Design and Implementation of a Telehealth Platform for Prenatal Management in Rural and Remote Areas

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***Abstract*—As stated by WHO, around 9.2% of 28 million newborn babies worldwide are stillbirths. Moreover, approximately 358,000 women died in 2008 due to birth complication. Most of these incidents occur in developing countries. Existing telehealth systems are not integrated in rural and remote areas. Midwives in those areas do not get any support by medical specialists during high risk pregnancy situations so that those cases usually end lethal. Therefore, in this study, a new telehealth platform for prenatal management also called as Integrated Remote Prenatal Monitoring is designed and implemented. The system consists of a server, prenatal data assistant and a workstation for an electronic health record. This represents a replacement for the current paper based medical record and teleconsultation. The Integrated Remote Prenatal Monitoring exchanges medical information between midwives in rural areas and doctors or specialists over long distances. In order to collect specific requirements for the system, a study has been performed at the indonesian hospital 'Rumah Sehat Budi Kemuliaan, Jakarta'. Results show a functional and user friendly webbased solution being implemented within the Django framework.**

I. Introduction

According to the statistics provided by the World Health Organization (WHO), there are around 28 million newborn babies worldwide and around 9.2% of them (2.6 million) are stillbirths [1]. In 2008, approximately 358 000 women died (1000 women per day) due to complications of birth such as unsafe abortions, infections, severe bleeding after birth, hypertension disorder, indirect causes like malaria, HIV, anemia and others [2]. Hemorrhage is monopolized as the main cause of maternal deaths worldwide (35% of all causes). Also almost 99% of all mortality rates for pregnant women occur in developing countries meanwhile two-thirds of stillbirths occur in South Asia [3]. The main cause of maternal and infant death was due to the lack of skilled birth attendants like midwives and physicians. These are not always available for essential care during childbirth as well as for obstetric emergencies like caesarean sections [4]. However, these regions generally suffer from inadequate or insufficient healthcare [5]. Regular checks up and monitoring are needed on both fetus and mother for prevention and early diagnosis in order to reduce the death rate. Ultrasound imaging is an efficient tool for identifying maternal mortality risk factors [6]. Unfortunately, the number of medical specialists beng 14 per 10,000, is too limited to cover the number of pregnant women who require ultrasound screening [7]. Moreover, existing ultrasound machines highly depend on trained operators [9]. However, as mentioned by United Nations Population Fund, if the improvement in midwifery services is upgraded by 2015, we can avoid the neonatal death of up to 3.6 million yearly [10]. However, due to low education and the scarcity of training, support and guidance from obstetricians and gynecologists towards midwives is highly required and these issues should get high attention and deep concern. Most of the existing Tele-prenatology systems found do not to consider human factors. As mentioned by Sukdershan Singh, at a national level, there is no in-depth study about any physician tele-consultation adoption [11]. Moreover, most of the obstetric management still uses paper based medical records instead of electronic medical records (EMR). Currently the paper records represent massive fragmentation of clinical health management and the fragmentation lead greater cost due to consequence effects on current and future patient care [12]. By using EMR as a replacement for paper records, the health services can get improved. Some of the advantages using EMR over paper health records are increased storage capabilities for longer periods, accessibility from remote sites, involvement of several people in order to retrieve information immediate [13]. Moreover, there is no need to move a far distance and medical alerts, reminders and many more advantages can be provided [14]. Hence, the aim of this research is to design and implement of a telehealth platform for prenatal management in order to reduce the existing maternal mortality rate with focus on rural areas whilst in the same way being able to indirectly support the United Nations to achieve two of their Millennium Development Goals, which are goal number four; to reduce the child mortality, along with the goal number five; to improve maternal health by the reduction of three quarters of the maternal mortality ratio and achieving universal access to reproductive health [15].

Research supported by UTM and MOE Collaborative Platform for Cardiovascular Disease Managemant under the vote nr. Q.J1300000.2509.07H21.

