life for everyone. Many students are disturbed by many problems existing in their studies, such as distraction, ineffective study, low reading or writing speed. As for students, low concentration level will reduce the learning performance thus impact students' further development. Many teachers and parents have recognized this problem and tried to resolve it for a long time. However, the conventional solutions for this problem, which most time end up to punishment or encouragement afterwards, are proved to be of not too much effect. To help the students concentrate on study is one of the ultimate goals for many educators. We recognized this problem and try to resolve it by designing this intelligent study accessorial system: "See-Saw".

Through lots of investigation and experiment, we found that when students are in low learning efficiency, they often show various physical behaviors which give much indication of concentration state. So we believe that this state can be detected by these features such as direction of gaze, eye blinking rate and actual eye closure, mouth shape, and sitting position.

At the same time, as an intelligent system, it is far from enough to give simple notification. So we designed some feedback in our system. For example, the system can give massage to the user when he or she is tired. From the data collected from the user, the system can give user advice about study time schedule which optimize user's learning performance. Based on the consideration mentioned above, we had the following system model.

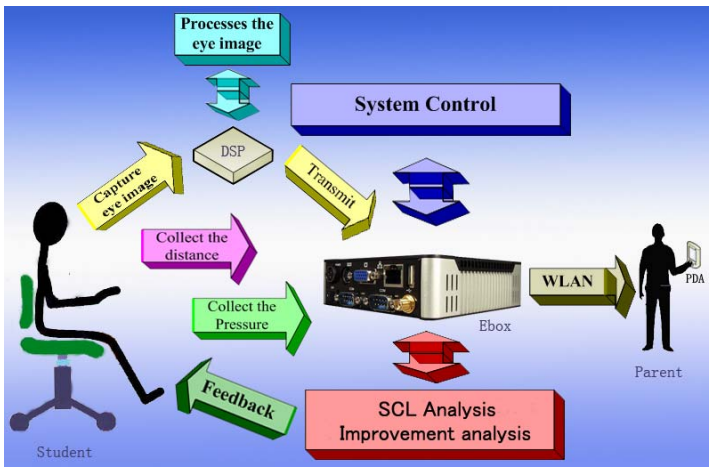

Figure.2 System model

In this model, Ebox plays the core role of our system. It first collects all information about users' study status from input devices like sensors and camera, then processes the information obtained according to the algorithms implemented by the software, and finally, gives feedbacks of users' current status through output devices like audio device, LCD and massage apparatus.

The goal of our system is to improve the users' learning performance, preparing them the ability of highly efficient self-study and helping cultivate healthy study habit by monitoring users' concentration level, sitting posture and giving feedbacks on them. One of our system's important functions is to determine the user's concentration level based on the various features extracted from the user's images. So the accurate, reliable, and real-time image processing module plays a key role in assuring our system's success. We choose DSP to processes the users' eye image and judge the users' Spiritual Concentration Level (SCL) by the specific algorithms. The high processing speed of DSP enables us to trace the users' status in real time and save the computational resource of Ebox.

To have a more comprehensive understanding of the user's study state, we also put the user's sitting position to our consideration. Using the Pressure sensors, Infrared sensors and the algorithm implemented in the Ebox, The system is able to help the user develop a good habit in sitting, which we believe will benefit him or her for the whole life.

Moreover, the problem of concentrative study is not only the priority concern of teachers in school, but also for the parents at

home. They would also want their children to adopt such good learning habit, especially when they're not around the children. As for most of the parents in China, both of father and mother are occupied with their job and work, so they don't have enough time to supervise their children to study at home everyday. When the parents are not around, children are tend to be interested in other things rather than study, or the effectiveness of their study will drop significantly. Lots of children admitted that they have such kind of sharp contrast in concentration and effectiveness in studying when their parents are around. Considering such contrast, the special PDA was included in our system, in order to keep in touch with the parents and report the real time studying state to them, which will replace the direct supervision from parents.

Lastly, to keep track of the user's study performances is our system's important goal, but not the ultimate. We feel it obliged to help the students, their families, educators and all the others who care for the education of next generation, to know better about our children's study habits, advantages and disadvantages. That is why we take the initiative to incorporate a statistical module into our system. After tracking and storing the user's study states for a reasonable period, we are able to provide concrete and reliable data for the educators to analysis the student's study habits. we hope this will bring on more scientific advice for each user and finally make profound changes in the field of education Lastly, to keep track of the user's study performances is our system's important goal, but not the ultimate. We feel it obliged to help the students, their families, educators and all the others who care for the education of next generation, to know better about our children's study habits, advantages and disadvantages. That is why we take the initiative to incorporate a statistical module into our system. After tracking and storing the user's study states for a reasonable period, we are able to provide concrete and reliable data for the educators to analysis the student's study habits. We hope this will bring on more scientific advice for each user and finally make profound changes in the field of education.

2.2 Performance requirements

- The system is a user-dependent system, which means that it should collect and analysis the data from the specific user. It will adjust the system parameter automatically to improve the system performance.
- The running of system should require minimum human administration. Data collection should be entirely automatic without interrupting the users.
- The tracking of the user's spirited state should be real-time. We expect the system should recognize the changing status and give feedback within a specific time (<3s).
- As the guardians of the students, parents can access students' study status at any moment.
- The system user interface should be easy to operate. Whether a children or parents should have no difficulty in operating See-Saw. The LCD is specially incorporated for the direct and clear display of information.

