A Content-Based Image Retrieval System for Outdoor Ecology Learning: A Firefly Watching System

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Abstract

In this paper, we devote to provide teachers and students with short-range wireless learning environment. The wireless learning platform consists of wireless handheld devices (PDA, notebook, etc.) carried by the guide and learners. A Content-based image retrieval system (CBIR) is constructed to provide learner with required information using image recognition and wireless transmission technologies, such that the objective of outdoor ecology learning can be achieved. A firefly database is used as an instance to illustrate the operations of CBIR system. Instead of learning from textbook, a real firefly in natural environment can be observed and learned through digital camera and image recognition system. During the learning activity, the teacher can use this CBIR system to control the learning progress, evaluate the learning effects and provide necessary assistances to students in order to have a flourish learning environment.

Keyword: *Content-Based Retrieval System, Wireless Communication, Mobile Learning.*

1. Introduction

Due to the wireless technology become popular, commercial products such as mobile phone, WLAN card and PDA have made its ways in communication markets. If the wireless communication technology can be applied to the learning process, there will be a profound impact of current learning models. In this paper, we propose to design and implement the image recognition core technology and construct a mobile content-based image retrieval system. The image recognition system includes image preprocessing, feature extraction and pattern matching three stages. The task of image preprocessing comprise use interaction, image blurring and image normalization. In the stage of feature extraction, we have developed and implemented methods of block average, principal component analysis (PCA) and kernel-based PCA to compute the discriminant feature vectors. Finally, the nearest neighbor rule is applied to perform pattern matching and similarity ranking. The results will be fed back to user through graphic user interface (GUI). The scenario of the learning assistant system is as follows. A digital camera and a wireless LAN card are integrated into a handheld device (PDA). In client side, after student takes pictures of firefly from outdoor scene through digital camera, the captured image will be sent to the server side of teacher's notebook. In the server side, the content-based image retrieval system can be used to retrieve the relevant information of the captured image. By browsing firefly images with similar shapes, students can learn knowledge of observed image through comparing the difference of similar images. This learning activity will help student's learning process.

The constructed content-based image retrieval system will be integrated with the mobile bird watching learning system into an outdoor nature scene learning system. This platform has not only conventional functionality, such as examination and reading activities between teacher and students, but also provided a mobile learning environment which can be used to communicate with a moving teacher or students. By using the carried wireless equipment, students can interact with teachers and classmate on remote cite. Using this platform, teacher and students can devote themselves to teaching, learning, evaluate and discussion activities. Through vigorous and lively learning environment, the motivation of learning and the performance of learning can be increased.

The remaining sections are organized as follows. The basic idea and the fundamental theory will be discussed in Section 2. In Section 3, we will describe the entire system architecture. The processing steps and functions of each block will be described in Section 4 in detail. Section 5 is the implemented system and experimental results. Section 6 concludes this paper.

2. Basic Idea and Theory

In this paper, we attempt to develop a mobile firefly-watching learning (FWL) system for supporting the independent learning. The operations of FWL are based on wireless technology and content-based image retrieval system, such that a mobile-learning environment can be constructed. Through this system, we could learn the family, name, ecology, and activity behavior of firefly at any-time and any-where. Furthermore, we could take notes during the firefly-watching activity and upload the note into teacher's mobile device through WLAN. Finally, teacher's comments will return to each learner's handheld device through wireless internet again. All these functions constitute the mobile firefly-watching learning system. Each learner can independently study and learn the ecological firefly-information in the outdoor environment. In addition, the instructor or teacher may properly help with learners. One important goal of this paper is to keep the nature duty of preserving the ecological environment. Three knowledge domains are considered in the FWL system, the content domain is the mobile firefly-watching, the learning domain is the self-regulation learning, and the technique domain is the wireless transmission and content-based image retrieval system. To integrate with three different knowledge domains, our outdoor mobile firefly-watching learning system for supporting the self-regulation learning model is developed. This new FWL system is to offer a new learning behavior of the outdoor nature classroom.

The spirit of the education is to help the learners with *self-confident*, *technology*, and *knowledge* when they try to seek the solutions. Then the learners can participate their own learning independently and actively. The characteristics of independent learning model are learning knowledge more independently, and acquiring information more easily. After that, the learners can extend their learning ability. Initially, the learner has no independent learning ability. In this circumstance, the scaffolding learning model helps and supports the beginner to learn knowledge easily. When the learner has enough knowledge and self-learn ability to overcome the problem, the instructor may relinquish control of decision making for the leaner.

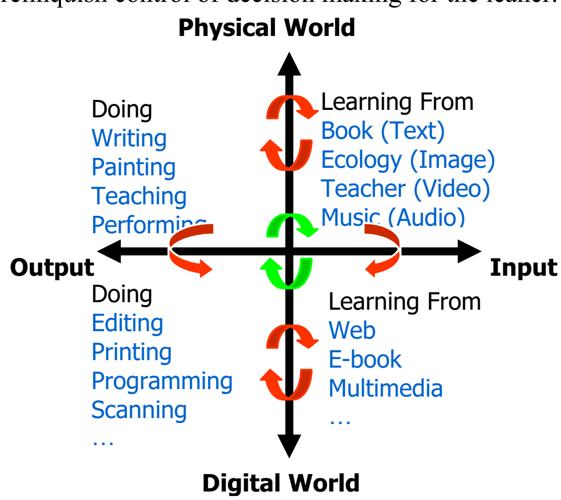

Figure 1: The proposed firefly watching system can be used as a bridge of inputs between physical and digital world.