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II. Materials And Methods

A. Design Process

There two other papers, which use alternative methods to achieve the same goal [16, 17]. Fig. 1 shows the system design process used in this research. From the figure, we can see that the research has been started with specifying the users' context and his need. The user here is assumed to be a

specialist, midwife or pregnant women. A knowledge base has been built dealing with mostly all related antenatal care and high risk pregnancies. Starting with a knowledge base, more effective design requirements can then be developed. After that, the specification of functional requirements is required. The specification of functional requirements is much more specific and forms the starting point of system design. The definition of the requirements provides a possibility to communicate between various stakeholders. Moreover, a new workflow and design for teleprenatal management are proposed. Furthermore, an algorithm for the prenatal protocol, an algorithm for the graphical user interface and standard operating procedure was developed. Further modifying solutions and design improvements are provided subsequent to the production solutions. Finally, the evaluation of the prototype was performed. This step considers clinical testing in order to test whether the prototype is safe and how well the system performs.

B. Human factors

In order to understand the user context and requirements, user capabilities need to be defined as well as tasks and the working environment. Requirements for the system have been defined on the basis of questionnaires filled out by doctors and specialists. Moreover, direct observation, critical incident analysis, job analysis, task analysis and time motion analysis have been performed [18]. All these studies have been carried out at several Puskesmas in Kampar, Riau. Human factors (HF) and ergonomics were almost similar and interchangeable. Ergonomics consider of the workplace, environment and machine tools during the design, whereas HF deals with physical, perceptual and mental capabilities in humans [19]. The importance of HF in engineering is the application of knowledge about human behaviour, abilities, limitations, and other characteristics to the design of tools, machines, equipment, devices, system, tasks, jobs, and environment to achieve productive, safe, comfortable, satisfying and efficient use [20]. However, another study provided expected overviews from the aspect of healthcare in terms of access, cost and quality against the use existing telemedicine [21]. Other approaches focusing on telemedicine in womens health in order to reduce mortality were elaborated [22-26].

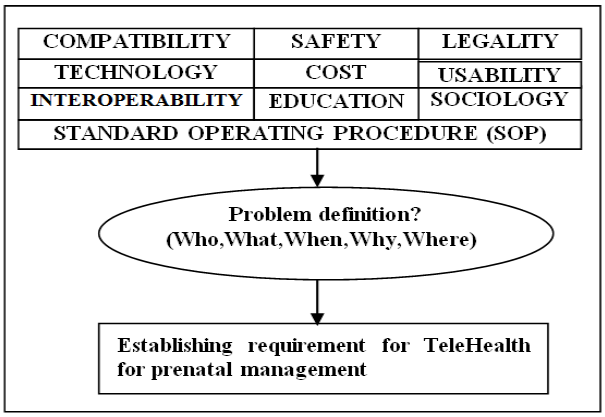

Figure 1. Requirement analysis for the establishment of a telehealth system for prenatal management.

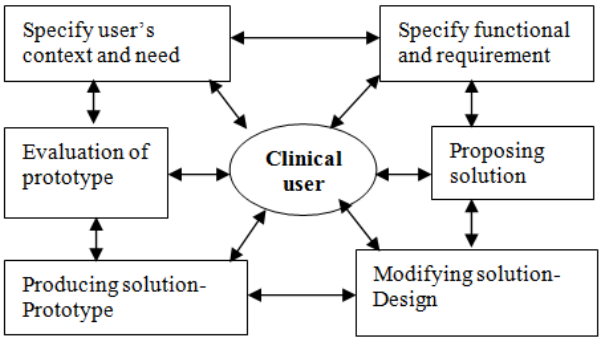

Figure 2. Clinical user context.

C. Critical success factors relating to Telemedicine

There are several factors that lead to the failure of the implementation of telemedicine. However, telemedicine involves many stakeholders, so all parties need to provide important roles for each task. There are several issues that need to be considered. Among these are strategical, management related, organisational, legal, regulatory related and safety issues. Moreover, there are also technical and infrastructural issues. As for the strategy and management issues among the implementation of telemedicine into existing healthcare systems, the most important consideration is to measure the readiness of the users. By using an interpretive case study as one research method, data were collected by using face to face interviews, as well as semi-structured interviews, audio records, observations and photographic data sets. Quantitative data were analyzed using the thematic coding analysis.

