HCI for m-Learning in Image Processing by Handhelds

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Abstract. The objective of this paper is to present a part of m-learning process developed at our University at the Faculty of Electrical Engineering in the field of image processing. The basic courses in this field are on the Faculty Web. The multimedia illustration of the basic methods in image processing is realized both on Desktop PC and on handheld (PDA) devices equipped with cameras and could be used individually by each student. The students can take photos with the cameras and interactively learn about the results of the image processing algorithms. For efficient use of the handheld devices we developed a suitable HCI. According to the surveys with 20 students at the last year of study, their experience with our specially developed tools for m-learning is very positive.

Keywords: Mobile learning, image processing, HCI, Gabor 2D, Pocket PC.

1 Introduction

Pocket PCs have become very popular in the last few years due to the increase of availability of different wireless services [1][2][3][4].

Mobile learning (m-learning) is defined as the ability of using handheld devices to access learning information like electronic books and other materials anytime and anywhere. M-learning has received a lot of attention these days as the next wave of learning [5][6][7].

The possibility of the handheld devices, like handhelds' mobility and touch-screen interactivity made them ideal for laboratory, classroom and terrain use. For this purpose an application which enables students to analyze images using the Gabor 2D transformation was developed. The students can also view the results of the transformation of images captured from camera, or from existing previously saved bitmap images.

In this paper, we will present our Human Computer Interface (HCI) for m-learning in Image Processing by Handhelds by illustrating one of the standard methods in this field. The multimedia illustration is available on handheld devices such as PDA devices and could be used individually by each student. It is also available on Desktop PC. The related work is presented in Section 2. The Section 3 gives the design and implementation of our application. Section 4 gives some examples of images captured from camera and from BMP file, which are used for transformation. In Section 5 the

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evaluation study is presented while the results of the evaluation are presented in Section 6. Section 7 concludes the paper.

2 Related Work

The theory-informed design, implementation and evaluation of a handheld learning device is described in [8], which is intended to support 9-11 aged children to capture everyday events such as images, notes and sounds, to relate them to web-based learning resources, to organize these into a visual knowledge map, and to share them with other learners and teachers. Our work is intended for the students in faculties who learned the subjects in signal processing.

The experience of designing a collaborative learning activity for a traditional historical/cultural museum is described in [9]. Based on a "Mystery in the Museum" story, a group of students collaborated to solve a mystery inside the museum, interacting through mobile devices. The application described in this paper is a puzzle game, and can be used for educational purposes, but with some limitations. Unlike this, our application is intended for students which can interactively use the interface by capturing images of landscapes using the Pocket PC camera.

In [10] some special issues in processing and streaming lecture videos were addressed. New approach for real-time content analysis and adaptive transmission of these videos over wireless networks is proposed. The effectiveness and scalability of the e-learning system was demonstrated. Experimental results of adaptive transmission of instructional videos over 802.11b wireless networks to mobile devices were also given.

The rationale for teaching human-computer interaction, primarily to upper-level undergraduates in computer science and in information sciences and technology is described in [11]. The structural schema and a browser is developed for some case studies. The case-based activities employed in the courses together with the experiences of instructors and students are also given in the paper.

An implementation of the concept of object replication approach for integrating synchronous and asynchronous distributed work using time-line based user interfaces, called Classroom Bridge can be found in [12]. It supports activity awareness by facilitating planning and goal revision in collaborative, project-based middle school science.

Results from a study of an automated capture and access system – e-Class are presented in [13]. The e-Class was designed to capture the materials presented in college lectures for later review by students. In [14] the benefits and challenges of using handheld computers to support learners in creating concept maps (a type of visual outline) were explored. The Pocket PiCoMap, as a learner-centered concept mapping tool for handheld Pocket PCs is presented.

The product named as e - Class was designed to capture the materials presented in college lectures for later review by students. Another comparison of the traditional (classroom) learning and e-learning can be found in [15].

In [16] a project for integration of the handheld machines into the classroom was documented. The design of three learner-centered handheld tools used as a part of a nine-month classroom study involving some eighth grade students is given in [17]. A review of related work identifies some of the challenges of building educational software within the constraints of handheld screens. Two broad design guidelines are presented. The first focuses on decomposing the learning activity and the second focuses on methods for implementing scaffolds.

Like all of these papers, our paper also describes HCI, where the handheld devices are used for image processing.

