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Developing a Computer Simulation Game as a Training Tool for Mining Self-Escape in Underground Coal Mining

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Abstract – Gaming technology has been growing these years rapidly. The game engines have the capability of creating a very realistic virtual environment model. This technology can also be used for mining purposes. In this research, the game engine is specifically used to develop a mine self-escape simulation game for training purposes. The game engine which is used to develop the simulation game is Unreal Engine 3. The main advantage of using such a simulation game as a training tool is because it allows the trainee to experience a dangerous situation while not being put in danger. This kind of training is considered better than conventional briefing, normally conducted by showing a video or pamphlet. Studies have shown that people retain more information when they are involved interactively in the learning process. In this research, a computer simulation game as a training tool for underground coal mine self-escaped has been successfully created using fire scenarios. The player/trainee should follow some procedures to get to the safety zone.

Keywords: Game engine, Virtual Environment, Unreal, Engine, Mine-self escape.

Introduction

The safety of the miners who work in an underground mine is very important. Studies conducted by the National Institute for Occupational Safety and Health (NIOSH) and the U.S. Department of Labor indicate that mining often has the highest annual fatality rate of any other private industry (CDC, 1994; Bureau of Labor, 1996). The people who will work and already working in an underground mine usually get a briefing about the safety procedures and what to do if something unexpected happens. The briefing is generally conducted by showing a video or pamphlet. Studies have shown that people retain more information when they are involved interactively in the learning process. This research was undertaken to design and develop a tool that can train and assess current and potential mineworkers on self-escape through the use of a simulation game.

According to research reports on strategies for escape and rescue from underground coal mines conducted by U.S. National Institute for Occupational Safety and Health, self-escape is defined as miners who are equipped and capable of timely escape under adverse conditions and hazardous air and who can act as first responders that can safely and knowledgeably assist others in escaping and can mitigate limited hazardous conditions until help arrives. What can be derived from this definition is that miners should be equipped with any tools or devices for survival and must be prepared to respond quickly because early-stage actions and decisions will significantly influence the outcome (Conti *et al.*, 2005).

The main advantage of using a simulation game as a training tool is that it allows the trainee to experience a dangerous situation while not being put in danger. According to Menaker *et al.* (2006), learning through experience is a powerful approach combined with today's advanced learning technologies. In this simulation game, a three-dimensional underground mine environment is created using a 3D graphics application software. The trainee will play as a miner working in the mine. A scenario is set asking the miner to go to the closest muster point by taking the closest path to the safety zone to abandon the mine.

The trainee should be aware and focus on the signs planted in the mine to know where their location is and where they should go from that location. Self-escape is a crucial part of underground mine safety, and

the use of a computer simulation game will allow more advanced training to be conducted by all mining companies. Training plays a critical role in preventing deaths, injuries, and illness on the job. Only with effective training can miners recognize possible hazards and know the safety procedures to follow (MSHA, 2008).

Materials and Methods

The mine plan of underground coal mine used as a map in this self-escaped simulation game is basedon a small part of an underground coal mine from one of the mines in New South Wales, Australia, which implements the longwall mining method. Figure 1 shows the layout of the mine environment.

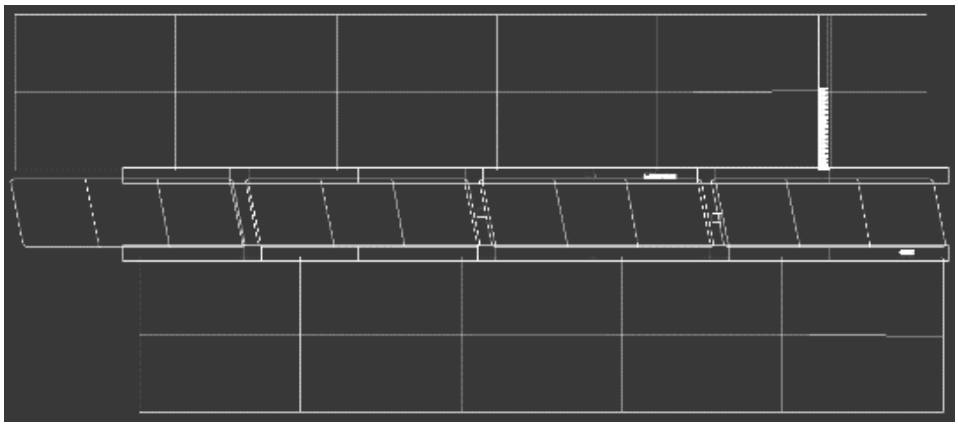

Figure 1. Mine plan (Top View).

