Mobile Technology for Illiterate Education

Hassanin Al-Barhamtoshy[1], Sherif Abdou[2] and Mohsen Rashwan[3]

[1]Faculty of Computing, Jeddah, Saudi Arabia, King Abdulaziz University, hassanin@kau.edu.sa
[2]Computers and Information, Cairo University, Faculty of Cairo, Egypt. s.abdou@fci-cu.edu.eg
[3] Faculty of Engineering, Cairo University, Cairo, Egypt. m.rashwan@fci-cu.edu.eg

Abstract: Literacy and adult education are an essential objective for realizing development and increasing production for any country. Egypt is one of the countries that still has high rate of illiteracy is around 30% of the adult population (age range 15-45). In Saudi Arabia the distant regions faces a similar challenge. Traditional literacy classes proved not to be very effective in solving the problem. Meanwhile mobile phones are the fastest growing technology devices worldwide and surprisingly they are used also by people with very low level of literacy. In this paper we introduce a literacy education application for mobile devices that implements an interactive process where the user practices the reading and writing skills with guidance from a dedicated teacher. We introduce novel mobile technologies that can foster the acquisition of reading and writing skills for illiterate citizens using Automatic Speech Recognition (ASR) and Automatic Handwriting Recognition (AHR) techniques. This poses several challenges: first, the speech recognition for an illiterate's reading is expected to have severe miss-pronunciations and deviation from the reference models. Also hand writing training requires dealing with the irregular strokes of the illiterate's handwriting with dis-fluent hand movements. Moreover running ASR in noisy environments and using a mobile touch screen for handwriting practice are other complexities that need to be handled. Finally, the application needs to fit with the limited computational resources of the common mobile devices.
[Hassanin Al-Barhamtoshy, Sherif Abdou and Mohsen Rashwan. **Mobile Technology for Illiterate Education.** *Life Sci J* 2014;11(9):242-248]. (ISSN:1097-8135). http://www.lifesciencesite.com. 34

Keywords: OCR, Speech Recognition, ASR, Handwriting, Illiterate education.
This work was supported by King Abdulaziz University (KAU) through their grant's number D1432 - 18-611.

I. Introduction

Literacy and adult education are an essential objective for realizing development and increasing production for any country. Egypt is one of the countries that still has high rate of illiteracy which according to recent reported statistics is around 30% of the adult population (age range 15-45 years). Many other Arabic countries faces similar situation. Several national plans and strategies were adopted in cooperation between the governmental Organization of Literacy and several other regional and international organizations. Unfortunately these efforts resulted in the education of small percentage of illiterate persons (less than 15 %) and the national target of having an illiteracy free country seems still way ahead [2].

One of the main reasons that have attributed to the failure of the national illiteracy eradication plans is the shortage of the qualified teachers who can provide an effective teaching for the illiterate adults. Also most of the literacy classrooms are centralized around the large cities and urban areas while most of the illiterate persons live in the rural areas especially that the higher percentage of illiteracy is among females who suffer to attend the distant literacy centers. Another factor is that most of the illiterate persons are usually busy in money earning jobs to support their families and they can't afford to attend a regular literacy class for duration of several months. Besides all the previous factors there is another major source of leakage, that many persons after attending the basic literacy course often relapse into illiteracy because they don't practice there acquired reading and writing skills and don't engage in post-literacy activities. This rate reached 30% in Egypt [2]. Research analysis for the reasons of the relapse of neo-literates back to illiteracy has shown that most of them consider the educational material as either too difficult or not interesting enough.

With all these challenges we need an innovative and effective solution to attack the illiteracy problem. One of the most growing technology devices are mobile phones. Today, there are more than 4 billion mobile phones, of which 2.2 billion are in developing countries and the United Nations estimates that half of all residents in re-mote areas will have mobile phones by 2012. With mobile technology, we have an opportunity to significantly increase the reach of education and literacy any-time and anywhere [5]. The mobile phone has been argued to be an appropriate device for educational delivery in the so-called developing world [3]. It is a low-power device that can be used in places without reliable electricity. Even though it is largely purchased for voice communications – which semi-literate users rely on for their social and economic needs – it is also able to run educational software that support visuals and voiceovers.

