

# A real-time simulator for ergonomics and displacement evaluations

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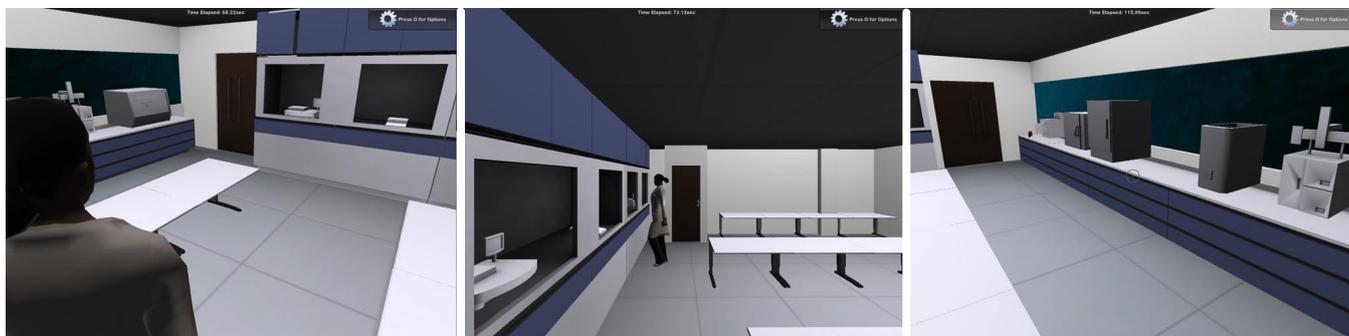


Figure 1: different camera views such as over the shoulder, side view and first-person camera

## Abstract

In many working facilities, employees face problems such as bad equipment disposition and narrow corridors. In these situations, workers struggle to move inside the laboratory, they constantly need to interrupt their tasks to make room for others, and often find themselves in a bad posture that causes long-term injuries. To overcome these issues, this paper presents a virtual environment simulator that will help analyze the physical disposition of the workers and furniture in the environment and how these elements affect the way the tasks are performed. By understanding how these variables are related to each other, it is possible to develop better room configurations that optimize workflow and circulation.

**Keywords:** ergonomics simulation, biomechanical analysis, virtual environments, control rooms

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## 1 Introduction

Ergonomics can be defined as the science of adapting the work environment to the characteristics of the workers. As applied to computer systems, it means the consideration of human factors in the design of systems to make them more attractive and easier to learn and use. Ergonomics is often combined with the concept of productivity. Productivity is an older concept whose definition is no longer appropriate. A new definition might be that productivity is the value of goods, services, or human and social benefits produced divided by the cost in money, irreplaceable resources, and negative impact on human beings. Whether or not there is un-equivocal evidence that ergonomic principles applied to the work environment result in increased productivity in traditional terms, there is a very high probability that ergonomic design will satisfy the requirements of the new definition [Fried 1982].

The designing and ergonomic project of a control room is part of a process of conception and development of a whole new production unit. From a practical perspective, Ergonomics interferes in the conception process, from the viability studies and initial stages of the conception to the implantation of the created situations. Moreover, it goes through working rooms definition, furniture definition,

computer-based equipments definition, screens settings, human recruiting and the organization of the work. [Santos and Zamberlan 2002]

Poor disposition of balconies and other furniture along with narrow corridors are a real problem in many working facilities worldwide. It is not hard to spot tools or objects, that are regularly needed, kept within unreachable heights, either too high or too low.

That poor disposition of equipment causes unnecessary issues. By paying attention to the routine of some workers, it is easy to notice how they struggle to move around the environment and constantly interrupt their tasks to make room for other co-workers. For instance, if a person is pushing a trolley through an alley and realizes that his co-worker left a drawer open, then he needs to stop his task to remove the obstacle in his way. In other situations, his co-workers could be standing in front of a balcony performing a task that cannot be interrupted until it's done. So, in that case, the person needs to wait for his co-worker to end his task before he can keep on pushing the trolley.