The systematic self-escape plans and procedures in mining emergency situations are obtained from the existing research conducted by Kowalsky *et al.* (2010). Those self-escape plans and procedures become the objectives that need to be achieved in the simulation game. A total of ten structural processes of step-by-step activity is determined in creating the simulation game. The ten structural processes are as follows:

- Gathering the data about self-escape procedures;
- Deciding the game engine that will be used;
- Creating the underground mine 3D environment model;
- Creating the 3D model of personnel (mineworkers) and equipment which are normally used in an underground coal mine such as shuttle car, roof support, shearer, etc.;
- Texturing the virtual underground mine environment, character, and equipment;
- Animating the objects;
- Importing the 3D model objects and animations to the game engine;
- Creating the scenario of an emergency in underground coal mines;
- Creating the class needed for the game and;
- Setting up the scenario and winning condition in the game.

Software for Simulation Development

The software needed to create this computer game simulation for mining self-escape is 3D Studio Max for education, Gimp, ConTEXT text editor, and Unreal Development Kit (UDK) editor. UDK is the free version of the popular and award-winning Unreal Engine 3. According to Doran (2013), UDK is a truly powerful tool for the game developer.

Object Development Method

The first stage in developing this self-escape simulation game is the creation of the objects related to the underground coal mine. The virtual underground coal mine for the game environment used the longwall mining method. The mine will consist of a mine plan, mining equipment, lifelines, crew transport vehicle, self-escape equipment, phone, FREEK (First Response Emergency Evacuation Kit), and a mineworker.The crew transport vehicle used in this simulation game is created based on the truck manufactured by PJ Berriman & Co. Pty Ltd (PJB). The mine plan used in this simulation game is just a small part of an underground coal mine.

All objects are created in 3ds Max, starting by creating basic three-dimensional shapes, which then be altered until they resemble the actual equipment. With the aid of digital photographs, an accurate representation of the objects can be developed. A step-by-step in developing the crew transport vehicle (PJB) is explained to show how the objects are created. PJB is modeled based on the reference image, as can be seen in Figure 2.

Figure 2. PJB references image.

Based on these pictures, the 3D model of the truck is created by modeling parts of the vehicle separately. All those parts are created using the polygon modeling technique because the truck has a complex shape. The finished 3D model of the PJB is shown in Figure 3.

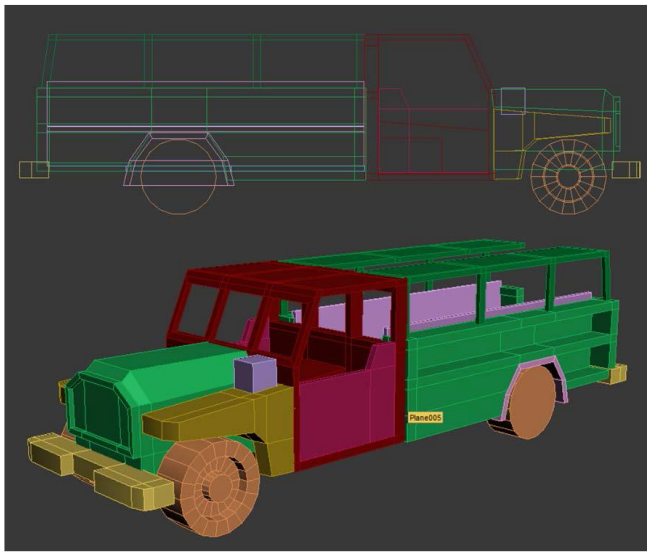

Figure 3. Finished 3D model of PJ Berriman.

The 3D model needed to be textured to look more realistic. Texturing is one of the most important things in this simulation game because textures are the ones that bring a model and a scene to life (Maestri, 2008). Texturing is done by using Unwrap UVW map modifier. Since the boundary of the UVW map has limited space, it is necessary to put the object faces that have a similar texture overlap to each other, so any drawing on that part will be applied to all of those objects. To make it easy to know which part of the object can share the same texture, the part of the 3D truck model needs to be exploded, as shown in figure 4.

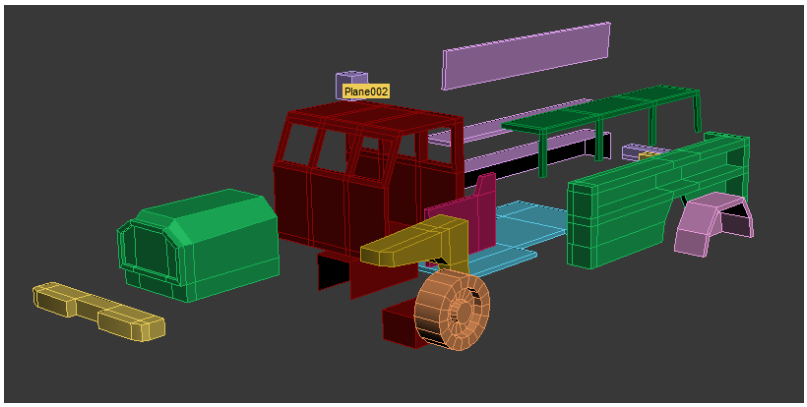

Figure 4. Separated parts of the PJ Berriman 3D model.