According to the World Bank, "despite growing hype - about the potential for mobile phones to improve education in developing countries - there are still precious few widespread examples of the use of mobile phones for education purposes inside or outside of classrooms in developing countries that have been well documented, and fewer still that have been evaluated with any sort of rigor" [4]. Matthew Kam, as part of MILLEE (Mobile and Immersive Learning for Literacy in Emerging Economies) developed computer games with audio and visual components to help students learning English as a Second Language (ESL) in rural India [6]. The game concentrates on simple language skills such as vocabulary, phonetics, sentence compositing and spelling. The project target children who cannot go to school regularly due to distance or due to child labor problems. The games were programmed into low-cost phones and modeled after the traditional village games that rural children find familiar. Results from several filed tests have shown that the MILLEE application is very effective in enhancing the second language skills for the children.

Another literacy program delivered through the mobile phone to disadvantaged female learners was implemented in Punjab, Pakistan. The five-month program, initiated by United Nations Educational, Scientific and Cultural Organization (UNESCO), targeted 250 females aged 15 to 24 years old in three districts. Learners, who completed the basic literacy course, were given a mobile phone each and received three text messages a day and were required to practice reading and writing the messages in their work book and reply to their teachers by text. Monthly assessments held at the learning centers showed significant improvement in literacy skills [7].

Mobile Aided Language Learning (MALL) has emerged as a new sub-filed from the general one of Computer Aided Language learning (CALL). Over the last decade several research groups have started to develop interactive CALL systems that incorporate pronunciation teaching based on speech recognition techniques. The "SPELL" project [8] focused on teaching pronunciation of individual words or short phrases. Another early approach, based on dynamic programming and vector quantization [9] to perform word level comparisons between recordings of native and non-native utterances of a word. The IBM's Watch-me!-Read product use automated speech recognition to track a reader's position and give feedback. It is targeted towards children grade K to 2 to help them become better readers. IBM's researchers collected over 110,000 words spoken by 1,800 children to model children's acoustics. During use a reader can read aloud from a book within the tutor. Books can be authored by teachers. The system recognizes mistakes and asks children to repeat misread words or gives assistance if the child gets stuck. The tool proved to be effective for improving the reading proficiency for the early stage students. The basic pronunciation analysis algorithms pro-posed in the literature [8, 10] are based on phonetic segmentations of the speech signal automatically generated by forced Viterbi alignment through Hidden Markov Models (HMM) [9]. Given these segmentations, scores are obtained from HMM likelihoods, phone durations or a combination of both of them. These scores can then be used to decide whether the pronunciation is acceptable or not.

Some CALL systems include modules for teaching the writing skills [13]. The handwriting lessons in these tools usually display some animations for the handwriting models on the computer screen associated with instructions to help the student to imitate the displayed model. Recently, devices with touch screen input, usually with special pen, have been available. With these systems children can write with a pen directly on-screen without having to lift up their heads to look at what has been written. With these new hardware tools, we have reached the technological capability needed to build interactive systems to assist in teaching handwriting to children. These new systems provide a learning environment very close to the real one for handwriting teaching with human teachers [14]. A research team at Cairo University in cooperation with Microsoft Innovation Center in Egypt has developed a tool for teaching Arabic handwriting to young school kids using tablet PCs. A field study for the tool with 500 students has shown a significant effect on improving the students' handwriting skills [12].

Most of the recent research in the Mobile Language Learning systems has been geared towards creating learning content for mobile devices rather than investigating how mobile devices can support reading and writing skills. In this work we present a literacy Educational Package delivered through the mobile phone. That application supports the daily literacy-based activities of the illiterate adults by promoting the self-study capabilities for the illiterate persons using interactive reading and writing teaching modules.

In the following sections, section 2 includes the description of the Mobile Literacy application and its components. Section 3 includes some initial evaluation results for the developed application. Section 4 includes the final conclusion and planed future work.

II. Description Of The Mobile Literacy Application

The traditional approach of teaching illiterate people relies on a human teacher in a regular classroom. The students receive large amount of educational information but the main challenge is to practice what they have learned. Many of them feel

reluctant to commit reading and writing errors in front of other students. The introduced Mobile Literacy system in this work provides the privacy self-study style for these adult learners which can encourage them to practice as much as they want at any time and any place. The main innovative feature of this system is providing immediate interactive and accurate feedback on the student performance by appraising the correct trails and by providing correction instructions on the incorrect trials. This system is not intended to be a complete substitute for the human class teacher but is an auxiliary tool to help him/her teach illiterates the basic skills of reading, writing and arithmetic that enable them to cope with the professional levels of the various institutions and participate in the different fields of comprehensive development.