In some activities defined as continuous processes, such as oil and gas production, steel and power plants, the interruption of the production is highly undesired. Any non-planned interruption in these productive processes may represent a collapse in the system or even a threat to the security of the workers and the population. The human role in these scenarios is decisive. Each person involved in the operations' control must have full knowledge of the procedures to follow and must be able to easily communicate with his co-workers. [Santos et al. 2009]

This paper proposes a virtual 3D environment simulator as a tool to overcome these issues. Three-dimensional models of the virtual environment and of the workers will be generated and inserted into the simulator. Each user will then control his own avatar representing himself, with both facial and body resemblance. Workers and co-workers will perform their daily tasks, as in real-life. The simulation works as tool to analyze the physical disposition of the workers and the furniture in the environment and how these elements affect the way the tasks are performed.

By testing different configurations of a room, one can simulate a variety of scenarios and observe their strong and weak points. For instance, it is crucial to understand the negotiation of space between two users carrying objects or pushing a trolley through a narrow alley. In more general terms, the usage of the simulator will help figure out how the users interact with each other and with the environment, focusing more deeply on the ergonomic perspective. By understanding how these interactions occur, better room configurations can be developed and these better designs will optimize workflow and circulation around the working environment.

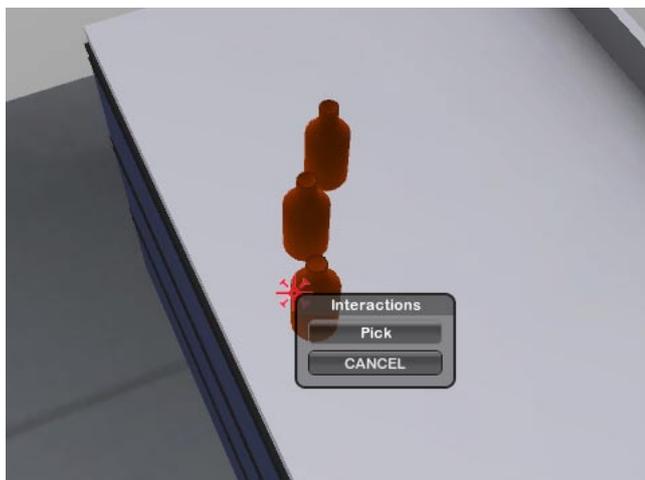


Figure 2: example of the interactions window



Figure 3: only the interactions available are displayed

## 2 Related Work

ERGO is a simulation environment for ergonomic assessment and task analysis. Ergonomics Analysis features include ergonomic posture, energy and lifting analyses [Donald 1998]. Unfortunately, the software provides neither analysis on the displacement of the user inside an environment nor his interaction with other users in the same environment. Therefore, it is not possible to understand how their physical displacement and interactions with the environment affect the way the tasks are performed.

Another simulation software is presented in [Santos et al. 2007] and the authors state that the use of simulation not only improves current processes but also allows for the testing of new processes before they are implemented. By using the standard tools included in the software, it is possible to have a virtual representation of the future workstation. Also, the software allows for the changing of a worker's personal characteristics such as gender, height, weight, and so on so the simulation can be adapted to a range of workplace scenarios. However, it is not possible to have more than one user interacting in the same virtual scenario to study how the tasks are performed differ due to the users' interactions with themselves and the environment.

There is a clear need of a networked virtual simulator that allows multiple users inside the same environment. This simulator will help understand how the users' interactions affect circulation and how their physical dispositions affect the way they perform their tasks.

## 3 The Simulator

The main objective of the simulator is to help design and evaluate complex working facilities, such as chemistry laboratories and control rooms. Also, it will help the design, evaluation and training of cooperative tasks.