3 Design and Implementation of Our Application

In this paper we will show the design and implementation of a HCI for support the education process in the field of image processing. The multimedia illustration of the basic methods in image processing (useful for students in faculties which study the signal processing courses) is realized on handheld (PDA) devices equipped with cameras and could be used individually by each student. The students can take photos with the cameras and interactively learn about the results of the image processing algorithms.

During the design process several problems had to be solved; one of them being the method of taking photos with the Pocket PC camera and analyzing individual pixels, while another one was the method of dealing with previously saved images. In the second case, it was necessary to adjust the dimensions of the image to the display of the Pocket PC. The results from the image processing are saved in BMP format and are later displayed by coding HTML pages including the BMP images and Java Scripts for navigating the images obtained from the transformation.

For the image processing application, the Gabor filter method is used and the image is convoluted with a lattice of possibly overlapping banks of Gabor filters [18] at different orientations and frequencies.

The goal of the 2D Gabor transformation [19][20] is to represent a digital image $f(x, y)$, where x and y represent spatial coordinates, either exactly or in some optimal sense (e.g., minimizing the mean squared error between the reconstructed image and the original image) by projecting it onto a set of 2D Gabor elementary functions. For a finite extent image $f(x, y), x = 0,1..., X-1; y = 0,1,..., Y-1$ partitioned into $K \times L$ non-overlapping lattices of size $M \times N$ where it is assumed that $X = KM$ and $Y = LN$, the approximated or reconstructed image $\hat{f}(x, y)$ can be written as

$$\hat{f}(x, y) = \sum_{m=0}^{K-1}\sum_{n=0}^{L-1}\sum_{r=0}^{M-1}\sum_{s=0}^{N-1} a_{mnrs} G_{mnrs}(x, y). \tag{1}$$

In this representation, there are $KM \times LN$ coefficients a_{mnrs}'s that have a symmetry property, i.e., the real part has an even symmetry, and the imaginary part has an odd symmetry. Thus, only half of the coefficients will be sufficient for the image representation. Each Gabor elementary function G_{mnrs}'s in (1) constitutes a sine and cosine wave modulated by a Gaussian window, i.e.

$$G_{mnrs}(x,y) = w(h_1(x) - mM, h_2(y) - nN) \cdot \exp\left(2\pi j\left[\frac{h_1(r)h_1(x)}{M} + \frac{h_2(s)h_2(y)}{N}\right]\right) \quad (2)$$

where $h_1(z) := z - \frac{M-1}{2}$, and $h_2(z) := z - \frac{N-1}{2}$ are introduced to center the Gaussian window at the center of the lattices; parameters M and N define the spatial distance between the centers of the elementary functions, which are usually called the Gabor logons, and $w(x, y)$ is the Gaussian window function of the form

$$w(x,y) = \left(\sqrt{2}\alpha\right)^{\frac{1}{2}}\left(\sqrt{2}\beta\right)^{\frac{1}{2}} \cdot \exp\left[-\pi\left(\alpha^2 x^2 + \beta^2 y^2\right)\right]. \quad (3)$$

The parameters α and β in $w(x, y)$ define the scaling of the Gaussian in the spatial domain along x and y coordinates, respectively. The values of these parameters are typically chosen to be the same, in which case, we get

$$w(x,y) = \left(\sqrt{2}\alpha\right) \cdot \exp\left[-\pi\alpha^2\left(x^2 + y^2\right)\right]. \quad (4)$$

From (4) and (2), it can clearly be seen that the Gabor elementary functions are parameterized for an invariant Gaussian window, which is positioned in fully overlapping Cartesian lattice location $\{x_m, y_m\} = \{mM, nN\}$, where (m, n) is the index for the lattice. The complex exponential that modulates this overlapping Gaussian is parameterized for the Cartesian lattice of 2D spatial frequencies: $\{u_r, v_s\} = \{r/M, s/N\}$ for integer increments of (r, s) spanning their range inside each lattice $[-(M-1)/2, (M-1)/2]$, $[-(N-1)/2, (N-1)/2]$, respectively.

