

An Educational Simulator for Training CPR Skills

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Summary

This paper describes the design and implementation of an educational simulator to help people of medical area for training CPR skills. Another of the reasons that this simulator was build was due to the necessity for an evaluation tool that helps the trainer to check the learning percentage of the trainee, since this educational simulator gives a module for this work.

Keywords:

Educational simulator, simulator design, simulator development, enhance training skills, CPR.

1. Introduction

The field of simulation has been growing for many years. In the medical field particularly, many simulators focus on patient treatment, which allows professors and students from the health area to practice efficiently. Other simulator types focus on diseases and on patient response to clinical surgeries. Because computer technology has become more powerful, the simulators enhance interactivity and experiences for feedback in the process of medical education and resident training [1].

In [2] clinical simulation concepts are discussed, which span a spectrum of sophistication, from simple reproduction of body parts to complex human interactions portrayed with simulated patients or high fidelity simulators.

One of the medical procedures that throughout its history has required effective training simulators involving recollection of quantitative data for its subsequent evaluation is CPR (cardiopulmonary resuscitation). Logically the simulator requirements should be in accordance with CPR training programs accepted by specialists.

This work describes the design and implementation of an educational simulator to help student nurses at the Universidad Autónoma de Yucatán, Mexico, to develop their skills in the process of CPR training. One main objective is to help to improve the learning process for cardiac treatments through an electrocardiogram simulator giving traces and cardiac treatments; also the simulator aims to be an evaluation tool to help the trainer to verify the learning percentage of trainees, because the simulator provides a module for this task.

Many studies have been developed in this area; in [3] an electronic resuscitation evaluation system) was developed

which distinguishes and tabulates pressure pulses received from the training mannequin during the CPR process.

In [4] the design and development of a prototype of a medical robot for CPR process is described. It is based on the principle of virtual work and using a control algorithm as alternative to perform chest compression adequately.

In [5] the development of an experimental system using a mannequin to improve the CPR process using interactive coaching while the performance data are recollected is described.

In [6] the authors describe an emergency simulation center including use of mannequins with integrated monitoring procedures to collect and evaluate procedure data during training with trainees at the emergency center.

2. Simulation

A model is by definition a static representation of a concept of the world. Simulation adds a temporal aspect to the model by represent how the modeled system changes with time. So, simulation can be defined as a time-varying representation of a model [7]. As well as this, we can think about simulation as a process by which it is possible to perform experiments on a model to see how a real system could behave if the same experiments are applied to it.

For example, plane designers could scale airplane models to prove the aerodynamic characteristics of their designs. By manipulating the design of wings or fuselage on the model, the designer can investigate how the changes can affect the air flow on these surfaces. If the model is a good representation of an actual plane then the designer will have evidence of how the system could behave with these changes. It is possible to perceive the advantage of simulation in that it is possible to conduct many experiments on a model with changeable conditions without having to build or modify the actual system because it is easier to change the characteristics of a model in a simulation than to rebuild a real plane.

2.1 Breakthroughs in simulation

Since 1980, academic and research centers have been focusing on how body functionality could be simulated in a similar form to the real form. Miami University obtained the first advance in the recreation of human body functions

with a mannequin named Harvey, upon whom many physic aspects of a cardiologic examination representation, including palpation, auscultation and electrocardiography. This was the first step towards the development of simulators that could replicate the human body functions appropriately [8].

During recent years the capacities of training simulators have increased with the help of computer science and other technologies. Many academic institutions have grown in sophistication creating simulation groups which maintain constant technological progress. With the current advances in software design and hardware manufacture the simulators have been refined to give efficient virtual procedures.

In the military, simulation has been used for years for training on combat scenarios, and it has been decisive thanks to organizations such as Defense Advanced Research Projects Agency (DARPA) and Telemedicine and Advanced Technology Research Center (TATRC) which have led the development of training simulators. The work conducted by academic institutions, private organizations, health institutions and the military has been an integral part of the definition and development of medical simulators as training tools for a variety of health care professionals [8].