2.3 Related research

Before the design of the system, we did lots of investigation. The concentration level detection systems found in the market are often used in the hospital, like the "Children concentration level analysis apparatus" made by ShangHai HaoSun tech company. They are big in size, expensive and hard to control. There is another concentration level detection system based on software. (e.g. Concentration level detection and training software developed by ShangHai Beicheng software company) This kind of software heavily depends on user behaviors which is not suitable for our goal. The system must detect users' concentration level without disturbing them and easy to use. Currently there are mainly four methods to detect the concentration level.

- Brain wave method. According to the frequency distribution and wave pattern of electroencephalogram, we can infer the concentration level the user. But electroencephalogram is easily distracted by outside factors and the equipment is too expensive. So it is not suitable for everyday use.
- Pupil recognition. Through the change of pupil's diameter, we can judge user's concentration level efficiently. The Austrian scientists found that the pupil diameter of people who is in high spiritual level changes 5~10 times a minute. However, it is difficult to measure the pupil diameter.
- Eye graph recognition. By using the Eye recognition algorithm and Perclos algorithm, we can judge whether the user is

tired.

- Using the correlation between pulse variance and spiritual level to detect user's spiritual level.

Considering the system cost and feasibility, we choose the eye graph recognition method to judge the concentration level. Because Perclos algorithm is used for detecting fatigue, we have made some change to it. Our algorithm adds some parameters like sitting posture, head position and mouse status so as to detect the spiritual concentration level.

2.4 Economical manufacture

The selection of components is critical for the implementation of the whole project. We analyzed our system function carefully and give the following descriptions of choosing the components.

The selection of DSP

Based on the requirement of our image processing algorithm, the image processing system can be considered as real time only when it can process more than 25 frames per second. So the image processing system must process one frame within 40nm. In order to save the limited resources for EBox, we choose DSP (TMS320DM642) as the image processor，facilitating the Ebox to complete the spirit detection.

TMS320DM642 is the fastest DSP among the TMS320C6000 family. Based on C64X CPU, it has powerful processing capacity, high flexibility and programmability. Its powerful capability can satisfy our requirement.

The image capture device in our system is CCD camera. The output signal of CCD camera is analog signal which can not input DSP directly, so we use Philips' SAA7115 image decoder to digitalize the signal. SAA7115 is the decoder which can provide low noise and has the capability of converting 2X over sampling analog signal to digital signal. SAA7115 has the SNR 10~15dB, which is the highest among the existing products.

Figure.3 CCD Camera

The DSP development boards sold in the market are often very expensive, but the TMS320DM642 chip itself is cheap. In order to cut down the system cost, we build the PCB board for the DSP system ourselves. If mass produce, it will save more than 50% of the cost compare to that of development board sold in the market.

Though the introduction of DSP will increase the cost of our system, we believe that it is a worthy investment, since the great enhancement of system's performance will definitely make it more competitive in the market.

Figure.4 DSP Board

The selection of microcomputer

Because the need of extension for Ebox, we use microcomputer in our system. Having fully considered the interface of Ebox and the need of extension functions, the use of microcomputer is a cheap and feasible solution.

Considering the system hardware layout, we adopted the microcomputer of ATmega AVR family and designed two MCU, which are called master MCU and Slavery MCU respectively. The Master MCU communicates with the Ebox directly and the Slavery MCU communicates with the Ebox thought its master. All the communications are via Bluetooth.

In consideration of the performance requirement, we chose the ATmega128 as the master MCU and the ATmega32 as the slavery MCU.

The selection of pressure sensor

We designed a plan of using strain foil and ADC ourselves. It is more flexible and cheaper than buying the integrated sensor from the market.

System maintenance

As an embedded system, the hardware cost accounts for big proportion to the total cost. Besides, the system maintenance is also what we concern about. See-Saw has many merits in maintaining the system. Because the core algorithms are in the Ebox which provides good stability, user can update the system software easily. The functions provided by See-Saw are relatively independent. If the periphery component is broken, user can change the correspond component or simply turn off the functions related to this component. This will not affect operation of other functions.

2.5 User experience

We would like to discuss the users' experience of our systems into the following two parts based on the direct user (students) and the supervisor (parents or teachers).

1) Students:

From the perspective of student users, we mainly focused on several advantages below:

- The instructions and manipulations of our system are easy to be learned by primary school or secondary school students, since the human-oriented functions are categorized into several major modules. Moreover, the specially designed users' interface will increase the friendliness of our system and thus make children feel more than comfortable to concentrate their study here, or consider the system as their intimate study partners.

Figure.5 Users' interface

- The process of evaluating the concentration is designed to be invisible to users. Therefore, children will not actually have the feeling of being watched during their study period. What's more, users can easily turn down the function of supervision anytime.
- Users can also enjoy the massage offered by system when they've finished the study of certain period or feel tired. Different from the common massage chair in market currently, the massage function of See-Saw can not only provide the traditional way of manual adjusting the mode, but also can intelligently and automatically adjusting the massage pressure and rhythm with the cadence of the music (The music or songs can be uploaded by users freely.) The well-rounded service will surely provide the users a special way of relaxation.
- The attention or the concentration rate of users are described by HP, which indicates the vitality value frequently used in Computer Games, however, we implement the name SP in our See-Saw system. On the one hand, SP values reflect the real-time supervision result which is the concentration rate of users. On the other hand, users can increase SP values through study of high effectiveness. In a word, Users can treat the See-Saw as an interesting and sensitive game of concentration rather than supervision. During the process of continuous check and increase the SP value, users will naturally become more concentrate with their study or assignments.
- The evaluation and analysis report is accumulated and categorized by the See-Saw system. Users can check the report every week or every month in order to have a better understanding of personal concentration curve or the progress of the study as well. Moreover, the system will also intelligently offer users a recommended schedule, which can greatly help users to arrange their study more scientifically.