D. Identification of research participants

In order to determine the appropriate sample size for estimating the proportion of the Kampar population, the statistic formula in (1) was used.

$$n = \frac{Z_{\frac{\alpha}{2}}^{2} \times \hat{p}(1-\hat{p})}{ME^2} \quad (1)$$

Where,

So, by taking $Z_{\alpha/2} = 1.96$ at $\alpha/2$ (with confidence level of 95%, α is 0.05 and the critical value is 1.96), ME = 10%,

$Z_{\alpha/2}$	=	Critical value of normal distribution
ME	=	Margin of error
$\hat{p}$	=	Sample proportion
n	=	Sample size

$\hat{p}$ = 85%, below is the calculation to define sample size for this survey. Here, the sample size calculated is 49 as calculated in (4).

$$n = \frac{Z_{\frac{0.5}{2}}^{\ 2} \times 0.85(1-0.85)}{0.1^2} \quad (2)$$

$$n = \frac{1.96^2 \times 0.85(1-0.85)}{0.1^2} \quad (3)$$

$$n = 49 \quad (4)$$

E. Data analysis strategy

As for quantitative data, which is the result from the survey, all data have been analyzed using SPSS software. For qualitative data, interview, an analysis was done using a thematic coding approach. For all interviews, transcribed data were analyzed using qualitative the manifest content analysis according to Graneheim and Lundman [27] First, the text was sorted to identify relevant meaning units, i.e "informants" responses to the aim of the study. In the second step, the meaning units were shortened to condense meaning unit. Susequently, the condensed meaning unit was coded. The codes were compared and sorted into sub-categories. Finally, the sub-categories were systematically abstracted to represent the "manifest" aspect of the dataset.

III. Design and Implementation

After identifying the problem and specifying functional requirements, the systems' configuration was designed. The system itself is divided into three parts being workstation, web application on cloud and prenatal data assistant used by the specialist. In web application on cloud, data will be sent in form of queries to the patient database.

A. Use Case Diagram

Use case diagrams are used to define the predictability and functionality of the system. They characterize the interaction between the actor/uses and the system [28]. The here developed use case diagram can be seen in Fig. 3. There are six actors involved in this system being medical doctor, midwife, patient, laboratories, administration and staff. Each of the subjects has its specific tasks and is involved in diferent actions.

C. Process of registration

To discuss the scene during antenatal care, it can be mentioned that the process starts with a registration. The pregnant patient will come to the obstetric provider and register during the first visit of antenatal care. The staff will then manage the registration and payment transaction for the expected mothers.

