2007 IEEE International Conference on
Robotics and Automation
Roma, Italy, 10-14 April 2007

A new learning method for obstetric gestures using the BirthSIM simulator

R. Moreau, M.T. Pham, T. Redarce
Laboratoire Ampere UMR CNRS 5005
INSA-Lyon
F-69621 France
richard.moreau@insa-lyon.fr

O. Dupuis
Hospices Civils de Lyon (HCL)
CHU Lyon Sud
69495 Pierre-Bénite, France
olivier.dupuis@chu-lyon.fr

Abstract— **Today, medical simulators are increasingly gaining attraction in clinical settings. These tools allows physicians to visualize the positions of organs, plan surgical interventions, and carry out more comprehensive post operative monitoring. A childbirth simulator provide a risk-free training and research tool for comparing various techniques that use obstetrical instruments or validating new methods. This paper presents a new teaching method to place forceps blades for obstetricians using an instrumented childbirth simulator. The proposed method is based on a physical simulator coupled with a computer graphics interface. Another aspect of this paper is to provide understanding marks to quantify the progression during a training. A first one allows to study the path in space and to quantify their repeatability, a second one allows to compute the error to a reference gesture defined by an expert. Both marks are complementary. Two novices were trained and they manage to have a more repeatable gesture and above all to become closer to a reference gesture, i.e. to reduce the injury linked to the use of forceps during instrumental deliveries.**

I. INTRODUCTION

Generally, the aim of a simulator is to allow people to learn, to teach or to train how to carry out a specific complex set of actions. As in aerospace [1], in aeronautics [2] or in transport [3], [4] a simulator offers a risk free training to future professionals and allows them to acquire a minimal experience before acting in real-life. In aeronautics, flight training include a compulsory simulator training period. In the same way, in the medical field, several companies have developed medical simulators [5]–[7]. Simulators for training are now available for example, in laparoscopic surgery [8], endoscopic surgery [9], [10], orthopedy surgery [11] or otologic surgery [12]. Simulators are also available for student doctors for educational purposes: for example for the palpatory diagnostic training [13] and also for the hysteroscopic procedure [14].

In obstetrics, there are no complete training simulators available [15], this is why the *Laboratoire Ampère* (previously named *Laboratoire d'Automatique Industrielle*) and the *Hospices Civils de Lyon (HCL)* have developed a childbirth simulator: BirthSIM. This simulator [16] and its instrumented forceps [17] have been designed to complete the traditional training in the childbirth ward. The simulator allows young obstetricians to acquire experience in various obstetric gestures (transvaginal assessment diagnosis, eutocic childbirth, instrumental childbirth by forceps). This training simulator can also be used to train for rare cases with various degrees of difficulty or to validate new instruments and new techniques and to evaluate capacities.

One of the advantages of a simulator is to by pass the constraints occurring in a childbirth ward during normal obstetric gestures training. During an instrumental childbirth with a forceps these constraints are [18]:

- In space: The gesture occurs inside the maternal pelvis and thus the novices do not see the instructor gestures and reciprocally instructors can not validate the novices gestures;
- In time: When an instrumental delivery happens, it has to be carried out as an emergency;
- Stress linked: The first forceps extractions carried out by novices are always awkward because of the risks injuries to the fetus;
- Rarity of the gestures: It is difficult to learn and to teach a gesture learned and taught by experience which does not occur often as instrumental childbirth is not a scheduled event.

In our previous paper [19] operators have just been measured to quantify the difference between novices and experts. The aim was to show the need of training for novices. In this paper, the training method is presented as well as the progression of novices according to the methods developed in [17].

The main goal of this paper is to show the advantage of this simulation tool within the scope of obstetrics. This paper is divided into three parts, the first part presents the tools used and the setting of the experimental protocol. The second part is devoted to the evolution of novices in learning an obstetric gesture using the BirthSIM simulator and the training procedure we developed. The obstetric gesture involved is a forceps blades placement. Finally, the last part will discuss how well the simulator works. In conclusion, we will present the works in progress and future research.