2) Parents:

- When the parents are not around, children are tend to be interested in other things rather than study, or the effectiveness of their study will drop significantly. Lots of children admitted that they have such kind of sharp contrast in concentration and effectiveness in studying when their parents are around. Considering such contrast, the special PDA was included in our system, in order to keep in touch with the parents and report the real time studying state to them, which will replace the direct supervision from parents.
- The PDA will send and receive the real-time instructions offered by parents on adjusting the study schedule, or the information send by the See-Saw system on the status of the effectiveness or concentration rate of the students. Having

had such detailed information, parents are able to accomplish the supervision work whenever they want, and thus have more free time and space to accomplish their work.

By checking the concentration curve of their children, parents can also give recommendations or suggestions to children, which will of great significance in helping their build up a more scientific way of study.

2.6 Cost and feasibility

Nowadays, the topic frequently discussed in primary and secondary education is the cultivation of a proper self-study habit. On the one hand, without the parental supervision and an effective learning schedule, students can hardly concentrate on the school work. On the other hand, the inappropriate study habit is the reason for various health problems which will seriously affect the academic pursuit as well as daily life for young students later on.

Recognizing the importance of education, a family with one or more children studying in school or kindergarten usually spends an average 3,522 Yuan (about 440 U.S. dollars) on their education, accounting for nearly a third of the household's annual income. The average expending for families at large cities, which are more likely to spend on education, could be even higher. However, after careful estimation, the cost of our See-Saw is right around 400 dollars. (We consider that the Parents own the PDA, so it was not included in the cost of the system.). With the rapid development of the economy in China and the increasing attention put on education, we believe more families would be willing to spend more money on the cultivation of their children. That is another reason why we are so confident on our system's market prospective.

Table.1 The estimated cost of our See-Saw

Ebox	DSP	LCD	MCU	Camera	Wireless Card	Sensors	Total
$100	$100	$50	$32	$30	$20	$20	$352

Therefore a 352 dollars well-rounded study system is available for most of Chinese families. Similarly, this is also a reasonable price for average American families. Furthermore, no similar product is available in the market now for customers and there is an increasing demand, among most Chinese families, on a well-rounded, intelligent study accessorial system to accompany the student when he or she is alone at home.

With the advanced functions, the accurate data processing, the human-oriented interface as well as the easy operation, the system will provide each child with a higher efficiency, concentration and a good study habit, which can benefit the child in their academic pursuit lifelong.

As a matter of fact, we firmly believe our See-Saw will be widely welcomed by parents and young children, and thus lead a trend of independent and healthy study.

3. Technical Overview

3.1 System description

The project has eight different parts including the Analysis system, the sensor system, the database system, the image processing system, the man-machine conversation system, the massage system, the mobile monitoring system and the fuzzy neural network professional system.

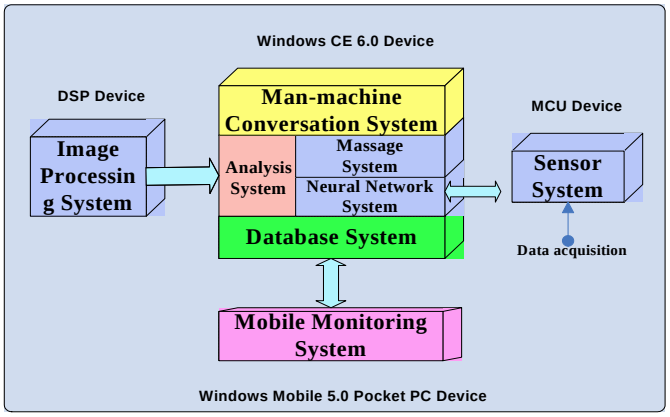

Figure.6 System description

3.1.1 Analysis Module

The analysis module includes three parts to detect the user's concentration states and sitting posture.

- Image processing system on DSP

Using the computer vision technology, the image processing system will collect and extract the user's various features which indicate his or her study states. These features include the student's head position, direction of gaze, eye blinking rate, actual eye closure, and mouth shape. We will pass these features to the Ebox and detect the users' Spiritual Concentration Level (SCL) by analyzing these features.

- The Ebox

As a central control unit, the Ebox judges the user's studying status by analyzing the data from the sensors and the DSP.

- ✧ Ebox judges whether the user's sitting position is reasonable by analyzing the data of the user's sitting position from microcomputer
- ✧ After collecting enough features about user's study states, Ebox will send these features to the fuzzy neural network system to classify the studying status. We design the fuzzy neural network by the fuzzy control theory.
- ✧ Ebox send the studying status to Pocket PC by WLAN, which will enable the parent to know their children's study states all the time without being there.
- ✧ The database will record the user's study state data in Ebox for the administrator to examine the system log.
- ✧ Ebox will give some reasonable advices to the user about his study plan, which will definitely help the user promote study efficiency.

- The sensor system

This part acquires the sitting position data and then sent them to the professional system in Ebox.

3.1.2 Recognition Algorithm

We detect the users' Spiritual Concentration Level (SCL) by analyzing the users' various study states. The detection of the users' concentration state includes the measurement of the student's head position, direction of gaze, eye blinking rate and actual eye closure, mouth shape, and sitting position. We have designed some practical rules to judge the user's concentration level by using these features above. Furthermore, in order to model the user's study state more appropriately, we have used Neutral Network Classifier to identify the user's concentration level.