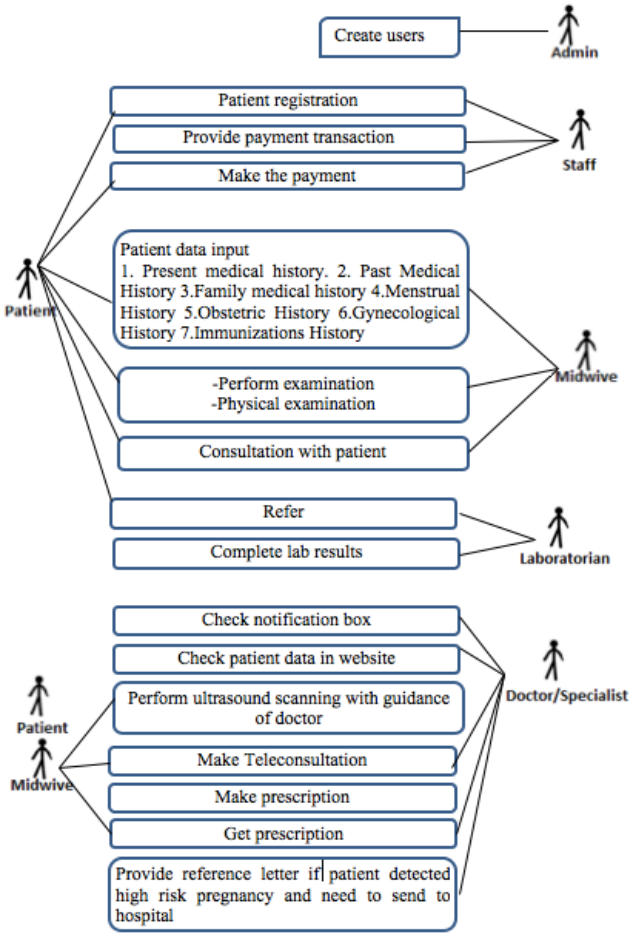

Figure 3. Use Case Diagram

The payment transaction might be requireded for medical services such as specialist teleconsultation, prescription, hospital admission, and so on. Patients with first time visits, need to register but it is not necessary anymore for subsequent visits of the same. The staff can track the patient directly within the system. After that, the responsible staff will coordinate antenatal care appointments with the midwife and the patient will proceed with the payment if required.

IV. Results and Analysis

Quantitative results have been categorized into five categories which are registration, medical history, check up, laboratory test, and questionnaire results about the midwives' skills.

A. Software Implementation

The developed online software consits of a graphical interface. Users need to register their email and get a password from the admin in order to access the system. There were restrictions created for the access of the website which are depending on the role of the user. Once logged into the system, a list of patient names and further IDs will appear. For first time patients, the developed registration form needs to be filled out. A screenshot for the registration of a new patient can be obtained from Fig. 4.

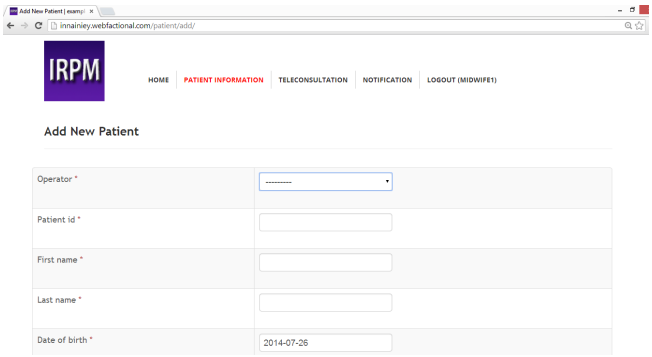

Figure 4. Registration of a new patient.

Moreover, the core of the software contains data sheets dealing with visits, basic patient information, demographics, medical history, routine check up, laboratory test and ultrasound scanning. This step represents a change in the routine of handling the patient data in paper form. Due to the usage in electronic form, the midwives are able to share the patients' information with spcialists located in far distances and even consult with them.

B. Medical history

All patients have to provide their medical history. This category is divided into seven parts, which are family medical history, past medical history, menstrual history, obstetric history, present medical history, gynaecological history and immunization history. Family medical history is a record of health information about a persons close relatives. These data are highly important in order to estimate the risk of specific health concerns. Often appearing diseases in the family line represent a high impact on the patient herself.

C. Laboratory test

Laboratory test results are stored in this section and provide a basis for long term observation of the patient. Data about the blood tests, urine tests and further laboratory tests has a significant influence on the treatment of the patient. This information might also be used as a reference for a medication. Futhermore, the blood group is stated, which is a basic clinical information in case of blood admission. Data about the date of the event, urinanalysis, serological test results for syphilis, the before mentioned blood group and and hemoglobin are inlcuded.

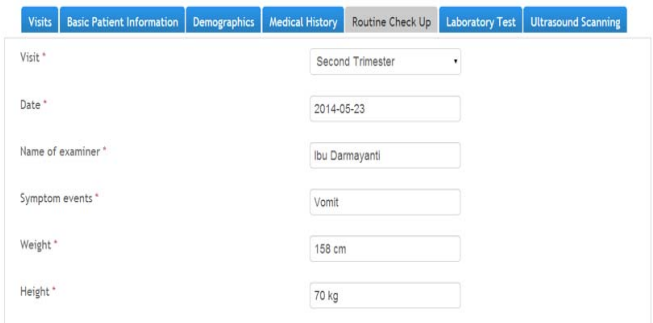

Figure 5. Screenshot of the software part for the routine check up.