Three main design issues governed the implementation of that application. First it should have an easy and user friendly interface so it can be used by illiterate learners. Second it had to integrate the advanced speech and handwriting recognition technologies in an optimized way so the system can be delivered through low cost mobile phones with limited computational resources. Third the system has to cope with severe pronunciations and spelling mistakes that are common in illiterates' readings and the irregular strokes and dis-fluent hand movements that are common in illiterates' handwritings.

The developed mobile literacy application consists of 4 main components:

1) Reading training module
2) Handwriting training module
3) High quality multimedia lessons
4) The main application.

A.Reading Training Module

The reading practice is designed for self-study where the student can read an example displayed on the device screen and the application verifies his reading using Automatic Speech Recognition (ASR) technology. This component is based on the ASR technology of RDI [1]. The procedure is based on calculating a matching score between the input utterance of the user and the system models. If that score exceed a specific threshold the user utterance will be judged as a correct one else it will be rejected. The system is also equipped with a confidence score that is utilized to ask the user to repeat his input in case of the unclear utterances which help to reduce the false rejections and acceptance error. Also system models can be adapted to match the acoustic characteristics of the user voice.

The architecture of the run-time component is depicted in figure (1). The user's utterance is processed by a phone de-coder to produce a phone lattice, a data structure (directed acyclic graph) that contains multiple hypotheses about the phones uttered by the speaker, thus representing the uncertainty that statistical models have about the input. Hereto, it uses an Acoustic Hidden Markov Model and a phonotactic N-gram model, which are both trained offline from standard language data.

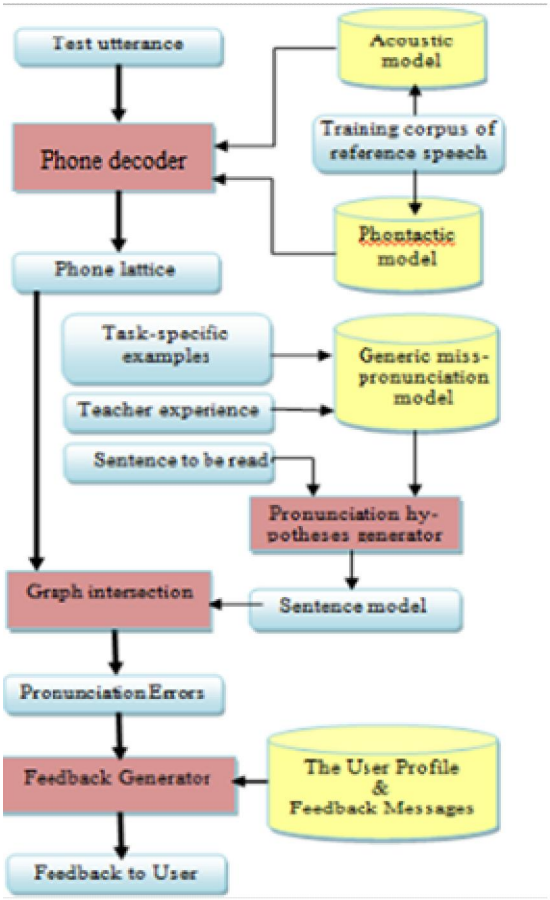

Fig 1. The Architecture of the Reading Training Module

The acoustic model is adapted to the speaker's voice with the standard adaptation technique called feature space MLLR [7] based on a short text that the user repeats sentence-by-sentence from prerecorded speech. The **phone lattice** is then **intersected** with a similar structure that contains a phone-level **pronunciation model** of the sentence for the expected words and predictable mistakes: mispronunciations, repetitions, hesitations. It also allows "any phone sequence" as an alternative to capture unpredicted mistakes. The **mistakes** are learned by example from data and from teachers' experience. The approach differs from the traditional speech recognizer which would decode the user's utterance combining all knowledge sources and where poorly matching acoustics are still accepted because there are no alternatives. In our approach, the phone lattice will

only contain phones that resemble the pronounced sounds. The intersection of the phone lattice and the sentence model is obtained through operations on finite state machines and directly signals if a mispronunciation model is used. The identified phone-level pronunciation errors are then combined with the user profile to **generate feedback**.

B.Handwriting Training Module

The handwriting practice is enabled to be self-study where the application display an animation for a writing example then the student imitate the example by handwriting on the device screen then the system verify his handwriting using Handwriting Verification technology. Following the methods used in schools for teaching handwriting the tool displays a transparent image for a handwritten training sample. The user writes over this transparent image. The tool sets specific control points on this transparent image. These points aren't visible to user but they are used to track his handwriting. Figure (2) includes a flow chart of the main modules of the proposed handwriting teaching tool.