To give a concrete description of motivation of the proposed FWL system, Fig. 1 illustrate learning process in physical and digital world. In Fig. 1, the x-axis denotes the inputs (materials) to learner and the outputs (behavior) of learner. On the other hand, the y-axis denotes the physical and digital worlds. In conventional learning model, the input and output for a learner are all in physical world. In most cases, the input is book while the output is assessed by examination. The current learning technology tries to use digital technology to assist learning. In most cases, the inputs and outputs are in digital form. However, there are a huge amount of knowledge exists in physical world. It would be a better learning approach, if knowledge comes from both digital and physical worlds. The proposed content-based image retrieval technology is used to transform physical image input into digital knowledge, so the rich ecology knowledge can be learned in a convenient way through digital and wireless technology.

The major challenge of the FWL system is the content-based image retrieval technique [2, 3, 4] in our designed system to support the independent learning model. The learner could use content-based image retrieval system to easily acquire the firefly information without giving any data about the characteristic during the firefly-watching activity. Meanwhile, the learner could observe the difference from the fireflies with many similar features. The FWL system is designed to help learner to have the ability of the self-determination, the self-checking, and the self-modification. Therefore, the traditional instructor role could relinquish control of decision making. The role of wireless network technology is to provide the e-knowledge and mobile learning knowledge. About some immediacy knowledge, it is possible for us to acquire information, even knowledge anywhere, anytime, in the near future based on mobile learning systems.

3. System Architecture

In the proposed mobile content-based image retrieval system, the image recognition technology is used to retrieve the information of the captured image from designed image databases. The system architecture is depicted in Fig. 2. The three main processing stages are preprocessing, feature extraction and pattern matching. The objective of the image preprocessing stage is to segment the object and to enhance the quality of image. To simply the complexity of the system and to make the system more interesting for learner, the objected is segmented using user interaction. User marks the head, tail, left and right side of firefly. The segmented image is then normalized to an upright and fixed sized image for feature extraction in the next stage.

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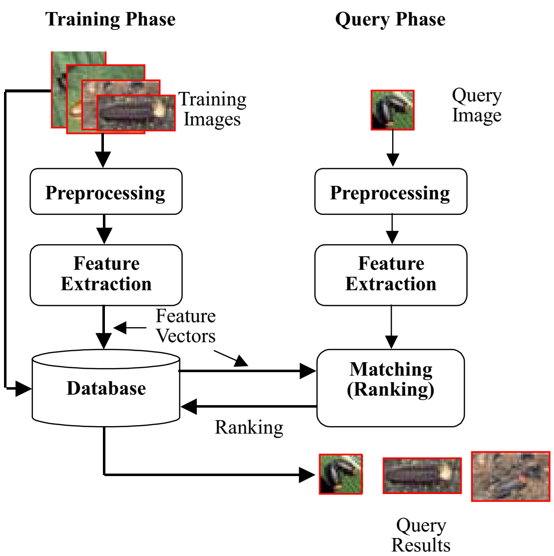

Figure 2: System architecture of the proposed content-based image retrieval system

4. The Content-Based Image Retrieval System

The feature vectors are computed using statistical-based approach. we use three different approaches to compute feature vector of query image. These three approaches are block average, PCA and kernel PCA. In block average approach, an image is divided into multiple image blocks; the mean value of each block is then computed as a feature vector. The square errors between blocks of source and destination images then can be treated as the dissimilarity between source and destination images. The dissimilarity between query image and each database image is computed individually and sorted such that the images in database can be order according the visual similarity. The major advantages of the block average are simple and efficient.

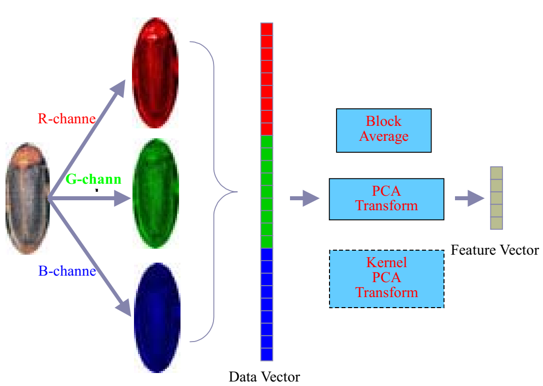

Figure 3: Process of Feature Computation.