The first prototype of the simulator contains a general purpose laboratory. The simulation itself will be controlled by the employees of the real laboratory, where they will perform their daily tasks, as in a real life situation. By analyzing their interactions with the environment, it is possible to develop better room configurations.

The simulator is a networking multiuser environment where four people can interact. Each user will control his own avatar. They will be able to move their avatar around the environment and perform some simple tasks such as opening doors, operating switches, grabbing and moving objects around. The users will be able to communicate with themselves through voice-chat. To increase the realism of the interactions, it is possible to implement facial expressions, such as a basic lip-sync.

The simulator creates a virtual environment where the users can perform tasks and interact with others co-workers as they would in

real life. The focus of the simulation is to understand the role of the physical disposition of the users and furniture in the laboratory and how these elements influence the way the tasks are performed. For example, some situations concern the opening of drawers and cupboards doors and how they affect the circulation.

To achieve accurate results, the 3D models of the avatars and furniture of the laboratory will be based on architectural data and 3D scans. Using a whole body 3D scanner, it is possible to represent with great fidelity the shape and the face of the user. This approach will grant more identification and fidelity with the real person. Also, some of the animations will be generated through the use of a motion capture suite which brings the movement animations even closer to the person's real life movements.

### 3.1 Avatars

The avatars must be as realistic as possible. For that reason they will be created starting from the 3D scans of real subjects. The rig of the character based on a skeleton must be compatible with the constraints of the motion capture suite files. The structure of the skeleton must include the fingers to grant grasping and pointing animations. Some facial bones, such as jaw, lips and eyelid will be needed as well to grant lip sync, gaze and some basic emotional expressions.

### 3.2 Animations

Some animations such as walking, standing still and running will be obtained in various "motion capture" sessions with the subjects that were previously scanned. The 3D artist will take care of the rest of the animations. Eyebrow lifting, lip-sync and other facial expressions will be procedural.

One of the main issues of the simulation concerns the displacement of the user in the laboratory that is often restrained by the limited space available. Different animations will be created to simulate avatars carrying objects with different sizes and weight to allow the users to identify the effort of his colleagues and to take the decision in accordance, for example helping the colleague or giving him space to move. For this matter, different camera views are available as shown in figure 1.

### 3.3 Displacement analysis

To help visualize the displacement of the workers inside the laboratory, trail lines are rendered to represent the path inside the environment. For instance, figure 4 shows the top view of the laboratory with the trail lines drawn on the floor. The trail lines can also be rendered for the objects as well. This helps understand not only the displacement of the users but also the displacement of the objects inside the laboratory.

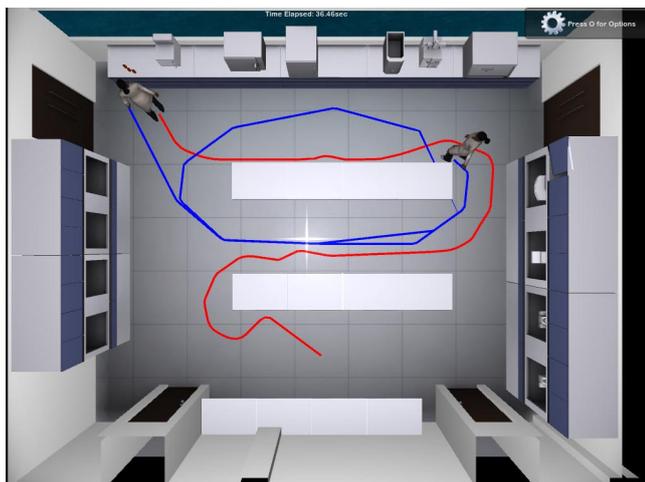


Figure 4: top view of the laboratory

Furthermore, a replay system is currently under development, which gives a great flexibility to the motion analysis. With this feature, it is possible to replay a specific event from different points of view, by selecting which camera is more adequate depending on the data to be investigated.