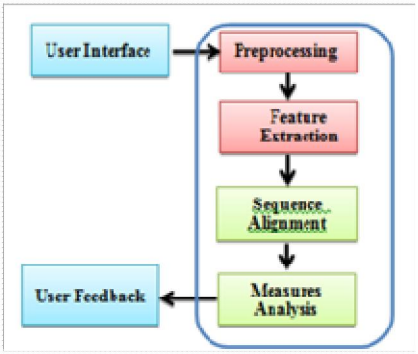

Fig 2. The Main Modules of the Handwriting Teaching Tool

Initially some pre-processing enhancement operations are applied to the handwriting signal. Then some informative features are extracted from the signal. These features include the required information for judging the quality of the hand-written input. The tool evaluates the user performance by measuring the difference between his handwriting and the reference writing. This process is done by initially aligning the user handwriting points with the reference template points to determine the parts that the user managed to correctly follow the reference writing and the parts that he deviated from it. Different measures for the quality of the user handwriting will be computed such as:

Fig 3. Sample for using the Distance Measure

Distance: Measure how much the student writing is close or far from the ideal sample. Figure (3) shows a sample for that measure with the segments that the student didn't manage to follow are displayed with a red color.

Number of Strokes: some literacy students tend to write in segmented style with large number of strokes. Figure (4) shows a sample for that segmented writing where the word "مدير" was written in 6 strokes instead of 4 as it should be. The reason for that phenomenon is that student tend to think while they write which interrupt their handwriting process. The in-creased number of strokes raises the possibility of making errors. Usually handwriting teachers encourage students to write words in paws, the ideal word parts, with each paw writ-ten in a single stroke if possible. Some exceptions are permit-ted for complex paws. The Number of Strokes measure is used to detect segmented writings. This measure is calculated by counting the number of strokes in each paw. If it exceeds the expected number the user gets negative feedback.

Fig 4. Sample of Segmented Writing

Direction: When students start to learn handwriting of complete words, if they have no guidance, they will develop their own way for the directions they follow. Sometimes these directions are odd and can complicate the handwriting process. Handwriting teachers usually advice their students to follow some ideal directions, that help them to do smooth and easy handwriting. These directions are usually displayed with some arrows above the related segments as shown in figure (5). This measure is implemented in the system by setting an order for the control points of the word. The student should pass over those points with the predefined order. If the student makes unexpected jumps he will receive low score with a feedback message that instruct him to follow the ideal directions. The segment where the student violated the ideal directions in his handwriting is highlighted.

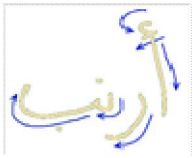

Fig 5. Sample of Direction Errors

Completeness: This measure is used to check whether the user has wrote the complete example or not. Figure (6) shows an example for incomplete word.

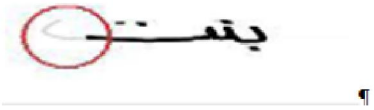

Fig 6. Sample of Completeness Errors

C. High Quality Multimedia-based Lessons

The literacy lessons were produced in the form of multimedia clips that are enriched with videos, cartoons, animations, pictograms and songs in an intuitive, easy-to-use and attractive format. The lessons were performed by expert literacy teachers who provided all the explanations and guiding instructions that help the student to understand the subjects. The tool allows the student to stop, return and play back any part of the lesson. Also it allows him to zoom in and zoom out to magnify the written examples.

D. The Main Application

The main application is the wrapper for all the other system components. It includes the user interface, the user profiling and the application management. It adopts an easy and straightforward design for the user interface to cope with primitive capabilities of illiterates. Maximum of two levels of menu selection is allowed. The basic functionalities are mapped to fixed keys to facilitate the user actions with only one key stroke. The user profile is used to trace his performance and help for recommending the study lessons. The user profile can also be reviewed by the class instructor to verify the user activity during his self-study periods. Another important feature of the main application is to allow the addition of new downloaded lessons and training examples to the current available list on the device.

The literacy application is divided into three levels. Each level has two modes, training mode and test mode, as it's considered as simulation of literacy classroom as shown in figure 7. In the training mode the student learn some examples. In the test mode the student practice the learned examples. In the first level the student learns the Arabic letters. In the second level the student start to learn full words. In the third level he learns full sentences.

Fig 7. Literacy the Application Main Screens

Figure 8 shows a screen shot from these three levels.