3.1.2.1 Image feature extraction

- Eye behaviors

Eye behaviors provide significant information about a person's alertness. If such visual behavior can be measured, it will be feasible to predict a student's state of drowsiness, vigilance or attentiveness.

a) Face detection

Complexion is the most distinct feature of face. The algorithm uses YCbCr space to locate face. Compare to RGB color space, value Y which represents brightness in YCbCr space is independent. Thus, using YCbCr space reduces the impact of light. If a pixel's Cb, Cr value satisfy the condition (100<=Cb<=132 and 135<=Cr<=160), it can be classified as complexion. After detecting the face color of the image, we can convert the image to a binary image. Let face color to be 0. Because face takes up big proportion of the image, we can simply detect the biggest connected area of face color. The detected area is the face. The following figure explains the process.

Figure.7 Origin image/Complex detection/Biggest connected area

b) Eye location

The most important thing to locate the eye is to find the eye's plumb coordinate. In order to eliminate the impact of mouth, we simply calculate the upper 1/2 part of the face.

First we calculate plumb grads matrix of the upper part area,

$$G(i, j) = I(i+1, j) - I(i, j)$$

Where I (i, j) represents the intensity of pixel (i, j). Then we project the grads matrix to the horizontal direction,

$$H(j) = \sum_i G(i, j)$$

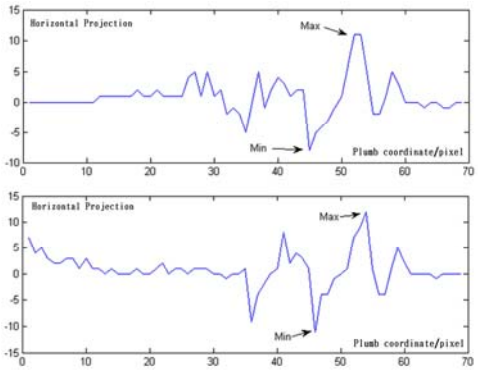

Figure.8 Horizontal projections of left eye and right eye

The result is showed in the following figure:

Since head may incline, the algorithm calculates the plumb grads matrix and the horizontal projection of left eye and right

eye separately. The area between minimal and maximal value of the projection is the plumb location of the eye.

c) Calculate the eye's opening degree

From the plumb coordinate of the eye, we can calculate the opening degree of each image. Since we calculate the SCL every 3 second, there are 30 images to calculate (10 frames acquired per second). We define a term "average eye opening degree":

$$Ha = \sum_{n} Hi / n$$

Hi is the eye opening degree of one image. And we define a term "eye closure proportion" as the total eye close time/total time. We define eye closure that when eye opening degree is smaller than 20% the max eye opening degree. We then use statistical way to calculate this value:

$$CP = \sum_{n} (f(image)) / n$$

Where f(image) is a bool function that judges whether an image is in eye closure state.

d) Spiritual states detection based on eye behaviors

If the eyes remain closed for an abnormal period of time (5-6 sec), the system draws the conclusion that the person is falling asleep and issues a warning signal.

Eye blink rate is also used as the measurement of user's concentration states. We measure the blinking of a student in real time by motion picture. If the user's eye blink rate had exceeded the default value set ahead, the system will consider the user is in fatigue.

- Mouth opening degree

When the user is in a normal, talking or dozing state, his/her mouth opening degree will be quite different. According to this fact, we extract the user's mouth shape and use the mouth open degree as the feature to detect the user's spirit states

a) Mouth location

Using similar methods described in the first section, we can locate the position of the mouth. We compute the plumb grads matrix of lower 1/2 part the image and then project it to the horizontal direction. The area between minimal and maximal value of the projection is the plumb location of the mouth.

b) Spiritual states detection based on mouth geometry character

After obtaining the user's mouth region, we analyze the height of mouth area to decide on the user's spiritual state.

Compared with mouth normal state, the mouth shape while talking and dozing is quite different. As a man speaks his mouth' shape will change continuously. Dozing in particular, the mouth is wide open while at normal condition the mouth is hardly open. When we detect the user's mouth shape is not in normal state, we could conclude the user is dozing or talking. All of these phenomena are forbidden to student under study conditions, so the system will send out the alert signal.

- Face orientation

The movement of head can indicate the user's concentration level. To measure the head motion behaviors, we need to locate the head position. We use the geometric center of the face to represent the head position roughly. Because we can not use one image to find the motion behaviors, the algorithm uses several numbers of images to calculate head motion behaviors. We define the following function to calculate head motion behaviors.

$$HM = (Dx + Dy)/2,\ Dx = \sum_{n} (x_i - x)^2 / n,\ Dy = \sum_{n} (y_i - y)^2 / n$$

Where Dx and Dy are the variances of coordinate x, y. HM represents the degree of head motion behaviors.

If the value of HM varies significantly for a period, it is almost in the case that the user is not concentrating on study.

3.1.2.2 Sitting posture analysis

The user's sitting position will indicate much information about his spirit states. If the sitting position always changes, we think the user must have a low concentration level. So identifying the users' sitting posture is one of our system important functions. With four sensors located in the chair, we could track the user's sitting position in real time.

The detection of sitting posture is through pressure sensor and infrared sensor.

We put four strain foils on the chair like the figure shows. According to the position distribution of sensors and the pressures on each sensor, we can calculate the position of bar center. From the infrared sensor, we can measure the distance from the user to the desk. The suitable distance between the user and the desk is about 10 CM. If that distance greater than 25 CM or smaller than 5 CM for a long time, it may cause crookback or myopia. If the user's sitting position is not correct or changes greatly for a long time, we will warn him of this situation.