An increasing sequential number is recorded and assigned at each task the user performs. This allows for an easier identification of repetitive tasks since number and tasks association patterns can be found.

### 3.4 Input methods

In this simulation, the keyboard and mouse navigation is used, resembling the classic FPS style present in many games and applications. When the user places the mouse cursor over an object, an interaction icon appears to help identify interactive objects.

Some objects can have several interactions associated with them. For instance, a glass bottle can be picked up from a place and dropped on another. In this situation the user can only pick up the glass bottle if the user has nothing in his hands, see figure 2. Consequently, the user can only drop a glass bottle on a balcony if he does have one in his hands. Therefore, only the interactions that are available at that moment will be displayed. Figure 3 shows the interactions available with the drawer: since the user has a glass bottle in his hand, he can choose between placing the bottle inside the drawer or just closing the drawer.

### 3.5 Technical Issues

It is desirable to have a variety of camera views to allow the analysis of the simulation from different angles. The main issue is that the input method does not work for all cameras. Each camera would require its own input method and the interactions with the objects would differ as well. Not only the users would be confused by this variety of ways of controlling his avatar but also this would require longer development time. The approach for this issue is to assign one user as a spectator. Then, he would be able to switch between several different camera views, such as the one show in figure 5 but he would not be able to control any avatar in the simulation. The users controlling avatars and participating in the simulation would be limited to a first-person camera.

Users will be able to communicate inside the simulation using voice-chat. The audio files from the voice-chat will also be used to drive a basic lip-sync mechanism that will facilitate the identification of the speakers. The sound will be spatialized to provide an intuitive feeling of the position of the audio sources in the virtual 3D environment. Furthermore, an icon on top of the avatars' heads could be used to help identify the speaker. At first a third-party software is used to provide the voice-chat feature, but an integration of the VoIP tool with the game engine is required to provide



Figure 5: over shoulder camera view

the spatialized audio. Besides that, there's also the need of identifying who spoke at which time to allow the implementation of the lip-sync animations.

## 4 Unity3D

Unity3D is a game engine that allows the development of 3D games much faster. It was the game engine chosen to develop this simulator.

Using Unity3D makes possible to import and integrate audio, images and 3D models made by other professionals using different external tools, visualize and modify their positions or behaviors in real-time. In more details, Unity3D removes the need of the game developer to use DirectX or OpenGL (even though it is still possible, if necessary), supporting the creation of complex Shaders written in the CG language from NVidia. Internally, the physics system is the popular PhysX, also from NVidia. For the scripts execution, Unity uses a high performance version of the Mono library, an open-source implementation of the .NET framework from Microsoft.

### 4.1 Game Object

As stated in the [Unity 2009c]: "Think of a Game Object as an empty cooking pot, and Components as different ingredients that make up your recipe of gameplay."

Each and every element inside a scene is a Game Object. Unity is based in a modern game objects architecture that is relied on composition, where game objects are specified through the composition of different functionalities, which can be added and removed.

Each functionality is implemented by a Component (class that inherits from a basic component). That generic container is known as game object and it works as a repository of functionalities, or more specifically, Components.

### 4.2 Components

Components are responsible for implementing the many different behaviors a game object can have. Components can be a script, collision geometry, or even a GUI Texture. What that implies is that game objects can represent everything in the scenario from a simple camera to a complex character, being different only by the set of Components that are attached to each one.

By default, all game objects automatically have a Transform component. This is because the Transform dictates where the game object is located, and how it is rotated and scaled. Without a Transform component, the game object wouldn't have a location in the world.

### 4.3 Animations

By adding an animation component to a game object, one can easily play, stop and switch between different animation clips.

Animation clips can be imported from external tools in many extension formats and they can even be created and edited inside Unity through the Animation View [Unity 2009a].

The Animation component holds a list of animations clips associated with that game object. Also, there's an option for allowing the animation to interact with physics and another for disabling the animation the game object is not currently visible.