II. TOOLS AND METHODS

A. The BirthSIM Simulator and its Instrumented Forceps

The BirthSIM simulator has been used in the framework of this study. This simulator consists of three components: mechanical, electro-pneumatic, and visual [15]. A block diagram of the system is shown in fig. 1. Operators can have haptic feedbacks on the mechanical component which accurately reproduces the maternal pelvis and a fetal head with their particular anatomical landmarks (ischial spines, coccyx, sacrum, and pubis for the pelvis and fontanels, sutures, and ears for the fetus). During this study, the training procedure also used a visual component. This component allows operators to be submerged inside the maternal pelvis and to see the instrumented forceps displacement around the fetal head. A forceps has been instrumented with two electromagnetic sensors (one in each blade) with the ability to measure six degrees of freedom (fig. 2) [19], [20]. Concerning the electro-pneumatic component, it is not involved in this study because it is based on the quality of the forceps blade placement and not on the extraction. A study of a dynamic control law for the pneumatic actuator can be found in [21].

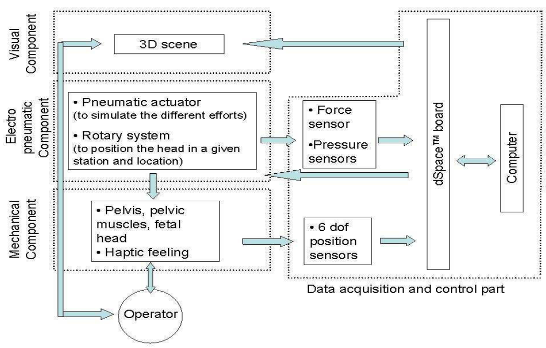


Fig. 1. Block diagram of the BirthSIM simulator

Fig. 2. Instrumented forceps with Minibird electromagnetic sensors

B. The Visual Component of the BirthSIM Simulator

Nowadays, simulators provided with a 3D visualization system are more and more used in medicine. Indeed, such simulators allow the reproduction of various types of operations in order to train, to teach, to check the knowledge and the know-how, and to try new techniques to validate them. These simulations offer several advantages: training without any risks for the patients, economy of time and money, greater availability of the operating room, etc. Such a training has to be completed with experience provided in the operating room.

Thus, to allow the medical team a greater interactivity with the BirthSIM simulator, a visual interface was developed. The user can watch the scene in real time on a screen and can observe where its obstetrical instruments are in comparison to the fetal head and to the maternal pelvis including various points of view of the same scene.

To make this possible, it was necessary to digitize the mechanical parts of the simulator: the maternal pelvis, the fetal head and the forceps. This include acquiring some points on the surface of the part using an optical system Actiris Pack [22].

This pack is composed of a camera system called Actiris Eyes, of a stylus Actiris Probe and a metrology software. The two cameras of Actiris Eyes permanently send flashes of light into the measurement zone. The reflective targets placed on the face of the handle return the flashes towards the cameras which transmit the data towards the computer. In order to acquire measurements, the user simply sets up contact with the stylus and the part to be measured. The result of measurement is immediately available, at the same time on the stylus and on the screen of the computer. Then, after this three-dimensional digitalization, a cloud of points is obtained and a mesh is created by triangulating the points. Fig. 3 shows the digitalization of the head. The same kind of digitalization is made for the forceps and the maternal pelvis. These models are then used for 3D visualization on the simulator.