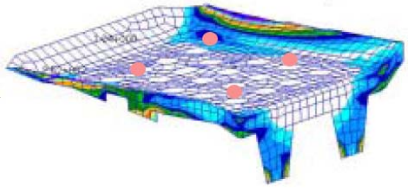

Figure.9 Sitting position detector

3.1.2.3 Natural Network Classifier

As discussed above, after extracting various features of the user's study state, we use many hand-crafted rules to judge the user's concentration level, which has some obvious disadvantages. First, writing rules manually requires an expert knowledge of the psychology and physiology. Second, the man-crated rule is actually linear function which is not the best way to decide human's complex concentration level.

Due to these disadvantages of hand-crafted rules, neural network classifier, which is better than other classifier in nonlinear model recognition, is used to learn the prediction of the user's spirit state from a large amount of training data.

- Feature Selection

Human's concentration state can be represented by various physical behaviors including the user's head position, eye blinking rate and actual eye closure, and mouth shape. So we develop the idea to input features representing these characteristics above into the neural network to train a better classifier.

As we all know, when people are in different spiritual states e.g. Vigor, doze or sleep, the shapes of their eye and mouth are quite different. The maximum height Hem of eye and the maximum height Hmm of mouth can indicate the user's eye and mouth opening degree. Moreover, we notice that the proportion of the total time that the user's eye is closed in a period of time is a good indication of the user's concentration level. So we define them as features for the Neural Network.

Also, the movement of head is closed related to the user's concentration level. If one's head behavior changes significantly for a certain period of time, the user is probably not concentrating on study. So we define it as another feature.

Moreover, the user's sitting position will indicate much information of spirit states. We use the pressure sensor to get the description of the user's sitting position and input it to the neutral network as the fifth feature.

Every 3 seconds, we use the DSP to process 30 face images of the user, the pressure sensor to track the user's sitting position, and extract these five features to make up an input vector Z:

Z = (Heye, Hm, Teye, Var, Psit)

Heye: the average of eye height

Hm: the average of mouth height

Teye: the proportion of total time when eye height is below the 20% of the maximum eye height.

Var: variances of coordinate of the head center

Psit: the description value of the user's sitting position from the sensor.

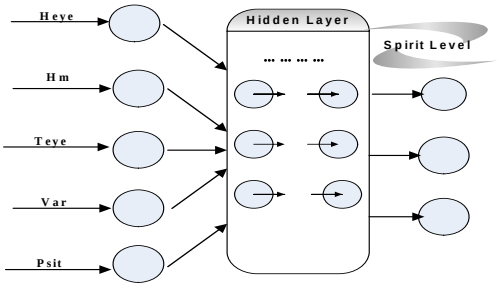

Figure.10 BP Network structure

- Neural Network structure

BP neural network is the most popular artificial neutral network. It has been developing into a classical model in the field of industry intelligent control. So we adopt the BP neural network to identify the users' spiritual states.

The training process, which takes much time, is conducted on the server offline. Once we have the trained neutral network classifier, we could use it to classify the user's spirit state in real time in the Ebox.

In our design, BP neural network has three layers structures in fig.4. Input layer has 5 nodes, representing five features of spirit characteristic. Hiding layer has 10 nodes. Output layer has 3 nodes which represent three different spirit states.

Transfer function is a sigmoid one: $\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$

The criterion function is: $E(W) = \frac{1}{2} \| Y - \bar{Y} \|^2 = \frac{1}{2} \sum_{k=1}^{nM} (Y_k - \bar{Y}_k)^2$

$\bar{Y}$ is the output of network and Y is the expected output of the network.

We use statistic data of user's study performance parameter to train the neural network. According to our testing experiment, the accessorial system can predict the user's spirit and concentration level accurately with the combination of the man-crafted rules and ANN-based classifier in real time.

3.1.3 Microcomputer System

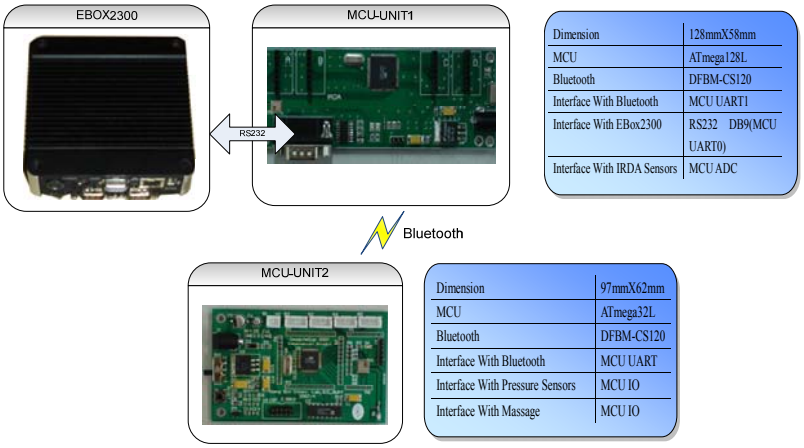

Figure.11 MCU System

From the figure above, there are two parts of the microcomputer

MCU-PART1: The microcomputer which uses ATmega128L as its core has the functions of infrared distance measurement and Bluetooth communication. The touch screen controller uses ADS7843 chip and connects MCU with SPI interface. The infrared distance measurement module uses MAX4250 operational amplifier to amplify the current of infrared incept pipe and uses ADC to collects the data. The Bluetooth module uses DFBM-CS120 as its core and works in Serial Port Profile. It communicates with microcomputer through UART.