D. Routine check up

The routine check up is a fundamental part of this software. It stores not only the visit number, which is required for good patient follow up but also the date and personal information like the name. This part also provides information about the examiner and the occuring symptoms being typical during pregnancy like vomiting. Moreover, biological parameters about weight and blood pressure are stored. Diagnosis values about the heart and chest auskultaion are provided. Comments about abdominal changes and fetal movements are provided. Moreover, details about vaginal examination are included.

E. Midwife skills

This questionnaire study lasted for one month. From Table 1, we can see that none of midwives stated to have very low knowledge about their skills. However, 35.5% have average knowledge. Most of them do have good knowledge 63.3%. Only 1.5% has very good knowledge. We have investigated and observed midwife skills during their practice when performing antenatal care until delivery. By using the Likert scale from very inexperienced (less than 1 year-1) to very experienced (5 years and more-5), respondents had the opportunities to rate their skills relating to midwifery from several aspects that we found important.

TABLE I. EVALUATION SHEET

	Number of right answer (Out of 30 questions)	**Frequency**	**Per-centage (100%)**
Have average knowledge	Valid 11	1	1.5
	12	1	1.5
	14	1	1.5
	15	4	5.9
	16	1	1.5
	17	3	4.4
	18	5	7.4
	19	3	4.4
	20	5	7.4
	Total	24	35.5
Have good knowledge	21	8	11.8
	22	14	20.6
	23	14	20.6
	24	5	7.4
	25	2	2.9
	Total	43	63.3
Have very good knowledge	27	1	1.5
	Total	1	1.5
Total		**68**	**100**

TABLE II. CATEGORIZATION OF THE KNOWLEDGE OF THE MIDWIVES

Midwife knowledge											
Level 1	Number of right answer (Out of 15 questions)	Frequency	Percentage (100%)	Level 2	Number of right answer (Out of 10 questions)	Frequency	Percentage (100%)	Level 3	Number of right answer (Out of 5 questions)	Frequency	Percentage (100%)
	Valid 7	3	4.4		Valid 2	1	1.5		Valid 0	34	50.0
	8	2	2.9		3	1	1.5		1	20	29.4
	9	4	5.9		5	2	2.9		2	11	16.2
	10	4	5.9		6	8	11.8		3	2	2.9
	11	3	4.4		7	14	20.6		4	1	1.5
	12	5	7.4		8	31	45.6				
	13	26	38.2		9	7	10.3				
	14	17	25.0		10	3	5.9				
	15	4	5.9								
	Total	68	100		Total	68	100			68	100

There are 8 skill characteristics that we measured which are handling normal pregnancy, managing high risk pregnancy, handling emergency cases, performing ultrasound scanning, interpreting ultrasound image, prescription of medical supplement, and identification of the position of the baby. We collected complete results out of our 50 respondents. For normal pregnancy, it was found that 27 of the total (54%) rate have experience in handling basic care for normal pregnancy, while only 19 (38%) are well experienced. Only one of them rated herself to be totally inexperienced. It can be clearly seen that none of them was very experienced using ultrasound and able to interpret ultrasound image data. Moreover, only 26 subjects showed experience in handling emergency cases. From 50 respondents, 54% of them (n=27) have independently practice midwife. Using SPSS, Chi-Squares was used to show the association between age, CGPA, period of working as midwife, have Independently Practice Midwife against level of midwifery skills for each skill characteristic.