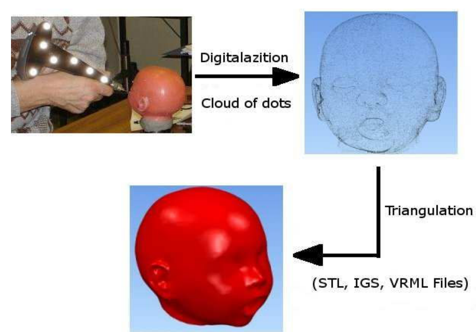


Fig. 3. Digitalization of the fetal head

Once the different elements are digitized, they are implemented in a virtual scene composed of a virtual delivery ward with a table. All the elements were implemented using dSpace™ software: Motion Desk [23]. This software allows to visualize different elements in real time in a virtual scene. Every mobile elements (both forceps blades and fetal head) were associated to an electromagnetic sensor. After calibrated them in order to make correspond the origin of the numerical model with the sensor, it is possible to visualize the scene from different point of views (fig. 4).

C. Definition of the different frames associated with the forceps.

The BirthSIM simulator enables the study of paths of the forceps during its placement. In studying the paths, the most interesting point to follow is the tip of the blade. This is the part of the forceps in permanent contact with the fetal head; it must surround the head to take position behind the

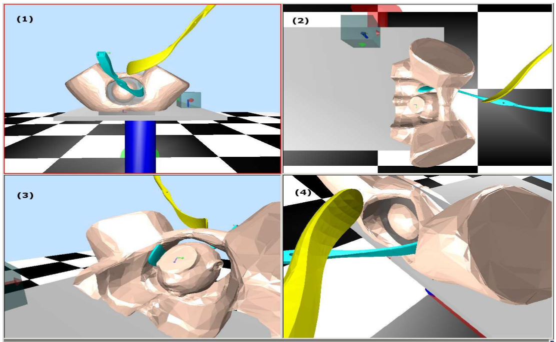


Fig. 4. The visual component of the BirthSIM simulator

fetal ears. However, the sensors are located at the other tip of each blade, as shown in fig. 2. Fig. 5 represents the different frames associated with one forceps blade. It was thus necessary to proceed to a frame transformation in order to follow the desired point (O_3 point in fig. 5)

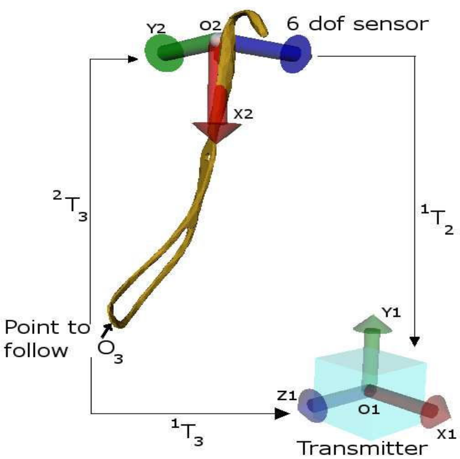


Fig. 5. Different frames associated to the forceps.

D. Experimental Protocol

Two novice obstetricians (N1, N2) were chosen to test the simulator training. Novices are young obstetricians with less than twelve months of obstetrical experience. The simulator training is supervised under the authority of an obstetrician expert who is the instructor. An experienced obstetrician is defined as having had ten years of experience, and using the forceps in more than 80% of his interventions. The fetal head is positioned according to the ACOG (American College of Obstetrics and Gynecology) classification [24]. The presentation is cephalic, that is to say the head comes in first and corresponds to a station and location OA+2 (Occiput Anterior location and station +2cm from the ischial spines plan). This presentation is reputed to be quite difficult. Indeed the station +2 indicates that forceps have to be placed deep inside the maternal pelvis to circumvent the fetal head, this is the difficult part. Location OA means that forceps will be placed in a symmetrical way, both blades will have similar path.

The training lasted three days at the rate of one hour a day. At the beginning of the training, the novices placed the forceps as they will do in the childbirth ward without any advice of the expert. Then, during the training, the expert explained to them how to correctly place the forceps using the mechanical and the visual components of the BirthSIM simulator. The novices placed ten forceps per training day. Their gestures were recorded progressively throughout their training which enabled their evolution to be followed. Three gestures per day were recorded and analyzed to see their evolution in time. At the end of the training nine measurements for each novice were obtained.