2.2 Why medical simulation?

Historically, the use of classroom and hands-on training by experts has been the common training mechanism for many medical training programs. Under these traditional training scenarios, experts offer the opportunity for novices to perform procedures under supervision. Although these activities allow trainees a gradual learning experience, there are normally complications associated with the training duration as well as the cost of having the trainer present.

As well as this, due to the high presence of human errors and their impact on patient safety, there is a need for innovative methods to ensure that the training program has the necessary practical experience before patient contact.

Simulators offer a safe environment in which a trainee can repeatedly practice a procedure without an impact on patient safety. As an example of the importance of simulation, the authors of [6] describe a significant impact point in health sector education and its relationship with future professionals.

Training with simulations is use more and more and hand-on training is always performed with the management of an expert. The trainees can practice with the simulator until they feel they have the necessary skills. As well as this, patient contact on the supervision of an expert is more beneficial to both the patient and the trainee [8].

3. CPR

CPR is an emergency live-saving technique which is used when a person has stop breathing or the heart has stop beating due to electric shock or suffocation [9]. In [10] CPR is described as an attempt to counteract cardiopulmonary failure (cardiac or pulmonary failure) through specific actions.

Undoubtedly, good CPR procedure can prevent the death of a person; however bad procedure can leave the patient with a cerebral or bodily damage.

3.1. CPR treatments

In [11] and [12] distinct treatments of CPR are described. Also, they mention that in order to perform a CPR treatment one of the following conditions must be present:

- a. The patient generates an isoelectric trace.
- b. The patient generates a ventricular fibrillation trace.
- c. The patient generates a ventricular tachycardia trace.

Depending of the case, what follows is a description of the necessaries steps for applying CPR procedure.

If there is an isoelectric trace, the following is necessary:

- Canalize (once)
- Do CPR
 - Ventilations (twice)
 - Massages or compressions (fifteen times)
- CPR is done up to four times, each time both the breathing and the circulation are evaluated. From the third time the normal trace should appear.
- Administer adrenaline, 1 mg. Repeat every 3 to 5 minutes (to help the heart to function).
- Administer atropine, 1 mg. Repeat every 3 to 5 minutes (to stabilize heart function).

If there is a ventricular fibrillation trace the following is necessary:

- Administer synchronic discharges of 200 to 600 joules depending on the situation.
- Administer adrenaline (optional)

If there is a ventricular tachycardia trace the following is necessary:

- Administer synchronic discharges of 200 to 600 joules depending on the situation.

Depending on the performance results of any step of the treatment, it may be necessary to start another treatment.

3.2. Traditional learning process for CPR

In training practices the learning process is generally performed as follows:

- A mannequin is used as a patient
- The trainer mentions the arrhythmia type
- The trainer performs the correct treatment for the arrhythmia.

3.3. Traditional evaluation process for CPR

The traditional evaluation process that the trainer performs is as follows:

- A mannequin is used as a patient
- The trainer mentions the arrhythmia type
- The trainer describes and performs the treatment for the arrhythmia.
- The trainer evaluates each step, noting his observations.
- The trainer can complicate the patient’s state and the trainee should respond accordingly.
- At the end the instructor gives a final score based on his observations.

4. Training Simulator: Design and implementation

For the training simulator design Unified Modeling Language (UML) was used to facilitate the comprehension of the system through visual representations. This language combines the best practices of diagramming applied to object oriented software development [13].

4.1 Simulator design

In [13] the use case model is defined as both a collection of diagrams and text which describe how the user hopes to interact with the system. Also in [14] the idea of utilizing one use case diagram to describe the system functional requirements is described.

The general functions (described in part 3 of this paper) were defined with two use cases: the practice mode and the evaluation mode. Fig. 1 shows the use case diagram of the simulator functionality.