### 4.4 Audio

The audio system in Unity relies on two components: Audio Sources and Audio Listeners.

The Audio Listener acts as a microphone-like device. It receives input from any given Audio Source in the scene and plays sounds through the computer speakers. It is traditionally attached to the Main Camera. The Audio Listener works in conjunction with Audio Sources, allowing 3D sounds experience. When the Audio Listener is attached to a game object in the scene, any sources that are close enough to the Listener will be picked up and output to the computer's speakers. Each scene can only have one Audio Listener to work properly.

The Audio Source is a container for an Audio Clip, which is the actual sound that will be played. The audio source has a world position and methods to Play, Stop and Loop the audio clip. It also provides the possibility to tweak the volume, pitch and rolloff values.

### 4.5 Scripts

Scripting inside Unity consists of attaching custom script objects called behaviours to game objects. Different functions inside the script objects are called on certain events. The most used ones are Update, which is called once every frame and where most of the code goes, and FixedUpdate, which is called once every physics time step and is the place to do physics-based game behavior. [Unity 2009b]. Behaviors programming inside Unity is done through scripts, that can be written in either of these 3 programming languages: JavaScript, C# or Boo.

## 5 Expected Results

With the data that the simulator will provide, it will be possible to design better room configurations, in a way that optimizes the workflow, by reducing the distance between equipments that are vastly used during the working journey.

By detecting equipments and furniture in position that may represent security threats during the execution of a task, it is possible to minimize risks in the environment, which provides a healthy and pleasant feeling of safeness for the workers.

The simulation will also be helpful on human factors. Understanding how workers interact with their co-workers and how they negotiate space when needed, either by helping his colleague carry a heavy object or by giving him space, can provide useful data for developing laboratories with much better circulation levels.

Another improvement comes as a consequence of better design configurations. By detecting tasks that place the worker in bad postures during long periods of time, many times a day, one can set the location of equipments within positions that are ergonomic adequate, in such a way to avoid poor postures and long-term injuries.

## 6 Future Work

As described earlier, the focus of this project is on the displacement of workers in a generic laboratory and how the circulation is compromised by the lack of space. The simulator allows multiple users

which helps comprehend, from an ergonomic perspective, how their interactions affect the way they perform their tasks.

By taking the workflow described above into consideration it is possible to develop a networked real-time simulator that is useful for ergonomic evaluations and for better design of laboratories and workstations.

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## References

- DONALD, D. L. 1998. A tutorial on ergonomics and process modeling using quest and igrip. In *Proceedings of the 30th conference on Winter simulation*, 297–302.
- FRIED, L. 1982. Nine principles for ergonomic software. *Data-mation* 28, 12, 163–166.
- SANTOS, V. M. C., AND ZAMBERLAN, M. C. P. L. 2002. *Projeto Ergonômico de Salas de Controle*, vol. 1. São Paulo.
- SANTOS, J., SARRIEGIA, J. M., SERRANO, N., AND TORRES, J. M. 2007. Research on virtual human in ergonomic simulation. *Computers & Industrial Engineering* 53 (September), 350–356.
- SANTOS, V. M. C., ZAMBERLAN, M. C. P. L., AND PAVARD, B. 2009. *Confiabilidade Humana e Projeto ergonômico de Centros de Controle de Processos de Alto Risco*, 1 ed. Editora Synergia, Rio de Janeiro.
- UNITY, 2009. Reference manual - unity technologies. [www.unity3d.com/support/documentation/Components/AnimationEditorGuide.html](http://www.unity3d.com/support/documentation/Components/AnimationEditorGuide.html).
- UNITY, 2009. Scripting manual - unity technologies. [www.unity3d.com/support/documentation/ScriptReference/index.html](http://www.unity3d.com/support/documentation/ScriptReference/index.html).
- UNITY, 2009. Unity manual - unity technologies. <http://unity3d.com/support/documentation/Manual/GameObjects.html>.