Fig 8. The Literacy Application Three Levels

Fig 9. The Application Games

In the third level the application includes two games. The first one as shown in Figure 9, the user has to order the sentence and then spell the whole sentence, if correct, user will be responded by playing a soundtrack as a positive feedback and the whole correct sentence is displayed complete to user, if else, user will be responded by playing a soundtrack as negative feedback. The second game is multiple choices where the user has to choose the correct answer and then spell the correct word.

III. Evaluations

To evaluate the Mobile Literacy application we composed a short course of 18 illiterate participants. The course was a mix between regular class sessions and self-study periods at home. The course started with a one in-class week where the instructor introduced the mobile device for the students and showed them how to use it. Then started to demonstrate the first lesson using the device and showed to students how to get into the practice examples and how to answer them. Then the instructor asked the students to study few lessons by themselves for a month. Then the course continued by repeated cycles of short in-class sessions, 2-3 days followed by long self-study periods. In these short sessions the instructor reviewed the students' progress, helped them on the device usability issues, explained the unclear lessons and tried some practice examples with the student. The instructor uploaded a copy of the users profile form their devices for the evaluation purposes. The course concluded with a final extensive session for a complete week where the instructor check the levels of the students and run a final exam.

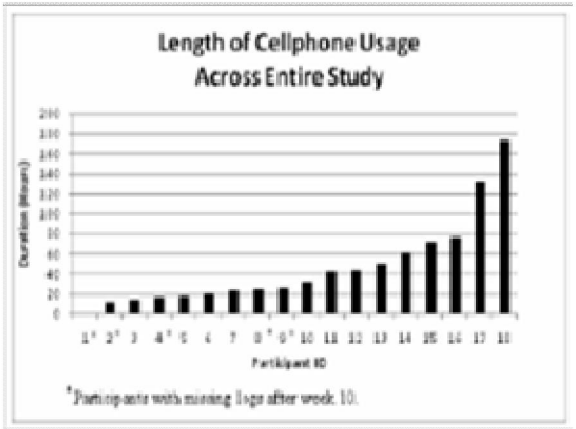

Fig 10. System usage Timing

The students' usability durations for the application were measured from their profiles. The students' usage time varied from few minutes to more than two hours. Figure (10) displays the students' usage times for this evaluation short course.

We measured the progress of the students by evaluating the number of words that they managed to learn and give the correct answers about them in the practice examples. Figure (11) displays the average students' progress for the course weeks.

From figure (11) we can see that the Mobile Literacy application was effective in increasing the learning progress of the students as their number of learned words increased significantly from 50 words to 200 words with the system usage.

Fig 11. Students Learning Progress

For the handwriting module we evaluated the percentage of the correct and wrong system feedbacks counted by the number of the correctly/incorrectly marked segments by the system on the displayed handwriting templates. Table (1) illustrates the evaluation results for the handwriting training module.

From table (1) we can see that the system managed to provide correct feedback for 92% of the cases when the students followed the same writing order of the guidance template. We see also that the system provided correct feedback for only 50% of the cases when the student used different writing order than the reference template. In the final exam the student's hand-writing proficiency was evaluated by counting the number of words they managed to write completely correct. Figure (12) displays the handwriting proficiency results of this evaluation.

TABLE I.

HANDWRITING TRAINING EVALUATION

Writing Order	Correctly Marked Segments	Incorrectly Marked Segment
Followed reference order	92 %	8 %
Different from reference order	50 %	50 %

From figure (12) we can see after using the handwriting training some students managed to write 90% of the practice examples correctly, without getting any negative feedback of the system. This means these students can be considered literate in handwriting. Also some students didn't manage to enhance their handwriting skills and still need more practice and guidance.

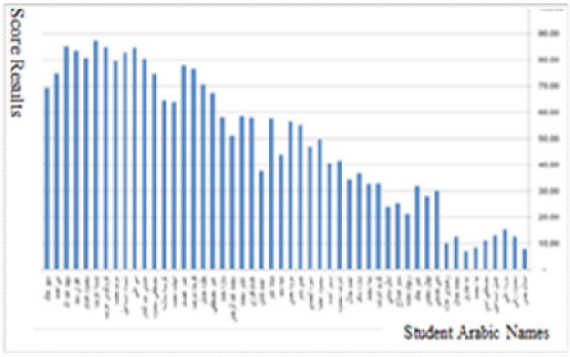

Fig 12. The Handwriting Proficiency Results

IV. Conclusions

In this paper we introduced a mobile literacy application as an assistant tool for literacy students. That application supports the daily literacy-based activities of the illiterate adults by promoting the self-study capabilities for the illiterate persons using interactive reading and writing teaching modules.