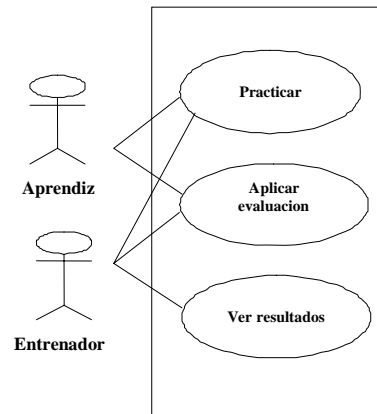


Fig. 1 Use case diagram of our simulator

A class diagram represents the static view of a system, that is, it represents how the objects are defined and located on a structure [13]. In fig. 2 the class diagram representing the structure of our simulator is shown.

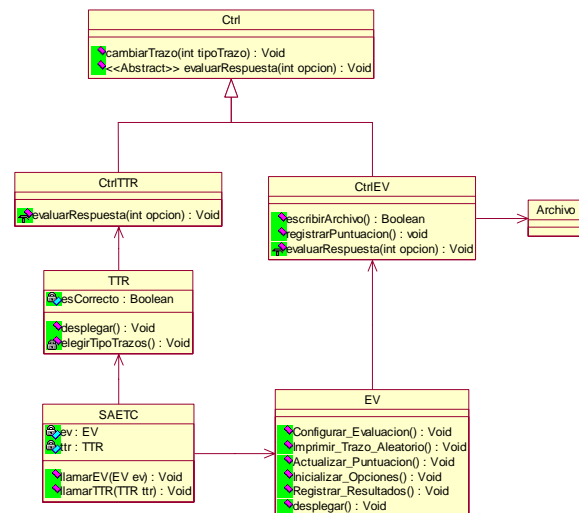


Fig. 2 Class diagram of the simulator structure

All system structures also require dynamic view modeling, which describes object interactions on the system. To model the dynamic view of the simulator, two types of UML diagrams are used: the sequence diagram and the activity diagram. These diagrams are important because they represent how the system will respond to the user’s actions, how the data is stored and how the objects are created and manipulated [13].

In fig. 3 the sequence diagram of the simulator practice process is shown and its interpretation is explained in the next paragraph.

Initially the practice mode uses the *Desplegar()* function to visualize the TTR screen which shows a series of possible traces. Next the trainee selects a trace which is shown on the screen using the *elegirTipoTrazos()* function. When the trace is shown on the screen, the trainee should navigate between different screens within the simulator until treatment is complete. At the same time an instance of *CtrlTTR* (the process control object) will evaluate the trainee's answers using the *evaluarRespuesta()* function either to increase the tally of correct answers or errors until treatment is finished.

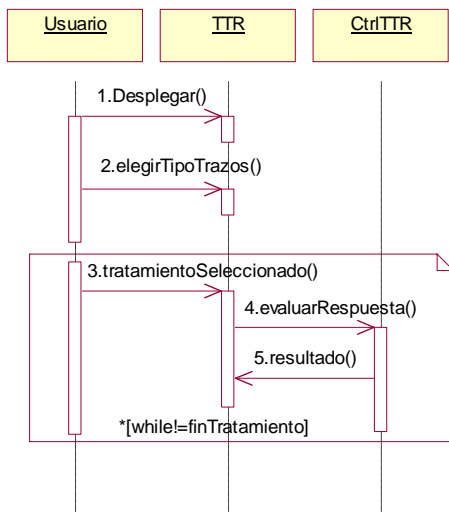


Fig. 3 Sequence diagram: practice

In fig. 4 the activity diagram of practice process corresponding to the diagram of fig. 3 is shown.