However, we found that there is a statistically insignificant relationship between age and CGPA against the level of midwifery skills. Exploring the relationship between independent practice midwife and midwife skill, it has been found that there is a statistical significant relationship, $p \leq 0.05$, between midwife owned independently practice and midwives handling high risk pregnancy. The questions were divided into three levels which are level 1 (Easy), level 2 (Intermediate) and level 3 (Difficult). Each level 1, 2, and 3 contained 15, 10, 5 questions respectively. Each question and answer was interpreted and grouped. For each correct answer 1 mark was assigned. We have grouped midwives knowledge's into 4 categories which are low, average, good and very good knowledge. For those midwives who get 1-10 marks, we have considered have low knowledge, 11-20 marks have average knowledge, 21-25 have good knowledge, and 26-30 have very good knowledge. All these data were entered into a standard package (SPSS version 16.0) and analysed using descriptive statistics. It can be observed that the greatest proportion being 26 (38.2%) answered 13 questions correctly for level 1, 31 (45.6%) answered 8 questions correctly in level 2, but only half of them could not answer all questions in level 3, which represented the most difficult questions. After that, midwives were categorized to four types of group, low knowledge, average knowledge, good knowledge, and very good knowledge based on their correct answers. We conclude that none of them have very low knowledge, 35.5% have average knowledge. Most of them have good knowledge 63.3%. Only 1.5% has very good knowledge. Overall, the internal consistency of reliability coefficients for the constructs in this study measured using the questionnaire based on the pilot study was acceptable, as the values were between 0.65 and 0.95 (Piaw 2006). However,as the sample size for the pilot study was small (less than 100), factor analysis procedures were not used, as sample size may affect the factor analysis by making the solution unstable (Guadagnoli & Velicer, 1988).

V. CONCLUSION

We conclude that a functioning webbased software was developed especilly for the needs of clinical staff in remote areas including all data required for the best possible attendendance of obstetrics patients. Out of the questionnairs applied in the rural areas of Indonesia, we conclude that most of the midwives perform traditional attendance of the pregnant patient only. Altough, the midwives showed good

knowledge in their skills with a percentage of 63.3%, only 1.5% prooved to have very good skills and knowledge. These results show that there is a big field for improvement of health related procedures. A further conclusion is that a special training of medical staff is required to decrease the maternal mortality rate of 9.2% worldwide and the death of 358 000 women per year in Indonesia during.

ACKNOWLEDGMENT

We would like to express our gratitude to all the participating midwives from Indonesia for their support in terms of data acquisition as well as Rumah Sehat Budi Kemuliaan in Jakarta for their clinical support. We also appreciate the organizational and structural support from Ilmenau University of Technology under the supervision of Prof. Dr.-Ing. Habil. Jens Haueisen and his team. This research was supported by UTM and MOE Collaborative Platform for Cardiovascular Disease Managemant under the vote nr. Q.J1300000.2509.07H21.