To train obstetricians in forceps blade placement the visual component of the BirthSIM simulator is involved. In order to reproduce the expert gesture novices can see the reference gesture on the screen. The reference gesture comes from an expert gesture which is considered as ideal. For the training the reference gesture is segmented into five particular points equally distributed on the path (every 1.5 seconds). Concentric spheres with several radius (one, two, and three centimeters) are defined (fig. 6). The origins of these spheres correspond to the coordinates of the particular points of the forceps blade tip which described the path used as the reference.

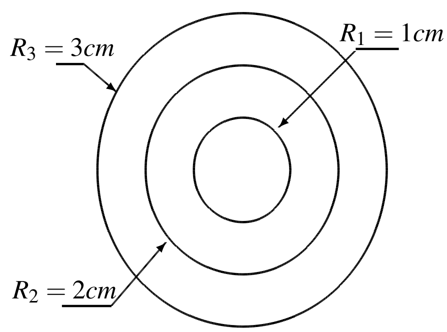
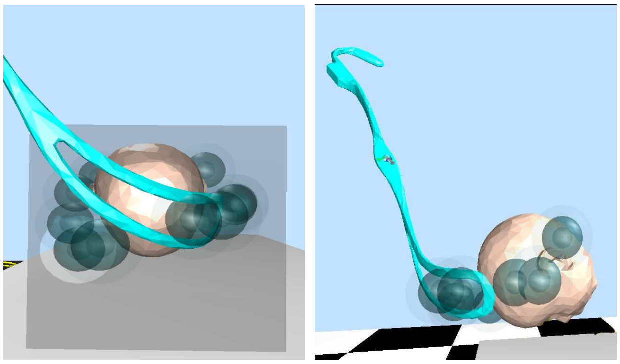


Fig. 6. Concentric spheres which are placed on the reference gesture

Once their position is determined in the workspace, the spheres are plotted on the 3D scene (fig. 7). To reproduce the reference gesture novices have to cross every sphere during the forceps blade placement. Operators can thus see their forceps blade and the reference gesture (represented by five spheres) in real time on the screen. These spheres (called guide spheres) allow novices to train placing forceps like an expert. In order to improve their techniques operators can also visualize their gestures off line. Gestures can thus be analyzed a posteriori compared to another operator or to the reference gesture.

E. Analysis Method

To follow the evolution of the forceps blades placement in 3D space, the two methods described in [17] are used. One of these methods of analysis enables the repeatability of the novices' gestures to be measured. This method is based on the study of three particular points of path (departure, return and arrival points). It calculates the smallest spheres gathering each one of these points on three trajectories. The



(a) Face view (b) Profil view

Fig. 7. The fetal head and the guide spheres

smaller are the spheres the more the operator gestures are repeatable. The analyzed trajectories are gathered into three groups, a group per day of training. To define the degree of repeatability, the value of the sphere radii is analyzed.

Concerning the second method, it enables the evolution of their error compared to a reference obstetric gesture to be monitored. The reference obstetric gesture was previously extracted from the record of one expert gesture. This method calculates the error between the novice gestures and the expert ones. As operators require different amount of time to place the forceps, trajectories had to be normalized according to an average time calculated from all the expert measurements (5.1 seconds to place the left blade and 5.3 seconds for the right blade). The error ε corresponds to the sum of the errors along each axis:

$$\varepsilon_x = \int_0^t |x_{ref}(\tau) - x_{op}(\tau)|\, d\tau \quad (1)$$

$$\varepsilon_y = \int_0^t |y_{ref}(\tau) - y_{op}(\tau)|\, d\tau \quad (2)$$

$$\varepsilon_z = \int_0^t |z_{ref}(\tau) - z_{op}(\tau)|\, d\tau \quad (3)$$

$$\varepsilon = \varepsilon_x + \varepsilon_y + \varepsilon_z \quad (4)$$

Where x_{ref} (y_{ref} and z_{ref} respectively) is the blade displacement along the $\overrightarrow{x}$-axis ($\overrightarrow{y}$-axis and $\overrightarrow{z}$-axis respectively) of the reference movement and x_{op} (y_{op} and z_{op} respectively) is the blade displacement along the $\overrightarrow{x}$-axis (the $\overrightarrow{y}$-axis and $\overrightarrow{z}$-axis respectively) of the operator whose path we want to compare.

This method is more complete than the one previously presented because it takes into account the whole path and not only three particular points.

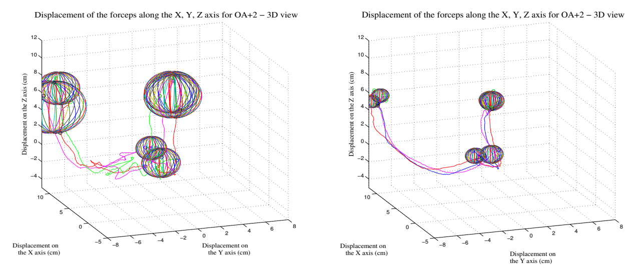
However the normalization process implies that the data need to be modified therefore both methods of analysis are complementary and enable the evolution of the novices to be followed during their training on the BirthSIM simulator.

III. Results

The first results of the training were the commentaries of the novices which were very pleased to be trained on such simulator. They appreciated acquiring a beginning experience without risking the health of the fetus and the mother.

A. Repeatability of the Gesture

Fig. 8 shows the paths at the beginning of the training and at the end of the training for novice N1. As previously stated we are mainly interested by the tip of the forceps which is in permanent contact with the fetal head, therefore it is the path of the forceps blade tips which are plotted on the following figure. Qualitatively, one can observe that the



(a) Before the training (b) After the training

Fig. 8. Paths of the novice N1 with the repeatability spheres.

gestures seem to be less hesitant and more similar to each other. Similar graphs were obtained for novice N2, they have not been plotted to avoid repeating the same kind of figures, as we are mainly interested on the quantitative analysis.

With this training method novices seem to improve their gestures as shown in table I. This table gathers the results in centimeters obtained for both novices. The nine forceps blades placements are gathered in three groups according to the training day.

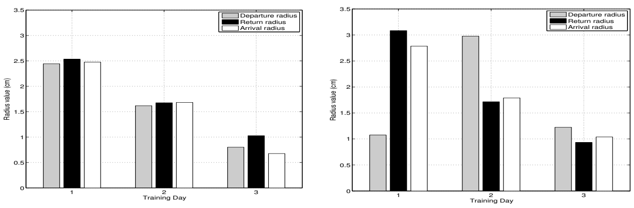
TABLE I

Table of the radii spheres in cm for novices N1 and N2 with the guide spheres training method.

Station and location OA+2		Novice N1		Novice N2	
		Left blade	Right blade	Left blade	Right blade
Day	Sphere				
1	Start	2.44	1.08	2.78	1.23
	Return	2.53	3.08	3.49	2.55
	Arrival	2.48	2.78	2.24	2.17
2	Start	1.62	2.98	1.80	2.62
	Return	1.68	1.72	1.20	1.83
	Arrival	1.68	1.79	1.20	1.67
3	Start	0.80	1.22	1.34	1.83
	Return	1.03	0.93	0.47	1.10
	Arrival	0.68	1.04	0.42	1.48

Novices globally reduce the size of their repeatability spheres between their first training day and their third training day. Concerning expert results, their repeatability spheres have a radius of 1.09, 0.46, and 0.23 cm for the left blade and 0.98, 1.15, and 1.3 cm for the right blade respectively for the start, return, and arrival spheres. The difference between all the radii of the first day and the third day indicates a decrease of 66% and 54% for novice N1 and 74% and 27% for novice N2 (respectively for left and right blade).