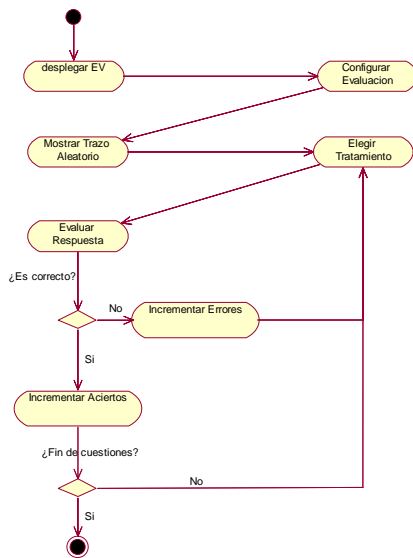


Fig. 4 Activity diagram: practice

In fig. 5 the sequence diagram of the learning evaluation is presented and in fig. 6 the activity diagram for the same process is shown. The sequence diagram interpretation of fig. 5 is explained in the next paragraph.

Initially the evaluation mode uses the *Desplegar()* function to visualize the EV screen which permits configuration of the evaluation with the *configurarEvaluacion()* function. Next the simulator presents different screens of the CPR process where the trainee or trainer can select any response through the *seleccionarResponse()* function. The simulator uses one instance of *CtrlEV* (a process control object) to evaluate the answers with the *evaluarRespuesta()* function and gives a result with the *resultado()* function. This procedure is repeated many times depending on the evaluation treatment type. At the end, the results are written by the instance of *CtrlEV* on a file using the *escribirArchivo()* function.

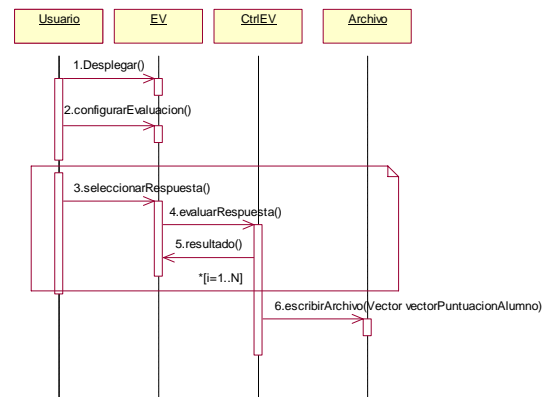


Fig. 5 Sequence diagram: evaluation

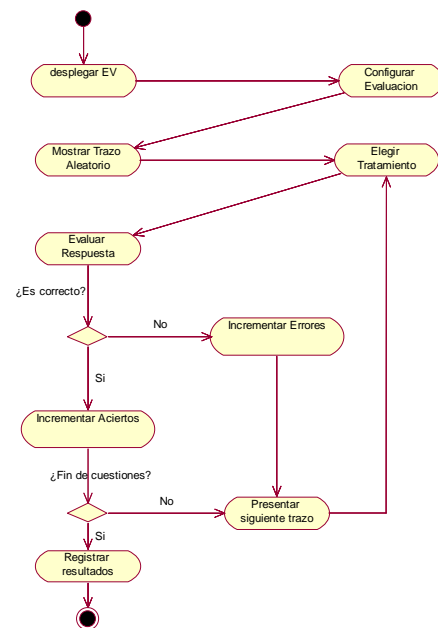


Fig. 6 Activity diagram: evaluation

4.2 Development Tools and Implementation

Upon conducting an analysis of development tools we decided use the Windows Operating System ® and the Visual Basic Programming Language ® due to the advantages and facilities given by the graphic libraries for the representation of required traces. In fig. 7 the main screen of our simulator is shown.



Fig. 7 Main screen of our simulator

A screen which is an important part of the practice process is shown in fig. 8. In this screen the user should decide how many joules are applied to the patient as part of a treatment.