Performance evaluation results for using an initial prototype of that application in a real literacy class has shown that it motivated the learning activities of the students and accelerated their learning rates. Also the application interface was handy and clear for most of the students and they managed to use it independently at their homes. The application was installed on low cost mobile devices of price range [$50-$100] and provided real time performance on those devices.

Although the speech recognition [15, 16] and hand-writing recognition [17] applications were integrated success-fully in that application some enhancements are still required to detect the non-sense speech inputs in case of interfering speech input and also improve the recognition of unordered handwriting.

Acknowledgment

Authors of this paper thankful to King Abdulaziz University (KAU) through their grant's number D1432 - 18-611.Their financially and support during the period of this research took place is greatly acknowledged.

References

1. Abdou S., Rashwan H., Samir A., Abdel-Hamid O., Shahin M., Nazih W., "Computer Aided Pronunciation Learning System Using Speech Recognition Techniques", INTERSPEECH 2006 - ICSLP, Pittsburgh, PA, USA, 2006.
2. Benyon D., Designing Interactive Systems, A Comprehensive Guide to HCI and Interaction Design, 2nd Edition, Addison Wesley, Pearson, 2010.
3. Kam M., Kumar A., Jain S., Mathur A., and Canny J., "Improving Literacy in Rural India: Cellphone games in an afterschool program". In Proc. of IEEE/ACM Conference on ICTD'09, 2009.
4. Yousif A., "Adult Literacy and Adult Education in the Arab States: Bahrain, Egypt, Oman, Saudi Arabia, Sudan, Syria and Yemen", Research paper prepared for the UNESCO Regional Conferences in Support of Global Literacy, Doha, 12-14 March 2007.
5. UNESCO, EFA Global Monitoring Report, 2006.
6. World Bank. Surveying the use of mobile phones in education worldwide. http://blogs.worldbank.org/edutech/surveying-the-use-of-mobile-phones-in-education-worldwide (Last accessed September 14, 2009).
7. Gales M., "Maximum likelihood linear transformations for HMM-based speech recognition," Comp. Speech and Lang., vol. 12, pp. 75–98, 1998.
8. Fuentes M., and Gonzalez M., "English Language Learning Activity using Spoken Language and Intelligent Computer-assisted Technologies", Special Interest Group on Speech and Language Technology in Education (SLaTE) workshop , Venice 24 - 26 August, 2011.
9. Hamada H., Miki S., and Nakatsu R., "Automatic evaluation of English pronunciation based on Speech Recognition Techniques" IEICE Trans. Inf. And Sys, E76-D(3):352-359, March, 1998.
10. Hiller S., and Spell A., "An automated system for computer-aided pronunciation teaching", Speech Communication, 13:463-473, 1993.
11. Mostow J., "Experience from a Reading Tutor that listens: Evaluation purposes, excuses, and methods". In C. K. Kinzer & L. Verhoeven (Eds.), Interactive Literacy Education: Facilitating Literacy Environments through Technology, pp. 117-148. New York: Lawrence Erlbaum Associates, Taylor & Francis Group, 2008.
12. World Wide Telecommunication Use: http://www.itu.int/newsroom/press_releases/2010/06.html
13. Communication information in Saudi Arabia: http://www.citc.gov.sa/English/MediaCenter/CITCinthemedia/Pages/PR_MED_118.aspx
14. Human Development Report 2011. Sustainability and Equity: A Better Future for All. Published for the United Nations Development Program (UNDP). http://hdr.undp.org/en/media/HDR_2011_EN_Complete.pdf .
15. Abdou S., Rashwan M., Al-Barhamtoshy H., Jambi K., and Al-Jedaibi W.,"Enhancing the Confidence Measure for an Arabic Pronunciation Verification System". Proceedings of the International Symposium on Automatic Detection of Errors in Pronunciation Training June 6 - 8, KTH, Stockholm, Sweden, 2012.
16. Al-Barhamtoshy H., Jambi K., Al-Jedaibi W., Abdou S., and Rashwan M., "Adaptive English Pronunciation Errors for Arab Learners of English", the 12th International Conference of Language Engineering, ESOLE-12, Ain Shams University, Cairo, Egypt, 2012.
17. Al-Barhamtoshy H., Abdou S., and Al-Wajih F., "A Toolkit for Teaching Arabic Handwriting", International Journal of Computer Applications (0975 – 8887), Vol. 49, No. 23, pp 17-23, 2012.