For fixed values of M and N, the choice of the Gaussian scale α determines the amount of effective overlap of the Gabor elementary functions across the neighboring lattice locations. It also determines the required support size (number of pixels) of each Gabor elementary function so that the truncation of the Gaussian tail produces negligible error. Therefore, if the truncation of the Gaussian is done outside each lattice the value of α should be chosen so that most of the energy of the Gaussian window lies inside the lattice. It must also be pointed out that since the image is partitioned into lattices and the Gabor elementary functions for each lattice are all

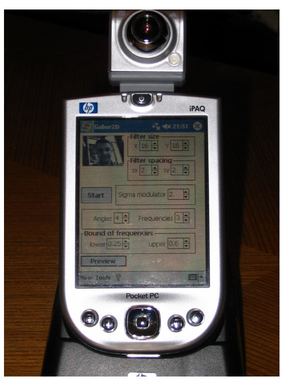


Fig. 1. Preview of the Gabor 2D application on Pocket PC device

centered, only translations that are equal to multiples of the lattice dimensions will result in a simple shifting relation of the transform coefficients.

The corresponding algorithm is implemented in the Gabor 2D application for Pocket PC, which was developed using Microsoft eMbedded Visual C++ 4.0 [21] and Microsoft Pocket PC 2003 SDK [22][23]. The preview of the above application is shown on Fig. 1.

4 Experimental Results

The interface of the Gabor 2D application for Pocket PC is shown on Fig. 2. Here the Gabor 2D parameters, like filter size, filter spacing, sigma modulator, number of angles and frequencies, lower and upper bound of frequencies can be set. The maximum values of the parameters are the following: filter size up to 32x32; filter spacing up to 8x8; sigma modulator up to 10; up to 9 different angles; up to 9 different frequencies; lower and upper bound of frequency up to 10. Greater values are not recommended, because the time needed for image processing can be too long.

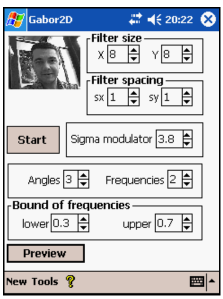


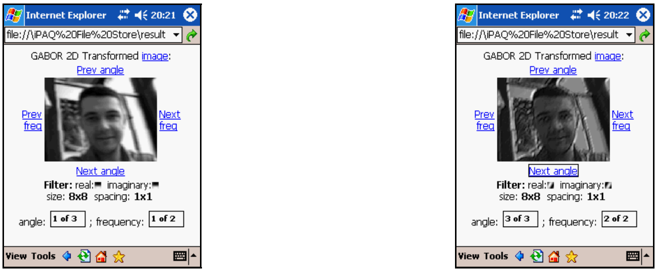
Fig. 2. Gabor 2D application for Pocket PC

Fig. 3. Source image from Pocket PC camera

The image used for the transformation can be captured from the Pocket PC camera or an existing BMP file can be used. These options are available on the Tools menu. The original image and the results of the transformation, together with the filters can be viewed later with a standard web browser. One example image captured from the Pocket PC camera is shown on Fig. 3.

The parameters used for the transformation of this image are the following: 8x8 fitter; 1x1 spacing of the filter; sigma modulator with value 3.8; three angles 0°, 60° and 120°; two frequencies; lower bound of the frequency equal to 0.3 and upper bound of the frequency equal to 0.7. After taking photos with the Pocket PCs, these parameters can be selected by students. In that way, the students can experiment the properties and different outputs of the Gabor 2D filter method.

After applying the Gabor 2D transformation on the image shown on Fig. 3. , we get real and imaginary results from the 8x8 filters for all angles and frequencies. Some of the resultant images are displayed on Fig. 4.



Angle of 0° and lowest frequency Angle of 120° and highest frequency

Fig. 4. Transformations of the image on Fig. 3

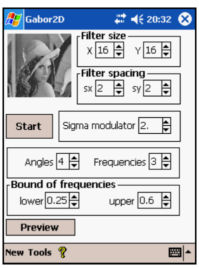
The obtained results can be viewed on appropriate links on the results web pages using the links for choosing angles and frequencies. Also, we can make comparisons with the original and transformed image.

Beside the resultant images, the real and the imaginary part of the filter, the size and the spacing of the filter are also displayed, as well as the selected angle and frequency.

In some cases, it is useful for the professor to give the same picture (as an example for analysis) to the students in order to emphasize some specific points.

In what follows, one more example of Gabor 2D transformation is given, where the used image is from a saved BMP file.

The parameters for processing of this image are shown on Fig. 5.



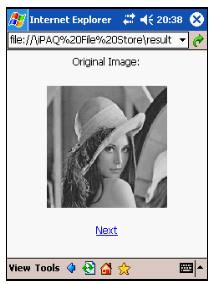


Fig. 5. Gabor 2D application with parameters for the second image

Fig. 6. Source image from BMP file

The image ready for transformation is shown on Fig. 6.