Fig. 9 represents an histogram of the evolution of the radii spheres according to the training day. For the same reason



(a) Left forceps blade (b) Right forceps blade

Fig. 9. Evolution of the spheres radii for novice N1

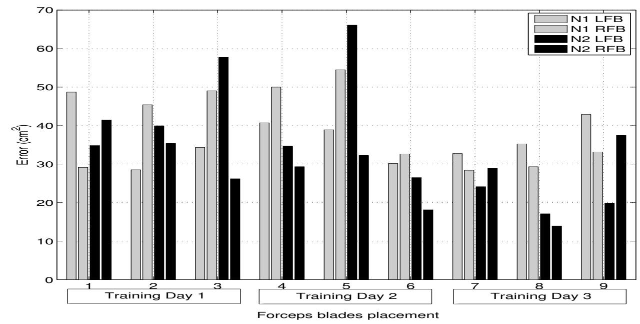


Fig. 10. Error during forceps placements.

as before (similar results) only one figure has been drawn to avoid overloading the paper with similar figures.

An overall reduction of the values of the radii is noticed what means that the novices carry out gestures in a more and more repeatable way. The novices thus have acquired a gesture with a higher degree of repeatability. However their paths were studied on only three particular points. To complete this study, we analyze the paths as a whole and then compares them to the reference path carried out by the expert.

B. Comparison With the Reference Gesture

A reference gesture is defined by an expert whose forceps blade placement is considered as ideal. The comparison is based on the results of calculating the integral of the error along the three axes.

The paths are compared to the reference one, the errors along each axis are cumulated and only the sums ε are shown at Table II.

TABLE II

ERROR ε COMPARED TO THE REFERENCE GESTURE FOR EACH NOVICE WHO WERE TRAINED WITH THE GUIDE SPHERES.

Station and location OA+2		ε for N1		ε for N2	
Training day	Placement	Left blade	Right blade	Left blade	Right blade
1	1	48.69	29.15	34.82	41.47
	2	28.53	45.42	39.96	35.37
	3	34.31	49.04	57.74	26.20
2	4	40.73	54.47	34.72	29.34
	5	38.91	32.61	66.09	32.23
	6	30.15	28.40	26.50	18.13
3	7	32.75	26.84	24.13	28.93
	8	35.23	29.32	17.10	13.93
	9	42.89	33.13	19.88	37.46

In this table, we notice a reduction of the global error ε for each novice before the training (placement 1, 2 and 3) and after the training (placement 7, 8 and 9).

Fig. 10 gathers the results of table II and represents, as a histogram, the evolution of the novices according to the placement which they carried out. On this histogram, LFB means Left Forceps Blade and RFB Right Forceps Blade. The grey bars represent novice N1 forceps blades errors (left and right), the black bars represent novice N2 forceps blades errors.

An error ε reduction is noticeable which means that the paths of the novices tend "to be closer" to the reference path defined by the expert. Both novices manage to reduce their errors between the first training day and the third training day: -1% and -27% for novice N1 and -54% and -22% for novice N2 respectively for the left and right blade.

IV. DISCUSSION

From the novices point of view, they appreciated to be trained on the BirthSIM simulator which allows them to avoid the constraints of the childbirth ward in order to learn the forceps blades placement. Indeed, while they are training on the simulator, they are not in an emergency situation so they could train without stress and risk of hurting the fetus or the mother. With the visualization interface, they could see the path of the forceps around the fetal head inside the pelvis.

The constraints are also present for instructors in a childbirth ward, thus the expert could explain with more time the forceps blades placement and by using the visualization interface of the simulator he could control the novice forceps path inside the pelvis.