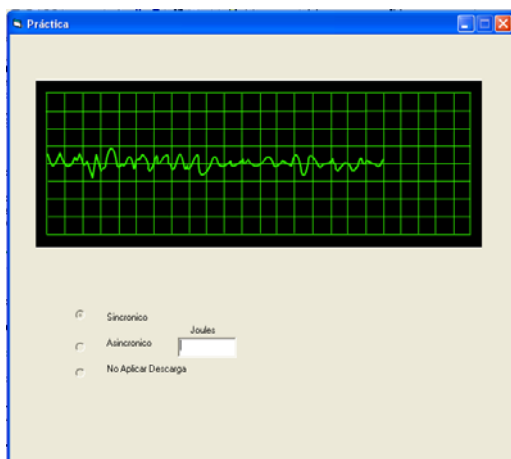


Fig. 8 Practice procedure screen

The main part of the practice section belongs to CtrlTTR class. The source code is shown next as an example:

```
Public Class CtrlTTR
    Public Function evaluarRespuesta(ByVal opcion As Integer)
        Select Case itipoTrazo
            Case 1
```

```
                Return False
            Case 2, 4
                If sSecuencia.Chars(iIndice) =
                    opcion.ToString.Chars(0) Then
                    iIndice += 1
                    Return True
                Else
                    Return False
                End If
            Case 3
                If opcion = 10 Then
                    If iIndice = 0 Then
                        bRespuesta = MessageBox.Show("¿Desea aplicar
                            Adrenalina?", "Pregunta", MessageBoxButtons.OKCancel,
                            MessageBoxIcon.Question)
                        If bRespuesta = DialogResult.OK Then
                            iIndice = 1
                        Else
                            iIndice = 2
                        End If
                        Return True
                    Else
                        Return False
                    End If
                Else
                    If opcion = 2 And iIndice < 2 Then
                        iIndice = 2
                        Return True
                    Else
                        Return False
                    End If
                End If
            End Select
        End Function
        Public iIndice As Integer
        Public sSecuencia As String
        Public itipoTrazo As Integer
        Dim bRespuesta As DialogResult
    End Class
```

The above code evaluates the trainees answers using the *evaluarRespuesta()* function base on the solution chosen, either to increase the tally of correct answers or the errors on the practice.

The evaluation process screen is shown in fig. 9. Here a trace is shown for which the user should decide the discharge type to perform, and in the lower part of the screen the trainee's score are shown.

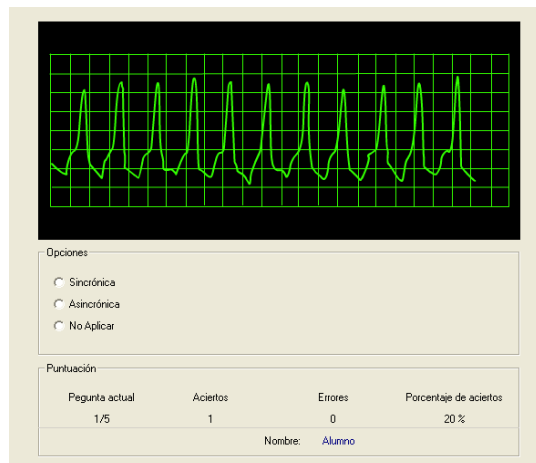


Fig. 9 A trace presented during an evaluation

5. Conclusions and Future Work

In this paper the development process of an educational simulator of training-evaluation with the objective of learning and improving CPR skills in trainees is described. Simulators are powerful tools for teaching new techniques, procedures and instruments, and can be used to help people get a better understanding and use of best practices, correct management of patient complications, appropriate use of tools and instruments and the skills to perform a procedure. Additionally it is helpful that the evaluation component of medical simulators can be easily customized to provide better valuation of activities and knowledge.

With the development of this educational simulator we hope to obtain the following benefits: to improve educational experience, to increase cost effectiveness and to allow more time for training.

Many parameters with relating to the simulator are going to be the objects of future study as mentioned in [15]. Among our parameters of interest are: the effectiveness of simulators as a teaching tool, a usability study and investigation of the relationship between the acquired CPR skills and their evaluation process.

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