The parameters used for the transformation of this image are the following: 16x16 fitter; 2x2 spacing of the filter; sigma modulator with value 2; four angles 0°, 45°, 90° and 135°; three frequencies; lower bound of the frequency equal to 0.25 and upper bound of the frequency equal to 0.6. Some of the resultant images for these parameters are shown on Fig. 7.

From both transformations we can see that the transformed images look better and more similar as the original for lower frequencies, but for higher frequencies they look darker and less detailed.

Angle of 90° and lowest frequency

Angle of 45° and highest frequency

Fig. 7. Transformations of the image on Fig. 6

5 Evaluation Study

The evaluation was done by questionnaire. Twenty randomly chosen examinees were surveyed anonymously. All of them were students at the 4th year of study at the Faculty of Electrical Engineering at the University “St. Cyril and Methodius” in Skopje – Macedonia, at the Department of Computer Engineering.

For the purposes of the evaluation, the examinees tested the Gabor2D application on Pocket PC devices in the Laboratory of the Faculty for 45 minutes.

5.1 Evaluation Criteria

The criteria by which the evaluation was performed for this particular study are as follows:

- **Familiarity with the educational problem**
  1. Have the students been going on lectures of the signal processing subjects? (possible answers: all, some, none)
  2. Did they pass the exams of those subjects? (possible answers: all, some, none)
- **Functionality of the HCI**
  3. Are they satisfied with the arrangement (design of elements) of the pictures, spins etc. on the screen?
  4. How interactive is the HCI (Could they easily select the parameters of the algorithms on screen)?
- **Usability of HCI**
  5. For which degree, curriculum, group of students etc. this HCI is suitable (appropriate)?
- **Visibility**
  6. Were the results of the processing algorithms clearly displayed?
  7. How much the process of visualization helped students during the studying of their exams?
  8. Do the students like the HCI from the point of view of the quality of visualization?

The questions from 3 to 7 were answered by ranking from 1 to 5, where 1 is lowest, and 5 is highest rank.

6 Results of Evaluation

Based of the survey for the familiarity with the educational problem, the obtained results for both questions are displayed on the Table 1 and 2 respectively as follows:

Table 1. Results of the Question 1

	Number of students	Percent
All subjects	9	45 %
Some of the subjects	11	55%
No one	0	0%

Table 2. Results of the Question 2

	Number of students	Percent
All subjects	7	35%
Some of the subjects	11	55%
No one	2	10%

The functionality of the HCI was evaluated with ranks between 1 and 5 and average results of 4.53 for Question 3 and 4.85 for Question 4 were obtained. It can be seen that the students evaluated the above criteria for functionality with high rank. However, most of the students prefer tapping on the Pocket PC screen using the stylus than typing on the keyboard.

Concerning the usability of this HCI, we provided some comments from a group of students in different fields of study at the Faculty of Electrical Engineering. The basic survey (presented in section 6 in this paper) was provided for the Computer Science group of students. It was also tested with a group of students from Electronics and Telecommunications Department (ETD) as well as a group of students from Control Systems Department (CSD). For the students from ETD the interface was very convenient, while for the students from CSD some additional help about the parameters used for Gabor 2D transformation is welcome.

One of the key evaluation criteria is the visibility, where the students answered on 3 questions.

For the first question the average rank was 4.8. Their explanations were that the application has clear interface and excellent preview of the results.

About the second question, the results were that the interface was not over-laden and they were easily got on the results of the transformation. However, this question is with low rank 3.38 because some of the students had prepared the exams theoretically and more time was needed for preparing. If they would have the application, the theoretical results would be obtained visually for shorter time.

The third question was ranked as shown on the Table 3.

Table 3. Results of the Question 8

	Number of students	Percent
Yes	19	95%
No	0	0%
I don't know	1	5%

As can be seen on Table 3, the HCI from the point of view of the quality of visualization was high ranked.

The explanations of the students were that the application has nice visual presentation of the theory.

General conclusion of the results of the survey is that the program is useful for the exams of signal processing area. For most of the questions the students gave high rank, between 4 and 5.

7 Conclusion

According to the surveys with 20 students at the last year of study, their experience with our specially developed HCI for m-learning is very positive. The students are very interested to be able to interactively understand the theoretical concepts about image processing presented by the professor, during their experiments with different images captured from the Pocket PC cameras. In that way, they can become familiar with the impact that different parameters can have on the image being processed. These examples could be very useful for explaining how Gabor 2D transform is used as pre-processing in image classifiers.