The second approach to compute feature vector is based on principal component analysis. A set of representative images are selected compute projection axes such that image projected on these axes will have largest variance and thus preserve most of the energy. Due to image samples have the property of high dimension and small number of samples, the computation of covariance matrix and eigen-pairs will cause problems. To compute PCA of image samples, we use the following procedures. To perform PCA of image samples, each image is first normalized into fixed size n. Assume there are total m samples, then these image samples can be represented as a matrix A with size $m*n$. The covariance matrix can be computed as $(A*A')$ with size $n*n$. However, the size $n*n$ are too large to compute for personal computer or handheld devices. Thus, we use sample covariance $(A'*A)$ with size $m*m$ to perform image analysis. Let Q denote the computed eigenvector matrix, then $(A'*A)*Q = \lambda Q$. Each column vector of Q then can be orthogonalized and normalized to form principal projection axes. By projecting image samples into projection axes, the dimension of sample can be reduced significantly.

In the third feature computation approach, the PCA approach is further improved by kernel PCA approach. In PCA transform, each entry in sample covariance is inner product of two images. Thus PCA is a linear transform. However, for the purpose of image recognition, the linear transform can be transformed into nonlinear transform by replacing the inner product with nonlinear kernel function (eg: Gaussian Function). So, the non-linear separable feature vectors will become linear separable in nonlinear space. With kernel PCA, the accuracy of image retrieval system can be increased.

5. Experimental Results

To validate the proposed approach, the system is implemented and test in elementary schools in Taiwan. The experiments are setup as follows. In the database, there are totally 46 fireflies. In database, images of egg, larva and imago of each firefly are stored. The features of each firefly are pre-computed and stored in database. When a test image is input to the system, the preprocessing, feature extraction process as mentioned in previous section are applied to compute the feature. The features are applied to compare with images in database. The matching degree and ranking are computed. The results are then output to screen according to the ranking of similarity.

The proposed system is implemented in a client-server manner. The client side device is a PDA while the server side device is a notebook. Fig. 4 shows some snapshots of the implemented server system. In Fig. 4, a test image is input to the system. The firefly images in database are unordered. After performing the matching process, the result is shown in Fig. 4. The correct result is shown in the first row and the third column of the right parts in 4. The learner can click the firefly images shown in right part of Fig. 4. When the learner chooses the image in the first row and the third column, the detail information can be observed by the learner.

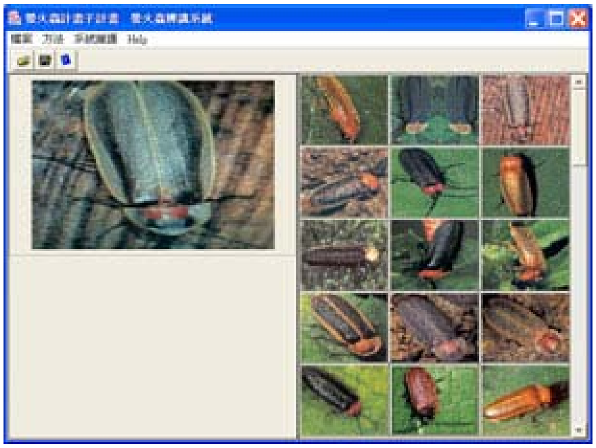

Figure 4: Snapshot of the implemented system. Results of the FWL system is shown in the right parts

To provide some field-test results of the system, the experiment for formative evaluation is conducted in the fall semester of 2003. One elementary school is chosen from the three participant schools of our previous study [1]. A class of 20 five-graders is randomly assigned into pairs as teams.

The experiment consists of four firefly-watching activities of independent learning. Before the experiment, the students have to experience two firefly-watching activities lead by guiders from local firefly societies. After the training and modeling, students are able to explore and identify the fireflies they watch in the nature environment on their own with the help of our system or guidebook in the next four activities.

Pretest and posttest are conducted to each team before and after the activity on PDA. The tests are based on the key features of species might appear in the firefly-watching site. Team performance on the tests is based on the percentage of correctness.

The firefly-watching procedures of independent learning are:

1. *Self-selection process:* The team learners find the target firefly of interest and take a close picture of it.
2. *Self-determination process:* After that, the learners transfer the picture and give searching conditions based on features they observed to the system. According to the searching results, the learners are able to determine the name of the observed firefly.
3. *Self-modification process:* The system further suggests the possible name list of the observed firefly through image mapping technique. This gives the chance for the learners to modify their previous searching conditions and conclude to different determination.
4. *Self-checking process*: The learner records their learning process to the journal, including picture of the searching conditions, searching results, suggestions from image mapping, and each determination they make. The information recorded on the journal allows the learners to check for correctness after the activity.
5. The data collected for evaluation includes journals and videotapes of each activity. Data are compared between activities, teams, and species to evaluate the growth of students' ability of independent learning and how they benefit from the system.

6. Conclusion

In this paper, we develop an independent-learning-based mobile firefly-watching learning system, which aims to construct an outdoor mobility-learning activity under the up-to-date wireless technology. The proposed FWL system is designed on the wireless mobile ad-hoc network. The major spirit of our system is to let the learners could take actions dealing with their own learning. Via the content-based image retrieval techniques, all of beginners to go outside for firefly watching can be faster and easier to acquire the information of firefly you observed. One other contribution of this system is the nature journal subsystem, which is an integrated learning method including the independent learning method and the brand-new wireless networks information technology. This work aims to provide an excellent experience for the future classroom learning platforms.

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