MCU-PART2: The microcomputer which uses ATmega32L as its core has the functions of Bluetooth communication, Data collection of Pressure sensors and massage control.

Table 2 Sensors description

Sensor type	Description		Function
Pressure Sensor	HU-101		Convert the pressure value the voltage signal.
Infrared distance sensor	Emission module JMP-BE-1210		Measure the distance between the user to the desk
	Reception module JMP-BE-1310		

3.1.4 Massage system

See-Saw has massage function which helps reduce user's fatigue. The massage patch of "National" can accelerate the blood circulation and speedup the reduction of fatigue. The patch can be controlled by Ebox directly and user can change the massage intensity easily through the control panel. Besides, the massage has the music mode that follows the rhythm of music. Firstly, Ebox addresses the music with

FFT and then classifies the music in low frequency, intermediate frequency and high frequency. Figure.12 Massage device

It will then calculate the average intensity value of each frequency domain as the control signal for the microcomputer and control the massage intensity according to the frequency domain that user has chosen.

3.1.5 Database

One goal of our system is log the long term study status of the student. So we can see whether the student improves his or her average concentration level. From the data collected, we can also find the student's study habit. For example, from the SCL curve of the day, we can see when the student is most efficient. Thus the system can provide suggestions for the student.

3.1.5.1 Database structure

The database of our system is based on Microsoft SQL server 2005. The following figure shows the structure of the database. The system logs student's status (Average eye open degree, Sitting position, Head movement level and Eye close proportion) from input devices. It also logs the SCL value calculated by the ANN in Table SCL.

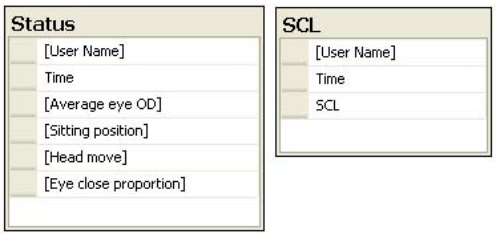

Figure.13 Data table

Because the memory of eBox is limited, we can not store all the information in eBox. So we provide some rules to compress the data.

1) The system stores the data from input devices (DSP and sensors) every 5 seconds. And the system compresses the data by getting the average value every 10 minutes. In the same way, the system compresses the data every day and every month.
2) The system uses the data to train the ANN every month. After training process, the data can be deleted so as to save space.

3.1.5.2 Date analysis

From the data collected, the system can find some rules about the student. From the SCL curve of several days, the system can see what time of the day the student is most efficient. The following curve shows one example:

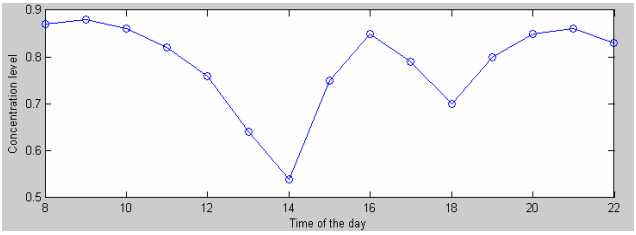

Figure.14 Time of the day VS SCL

From the figure showed above, we can see the student is most efficient in the evening. So the system can advise the student to do the most important task in the evening. Similarly, the student may be advised to relax in the noon, when he is not so concentrated. The system can also find the student's concentration span, so it can advise student to rest when he is tired.

3.1.6 Mobile Monitoring System for Pocket PC

The Mobile Monitoring System (MMS) is the client software in our system to help the user's parent acquire children's studying status，As the limitation of the hardware and software of Pocket PC, the MMS for Pocket PC is designed to meet the following requirements:

- The MMS provides minimum interaction with players.
- The MMS provides friendly interface so that parents can use the software without help.
- The MMS should take low resources on the PPC, which includes: CPU rate, memory size and the network bandwidth.
- The MMS can run on the background to notify the user's parent about their children's studying status.

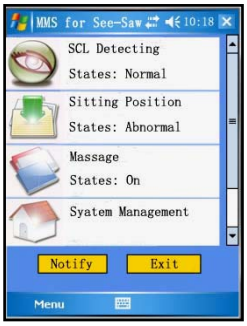

Figure.15 MMS for See-Saw

The main features offered by MMS are obtaining SCL，drawing SPB，getting the sitting state, controlling the notification and massage function of the Ebox.

3.2 System Consideration

As there are two kinds of devices which we developed for students and parents, which platforms to run on the different

devices is a critical problem in our design. There are a lot of candidates under selection: Windows CE, Linux, Symbian OS and Palm OS. Hence, we listed some considerations to help us to figure out our target platform.

- The target platform can be run under the two kinds of target devices and can be competent to deal with the difference between mobile and embedded circumstance.
- The development of target platform is uniform and easy regardless of the hardware difference. In other words, the language used to develop and the development environment should be the same and the development environment can directly support build, debug and deploy on the target platform.
- The platform and the development environment provide sufficient, reliable and scalable functionalities exposed to our clients and have a broad customer especially on MMS so that it can be easily accepted in the market.