References

1. Pierce, J.S., Mahaney, H.: Opportunistic Annexing for Handheld Devices: Opportunities and Challenges. Georgia Institute of Technology (2004)
2. Fallon, M.A.C.: Handheld Devices: Toward a More Mobile Campus, Syllabus (November 2002) http://www.campus-echnology.com/article.asp?id=6896
3. Laberge, S., Vujosevic.: Building PDA Databases for Wireless and Mobile Development. Wiley Publishing, Inc, Indianapolis, Indiana (2003)
4. Roschelle, J., Pea, R.: A Walk on the WILD Side: How Wireless Handhelds May Change Computer-Supported Collaborative Learning. Int'l J. Cognition and Tecnology 1, 145–168 (2002)
5. Aggarwal, Anil.: Web-based learning and teaching technologies - opportunities and challenges. Idea Group Publishing, Hershey, Pa (2000)
6. Finn, M., Vandenham, N.: The Handheld Classroom: Educational Implications of Mobile Computing, Australian Journal of Emerging Technologies and Society, 2(1) (2004)

7. Kinshuk, Goh, T.: Mobile Adaptation with Multiple Representation Approach as Educational Pedagogy. In: Uhr, W., Esswein, W., Schoop, E., (eds.) Wirtschaftsinformatik, Dresden, Germany (2003)
8. Sharples, M., Corlett, D., Westmancott, O.: The Design and Implementation of a Mobile Learning Resource. In: Personal and Ubiquitous Computing, 6, 220–234. Springer, London (2002)
9. Cabrera1, J.S., Frutos1, H.M., et al.: Mystery in the Museum: Collaborative Learning Activities using Handheld Devices. MobileHCI'05, Salzburg, Austria (September 19-22, 2005)
10. Liu, T., Choudary, C.: Realtime Content Analysis and Adaptive Transmission of Lecture Videos for Mobile Applications. MM'04, New York, USA (October 10-16, 2004)
11. Carroll, J.M., Rosson, M.B.: A Case Library for Teaching Usability Engineering: Design Rationale, Development, and Classroom Experience. ACM Journal on Educational Resources in Computing, Article 3, vol. 5(1), (March 2005)
12. Ganoe, C.H., Somervell, J.P., et al.: Classroom BRIDGE: using collaborative public and desktop timelines to support activity awareness. UIST '03, Vancouver, BC, Canada
13. Brotherton, J.A., Abowd, G.D.: Lessons Learned From eClass:Assessing Automated Capture and Access in the Classroom. ACM Transactions on Computer-Human Interaction 11(2), 121–155 (2004)
14. Luchini, K., Quintana, C., Soloway, E.: Pocket PiCoMap: A Case Study in Designing and Assessing a Handheld Concept Mapping Tool for Learners. CHI 2003, pp. 5–10, Ft. Lauderdale, Florida, USA (April 2003)
15. Zhang, D., Zhao, J.L., et al.: Can e-Learning Replace Classroom Learning?. Communications of the ACM, vol. 47(5) (May 2004)
16. Jipping, M.J, Krikke, J., et al.: Using Handheld Computers in the Classroom: Laboratories and Collaboration on Handheld Machines, SIGCSE 2001 2101 Charlotte, NC, USA (2001)
17. Luchini, K., Quintana, C.: Soloway, Design Guidelines for Learner-Centered Handheld Tools, CHI 2004, Vienna, Austria (April 24–29, 2004)
18. Anderson, D.: Image Object Search Combining Colour With Gabor Wavelet Shape Descriptors; B.Sc., University of Victoria (1997)
19. Ibrahim, A., Azimi-Sadjadi, M.R.: A Fast Learning Algorithm for Gabor Transformation. IEEE Transactions on Image Processing 5(1), 171–175 (1996)
20. Teuner, A., Hosticks, B.J.: Adaptive Gabor transformation for image processing. IEEE Trans. Image Processing 2(1), 112–117 (1993)
21. Microsoft eMbedded Visual C++ 4.0 (Microsoft Corporation 2004) http://msdn.microsoft.com/mobility/othertech/eVisualc/default.aspx
22. Pocket PC Downloads – Power Toys 2004 (Microsoft Corporation, 2004) http://www.microsoft.com/technet/prodtechnol/wce/downloads/ppctoys.mspx#EFAA
23. Windows Mobile Based-Pocket PC (Microsoft Corporation, 2004) http://www.microsoft.com/windowsmobile/pocketpc/default.mspx