From the repeatability point of view, the dispersion of the novices' gestures decreased on the whole. Certainly, for some gestures the values of the radii increased (radius of the departure sphere for N2 and his right blade) but the departure point is much less crucial than the return and arrival points. They have acquired a better repeatability and especially a surer gesture. At the end of the training period both novices managed to reduce their radii values. The simulator training allows novices to improve their gesture. They managed to reduce their repeatability spheres of 66% and 54% for N1 (left and right blade respectively) and of 74% and 27% for N2 (left and right blade respectively). This last result is so low compared to the other results because it is due to the raising of the value of his departure sphere for the right blade. Novices have acquired a surer gesture in placing the forceps blade placement.

From the point of view of the comparison to the reference gesture, the paths have converged closer to the reference. The error tends to decrease for both novices. A longer training should provide even better results but in less than three days at the rate of one hour a day, novices acquired the correct obstetric gesture.

The training method with the guide spheres allows novice obstetricians to acquire a better initial experience more quickly. They managed to place the forceps with less hesitation whereas in a classical training, according to our expert experience, they will need at least two semesters before obtaining such good results. Of course to validate these first results, a more complete study is necessary with a larger novice sample and a comparison of the traditional training and this simulator training. Unfortunately this was not possible within the scope of this paper because there were not enough novices available at the hospital. One would need a study on several hospitals to make it more representative. Moreover, more measurements and a more significant follow-up of the novices are necessary to complete the study. However these first results are encouraging for the continuation of the research. They show that a simulator training is useful for the novices in the beginning stage of their experience before acting in a childbirth ward which is a necessary step in their degree course to become an obstetrician.

V. Conclusion

In conclusion, this paper shows the advantages of training on a childbirth simulator provided with instrumented forceps. The advantages of the simulator training are multiple for the patients (the risk reduction of the compulsory training period done on real patients), for teaching (fundamental principles training, simulations of rare cases, individual and adaptable training, with or without constraints) and for experimental new techniques. In particular this study presents a new training method using the visual component of the BirthSIM simulator. This method allows to represent the reference gesture of an expert by some guide spheres equally distributed along the path.

The analysis of a first clinical study shows that the gestures of the novices who were trained on the simulator progressed and acquired a high degree of repeatability in their gestures. Their gestures are less hesitant and they tend to get closer to a reference path defined by an expert obstetrician. The method we developed with the guide spheres allows to train novices better and quicker than a classical training. This kind of training should complete the traditional training. Criticisms of the novices and of the instructor enable the simulator to be adapted to their needs.

A new campaign of measurement should be soon launched with the use of the electro-pneumatic component so that the novices can train to extract the fetus once the forceps is correctly placed and forceps and head displacements could be measured and studied during the extraction.

Acknowledgments

The authors gratefully acknowledge the contribution of Pierre Boulanger for his very pleasant welcome in his laboratory (AMMI Lab, Department of Computing Science; University of Alberta, Edmonton, Canada).

References

[1] ATLAS Aerospace, http://www.atlasaerospace.net/eng/index.htm, website checked on 20-04-2006.

[2] Muffler R.J. AV-8B HARRIER II Training capabilities. In *AIAA Flight Simulation Technologies Conference*, pages 11–15, St Louis, MO, USA, 1985. ISSN 0146-3705.

[3] Foerst R. Fahrsimulatoren, http://www.drfoerst.de/simulator.htm, website checked the 20-04-2006.

[4] Hoskins A., El Gindy M., and Vance R. Truck Driving Simulator Effectiveness. In *Winter Annual Meeting, Symposium on Advances in Vehicles Technologies*, New Orleans, Louisiana, USA, 14–19/11/2002.

[5] Simulaids Corporation, http://www.simulaids.com/, website checked on 20-04-2006.

[6] Laerdal, http://www.laerdal.com/, website checked on 20-04-2006.

[7] Simulution, http://www.simulution.com/, website checked on 20-04-2006.