After careful tradeoffs among different platforms, we finally choose Windows CE as our target platform according. To run application on Windows CE, we need to build an appropriate OS image in the Ebox firstly. Considering the function of the application, this step involves the identification of the framework, drivers to the related devices, classes and libraries used in the application. Those essential components must be included in the Windows CE image. However, because of the memory limitation for Ebox, the Windows CE image should also be compact to ensure adequate space for the applications. The indispensable components included in the image are listed below:

- .NET CF 2.0 – A compact version of .NET Framework provides extensive classes help to build more reliable and scalable program.
- . VS2005 CoreCon – A series of program provided by Visual Studio 2005 to enable deployment and debugging with the target Windows CE OS under VS2005.
- Core OS Services: The serial port support, USB Host Support, debugging tools and power management was chosen as the core OS services. These components are essential to ensure Ebox works normally.
- GDI+ Support – Although the Windows Forms based-on the .NET CF 2.0 supplies the basic windows forms control such as button, labels , etc, we have to extent this controls under the support of GDI+ in order to achieve better UI experience.
- Third party component: This component includes ICOP_Vortex86_60B_BSP and our application was added to the OS image under this category.

3.3 Development Tools

In terms of design, we used Microsoft Project such as Microsoft Word and Microsoft Visio to document generation, and diagram creation. In our project, the following tools were also used in developed our system:

1. Platform Builder:

Platform Builder is an advantage tool to build the image for the Ebox. Various tools in Platform Builder were frequently used in course of developing the See-Saw such as the remote file view, the remote process viewer and the remote registry editor.

2. Source insight:

This complier is designed for program on the microcomputer. We developed the hardware program by standard C then download it into the microcomputer to run the data acquisition and controlling function.

3. Microsoft Visual Studio 2005:

Microsoft Visual Studio 2005 was used to develop our application. The language we use is C# and C++. They are more convenient for us to develop an application which has a user friendly interface.

4. Code Composer Studio:

We use the Code Composer Studio to develop our image processing application with standard C.

5. Windows Mobile 5.0:

As we have no real devices of Pocket PC, we developed and debugged our MMS under the Windows Mobile 5.0 Pocket PC simulator including in Windows Mobile 5.0 Pocket PC SDK

3.4 Testing

The following figures show our testing environment.

Figure.16 System structure

Figure. 17 Slavery MCU and Pressure sensors

- **The test of neural network**

In our experiment, we use 60 samples of the user's study behavior features to train the neural network. After training neural network classifier, we conduct an experiment in which 30 set of user's study states are classified. Results of the experiment are very ideal, and the rate of right classifying study state is more than 80%. The following figure shows the declining of mean-squared error with time.

According to our testing experiment, the accessorial system can predict the user's spirit and concentration level accurately with the combination of the man-crafted rules and ANN-based classifier in real time.

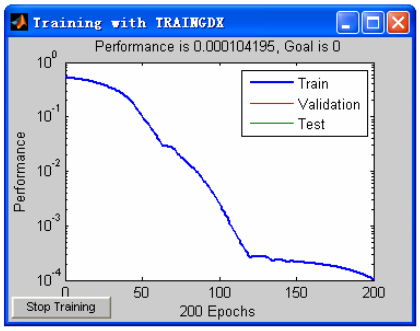

Figure. 18 mean-squared error

- **Concentration level detection test**

Based on the neural network trained, we did the following actual concentration level test. A student used our system to study about 40 minutes. He lost his attention for about 10 minutes on purpose. The figure and the data table below show the result of the test.

Table.3 Testing sample data

Time (min)	Heye	Hm	Teye	Var	Psit	SCL
5	0.78	0.45	0.24	0.45	0.12	0.63
10	0.82	0.32	0.19	0.26	0.07	0.78
15	0.85	0.47	0.32	0.62	0.21	0.45
25	0.62	0.63	0.21	0.72	0.19	0.68
30	0.72	0.67	0.18	0.24	0.05	0.79
35	0.76	0.35	0.18	0.25	0.16	0.76
40	0.79	0.68	0.19	0.42	0.1	0.78

Figure. 19 SCL testing result

The result shows that the user had a low concentration period, when the concentration level fell below 0.5. It is correspond with user's actual study performance.

- **Sitting position detection test**

The calculation of sitting position relies on the pressure value of the 4 Pressure sensors. The algorithm implemented in the Ebox will calculate the barycenter. Following table shows a set of testing data.

Table. 4 Sitting position testing data

Time (min)	F1	F2	F3	F4	Center	Offset
5	0.34	0.45	0.23	0.24	(12,15)	3
10	0.56	0.43	0.76	0.38	(16,14)	1.4
15	0.35	0.55	0.38	0.54	(6,19)	11.4
20	0.62	0.28	0.54	0.32	(17,23)	9.2
25	0.52	0.36	0.42	0.35	(13,12)	4.5
30	0.35	0.53	0.36	0.45	(15,25)	10
35	0.24	0.63	0.43	0.26	(14,17)	2.5
40	0.53	0.35	0.21	0.62	(5,14)	10.4

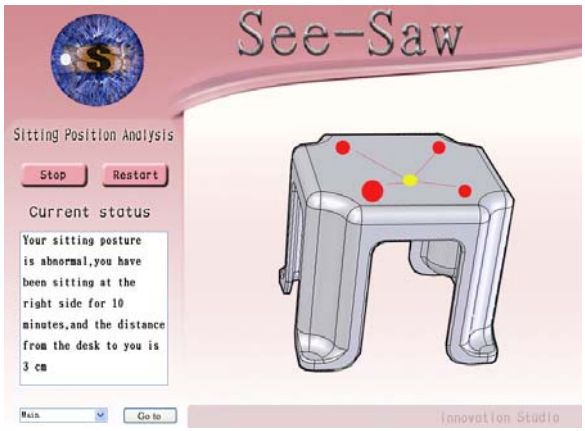

Figure. 20 Sitting position testing

From the result, the position offset excesses 10 CM at 15, 30, 40 minutes, when the system gave warning signal to the user.