REFERENCES

[1] WHO, "World Health Statistics 2012," Geneva, World Health Organization, 2012.
[2] K. S. Khan, D. Wojdyla, L. Say, A. M. Gülmezoglu, P. F. Van Look "WHO analysis of causes of maternal death: a systematic review," The lancet, 2006, pp. 1066-1074.
[3] WHO, "Maternal Mortality (Fact sheet N°348)," Geneva, World Health Organization, 2014.
[4] WHO, "E-Update, Maternal, newborn child and adolescent health featured at World Health Assembly," Department of making pregnancy safer, 2011, pp. 1-5.
[5] S. Thaddeus, D. Maine, "Too far to walk: maternal mortality in context," Social science & medicine, 1994, pp. 1091-1110.
[6] S. L. Clark, M. A. Belfort, G. A. Dildy, M. A. Herbst, J. A. Meyers, G. D. Hankins, "Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery," American journal of obstetrics and gynecology, 2008, p. 36.
[7] F. Arias, A. G. Bhide, S. Arulkumaran, K. Damania, S. N. Daftary, "Practical guide to high risk pregnancy and delivery," Elsevier Health Sciences, 2012.
[8] K. Å. Salvesen, C. Lees, B. Tutschek, "Basic European ultrasound training in obstetrics and gynecology: where are we and where do we go from here?," Ultrasound in obstetrics & gynecology, 2010, pp. 525-529.
[9] M. F. MacDorman, G. K. Singh, "Midwifery care, social and medical risk factors, and birth outcomes in the USA," Journal of Epidemiology and Community Health, 1998, pp.310-317.
[10] J. E. Lawn, K. Kerber, C. Enweronu-Laryea, S. Cousens, "3.6 million neonatal deaths—what is progressing and what is not?," In Seminars in perinatology, 2010.
[11] N. Maarop, K. Y. Win, M. Masrom, H. Singh, S. Singh, "Exploring factors that affect teleconsultation adoption: In the case of Malaysia," 2011.
[12] C. Parry, E. A. Coleman, J. D. Smith, J. Frank, A. M. Kramer, , "The care transitions intervention: a patient-centered approach to ensuring effective transfers between sites of geriatric care. Home health care services quarterly, 2003, pp. 1-17.
[13] K. Noraziani, A. Nurul'Ain, M. Z. Azhim, S. R. Eslami, B. Drak, A. S. Nurul, "An Overview of Electronic Medical Record Implementation in Healthcare System: Lesson to Learn," World Applied Sciences Journal, 2013, pp. 323-332.
[14] D. I. Thompson, J. Osheroff, D. Classen, D. F. Sittig, "A review of methods to estimate the benefits of electronic medical records in hospitals and the need for a national benefits database," Journal of healthcare information management, 2006, pp. 62-68.
[15] United Nations, "The Millennium Development Goals Report," United Nations, 2013, pp. 24-33.
[16] C. Pahl, V. Detschew, D. Weingaertner, E. Supriyanto, "Role of OpenEHR as an Opensource Solution for the Modeling of Gestation Related Patient Data At a Brazilian Example," IEEE Conference on Biomedical Engineering and Sciences, 2014 (Under Review).
[17] Y. N. Aditya, C. Pahl, E. Supriyanto, "Review and Design of a Midwife Prenatal Kit for Examinations in Developing Regions," IEEE Conference on Biomedical Engineering and Sciences, 2014 (Under Review).
[18] M. B. Weinger, O. W. Herndon, D. M. Gaba, "The effect of electronic record keeping and transesophageal echocardiography on task distribution, workload, and vigilance during cardiac anesthesia," Anesthesiology, 1997, 144-155.
[19] C. Stephanidis, "User interfaces for all: concepts, methods, and tools (Book style)," CRC Press, 2001.
[20] P. Carayon, "Handbook of human factors and ergonomics in health care and patient safety," CRC Press, 2011.
[21] R. Bashshur, G. Shannon, H. Sapci, "Telemedicine evaluation," Telemedicine Journal & e-Health, 2005, pp. 296-316.
[22] C. Pahl, E. Supriyanto, N.H.B. Mahmood, J. Yunus, "Cervix Detection Using Squared Error Subtraction," Modeling Symposium (AMS), 2012 Sixth Asia, 2012, pp. 121-125.
[23] C. Pahl, E. Supriyanto, "Personalized Cervix Ultrasound Scan Based On Robotic Arm," PSRC - Planetary Scientific Research Center Proceeding, 2012.
[24] C. Pahl, "Novel Method For Automomous Ultrasound Scanning(Thesis style)," Universiti Teknologi Malaysia, 2012.
[25] C. Pahl, A. Jeffree, Y. Myint, E. Supriyanto, "Cervix Segmentation in Ultrasound Data Based on Numerical Technique," WSEAS International Conference on Biomedicine and Health Engineering (BIHE'13), 2013.
[26] Y.N. Aditya, H.N. Abduljabbar, C. Pahl, L.K. Wee, E. Supriyanto, "Fetal Weight and Gender Estimation using Computer based Ultrasound Images Analysis," International Journal of Computers, 2013, p.11.
[27] U. H. Graneheim, B. Lundman, "Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness," Nurse education today, 2004, pp. 105-112.
[28] A. B. Mutiara, A. Muslim, Y. Oswari, R. A. Miharja, "A Model of OpenEHR Based Electronic Medical Record In Indonesia," arXiv preprint arXiv, 2012.