[8] Baumann R., Maeder W., and Glauser G. The pantoscope: A spherical remote-center-of-motion parallel manipulator for force reflection. In *IEEE International Conference on Robotics and Automation (ICRA'97)*, pages 743–750, Albuquerque, New Mexico, USA, 1997.

[9] The KIZMET simulation homepage, http://iregt1.iai.fzk.de/, website checked on 20-04-2006.

[10] Karouia M., Arhets P., and Aigrain Y. A novel design of endoscopic surgery training simulator. In *35th International Symposium on Robotics (ISR'04)*, page 66, Paris, France, 23–26/03/2004.

[11] Zambelli P.Y, Bregand C., and Dewarrat S. Planning and navigation solution in resurfacing hip surgery: a way to reduce the surgical approach. In *Poster session, 3rd Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery*, Marbella, Spain, June 2003.

[12] Grumert R., Strauss G., Moeckel H., Hofer M., Poessneck A., Fickweiler U., Thalheim M., Schiedel R., Jannin P., Schulz T., Oeken J., Dietz A., and Korb W. Elephant - an anatimical electropnic phantom as simulation-system for otologic surgery. In *IEEE International Conference of the Engineering in Medicine and Biology Society (IEEE EMBC 2006)*, pages 4408–4411, New York City, USA, September 2006.

[13] Chen M-Y, Williams II R. L., Conatser JR. R. R., and Howell J. N. The virtual movable human upper body for papatory diagnostic training. In *Digital Human Modeling for Design and Engineering, DHM'06*, Lyon, France, 2006.

[14] Lim F., Brown I., McColl R., Seligman C., and Alsaraira A. Hysteroscopic simulator for training and educational purposes. In *IEEE International Conference of the Engineering in Medicine and Biology Society (IEEE EMBC 2006)*, pages 1513–1516, New York City, USA, September 2006.

[15] Silveira R. *Modélisation et conception d'un nouveau simulateur d'accouchement (BirthSIM) pour l'entraînement et l'enseignement des jeunes obstétriciens et des sages femmes*. PhD thesis, Institut National des Sciences Appliquées (INSA) de Lyon, France, 2004.

[16] Silveira R., Pham M.T., Redarce T., Bétemps M., and Dupuis O. A new mechanical birth simulator : BirthSIM. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'04)*, pages 3948–3954, Sendai, Japan, 2004.

[17] Moreau R., Olaby O., Dupuis O., Pham M.T., and Redarce T. Paths analysis for a safe forceps blades placement on the BirthSIM simulator. In *IEEE International Conference on Robotics and Automation (ICRA'06)*, pages 739–744, Orlando, USA, 2006.

[18] Dupuis O. *Apport du forceps instrumenté dans la sécurité de l'extraction instrumentale*. PhD thesis, Institut National des Sciences Appliquées (INSA) de Lyon, France, 2005.

[19] Dupuis O., Moreau R., Silveira R., Pham M.T., Zentner A., Cucherat M., Rudigoz R.C., and Redarce T. A new obstetric forceps for the training of juniors doctors. A comparison of the spatial dispersion of forceps blade trajectories between junior and senior obstetricians. *American Journal of Obstetrics and Gynecology (AJOG)*, 194 (6):1524–1531, 2006.

[20] Minibird Installation and Operation Guide, Ascension Technology Corporation.

[21] Olaby O., Moreau R., Brun X., Dupuis O., and Redarce T. Automatic childbirth procedures implanted on the BirthSIM simulator. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'06)*, pages 2370–2375, Beijing, China, 2006.

[22] Actiris Pack, ActiCM. http://www.acticm.com/gb/pack.htm, website checked January the 8th.

[23] Motion Desk 3-D Online Visualization Guide, dSpace.

[24] Cunningham G., Gilstrap L., Leveno K., Bloom S., Hauth J., and Wenstrom K. *Williams Obstetrics*. the McGraw-Hill Companies, 22nd edition, 2005. ISBN 0071413154.