- **Database test**

With the data collected from the sensors, the database will provide us with lots of information. It also has some basic analysis function. The following figure shows an analysis of the lowest concentration level time. The database statistics the time when the user is least concentrate from May 2 to May 10. It clearly shows that the user has his lowest concentration level in the noon, so the system will advise he is relax in the noon.

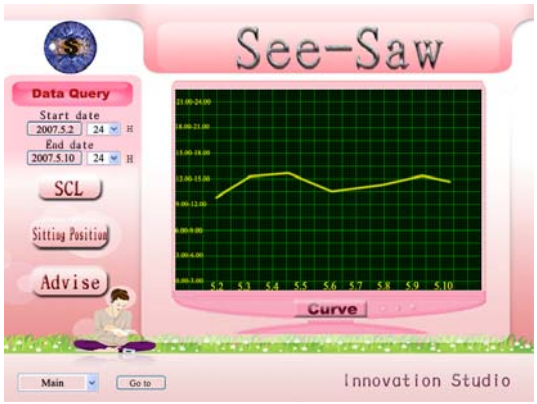

Figure. 21 Database testing

4. Team organization

- **Team organization**

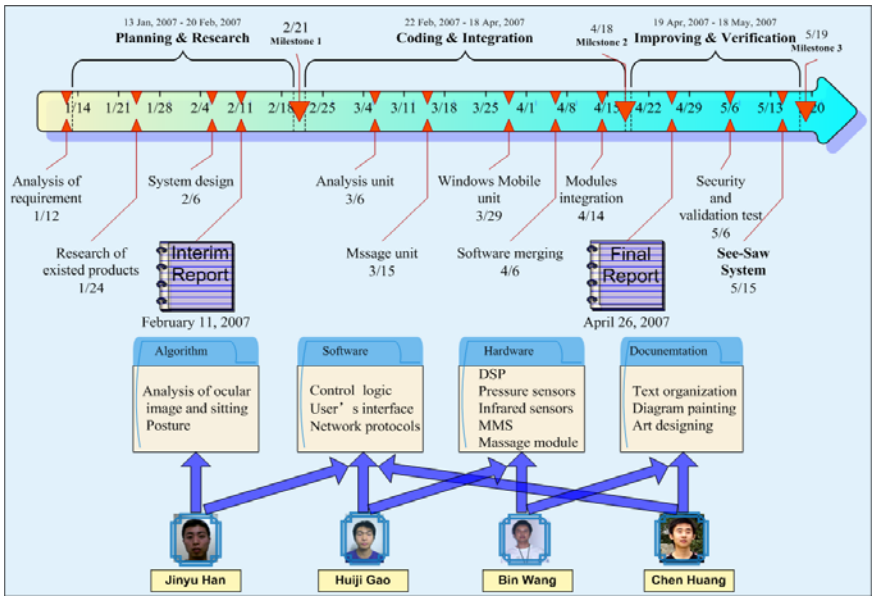

Figure.22 Team organization

- **Project status**

After five months close collaboration, our team have completed many valuable works and presented this intelligent system "See-Saw". We have implemented the functions of SCL detection, Massage module, Database，sitting position detection, and statistical analysis module. We have completed the design of the DSP board and put it into industrial manufacture.

Due to the lack of a real device of Pocket PC, we only simulated the Mobile Monitoring System using the Windows Mobile 5.0 Pocket PC SDK. Moreover, we need have to collect more user statistical data of his study status to further improve our system's accuracy.

5. Summary and future wok

The See-Saw is an automatic, intelligent, reliable, and easy-to-use study accessorial system to solve various study problems confronted by the students. The system provides comprehensive and intelligent solutions to the students, parents and educators and can be quickly implemented in the real world:

- The system could intelligently keep track of the user's concentration level in real time and warn the user about his or her distraction while studying.
- Wireless technology helps the parents use mobile devices such as PDA to acquire their children's study status easily and quickly whenever and where they are.
- The sitting position detection module is an effective solution to prevent the children from developing the unhealthy sitting habits which are very likely to cause other health problems such as myopia or kyphosis.
- See-Saw's massage function is very effective in reducing the user's fatigue while study. It can accelerate the blood circulation and speedup the reduction of fatigue.
- The incorporation of the statistical module enables the parents and educators to have a more comprehensive understanding of the students' study habits.
- The system is highly automatic and intelligent agent which could adjust the user to cultivate efficient study habits with as little interruption as possible.

Although we have worked very hard to make "See-Saw" an intelligent and reliable companion for our children students. A lot more work need be done in the future. We will continue to enhance our system so that it can be accepted in the future market and serve its purpose more successfully.

- More accurate predication of the user's spirit status. Through the continual improvement of the spirit detection algorithm, we will further increase the See-Saw's predication ability.
- SMS supported. For some devices without network capability, Short Message Sending may be a good way for the parents to control the See-Saw away from home.
- More effective and scientific solutions to enhance users' concentration level. At present, See-Saw could give out simple sound signal or music to warn the user of his or her distraction and do massage for the user. Our next work is to incorporate the Magnetic Stimulation to Reduce the user's Fatigue while study and other effective methods to enhance the user's concentration.
- Central server to connection with all the See-Saws in a specific area. With a central server to manage and analysis all the students' study status data, our educators are able to get more comprehensive understanding of the students' study status in this area.

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