Each model has its UVW map so that one model might consist of many separated UVW maps. They must be combined to reduce the draw calls. Too many draw-calls can lower the game performance. The final UVW map for this transport vehicle model is shown in Figure 5.

Figure 5. UVW map for PJ Berriman.

The final UVW map is just an image acting as the reference for texturing. This image is used in Gimp software as the top in the layer hierarchy with a lower opacity than other layers. During the texturing process, it will be easy to see where to put or draw texture for a specific object. The final result for the crew transport vehicle is shown in Figure 6. All the other objects for mining emergency equipment are modeled in the same way.

Figure 6. PJ Berriman after texturing.

Self-Escape Scenario

The scenario implemented in this research is about escaping from a fire in an underground coal mine that came from the shearer. Shearers are the most commonly used cutting machines in an underground coal mine. How the information is presented is by using in-game animation. The player then needs to go to the nearest phone to contact the control room. A phone is located somewhere in the mine and can be reached by following the lifelines. As the environment is so dark, the player can find the phone by looking for the phone sign. The lifelines and the phone sign are intentionally created to be lit up slightly in the dark. After contacting the control room, the player needs to follow the lifelines to reach the FREEK location. Once the player reaches the FREEK, he/she needs to put on the CABA suit. The player needs to follow the lifelines again to get the crew transport vehicle/PJB.

Game Development

The game development starts after all of the 3D objects, and their textures and animations are exported to the UDK editor. As this simulation game is considered a custom game by UDK, some classes should be created. The first class is called the game info class. GameInfo is just an Actor that is created once when a map is loaded. It handles the game rules (spawning players, time limits, scoring, tells the game when to start, decides when the game is over, etc.). It acts as an entry point to the game because it determines what other objects will be used in the game. The next class that needs to be created is the player controller class and pawn class. The pawn represents the player's physical presence in the game. The player controller takes input from the player, processes this input, and translates them into the movement for the pawn it controls. The other two important classes that need to be created are the camera class and HUD (Heads-Up Display) class. The camera class is required to set the camera's location and control the camera movement during the game. The HUD class functions to display some information, such as player health, contamination level, timer, etc. Finally, the simulation game scenario is created by scripting and use UDK kismet. The simulation game is set to be over when the player successfully escapes the underground mine by going through all safety procedures. The game is also set to be over if the player is exposed to the CO_2 gas for too long without wearing a self-support device. Another game over might be because the player spends too much time in the underground coal mine with CO2 all over the place, so he runs out of oxygen in his SCSR or fails to find the escape route. As UDK was first developed in 1998 to power the original unreal game and based on C++ programming language (Doran and Gatzidis, 2012), all the codes needed in this simulation game are written in C++.

Results

Products for Virtual Underground Coal Mine

Many objects for the virtual environment were created to be used in the self-escape game simulation. However, only particular objects are chosen due to time constraints, so not all objects were included in the final simulation. The objects are mine plan (pillars, floor, and roof), roof supports, shearer, bolting roof support, FREEK, phone, PJB, shuttle car, continuous miner, and mineworker (figure 8).

Figure 7. Some objects in a simulation game.

Game Animation and Control

There are two animations created for this self-escape game simulation. The movement of the mineworker is the main animation used in the simulation (figure 9). There are four types of animation for the mineworker: moving forward, moving to the right, moving to the left, and moving backward. Another animation is the rotation of the shearer cutter. Fire animation used particle system available in UDK.

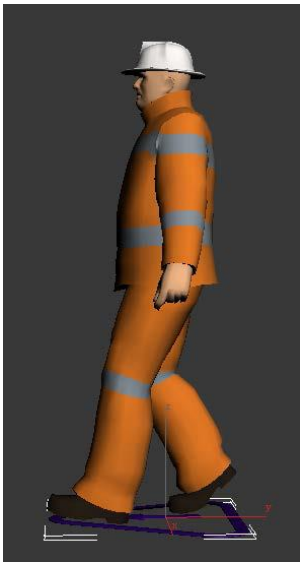

Figure 8. Mineworker walking animation.

This game's navigation control follows the normal navigation control for most first-person or third-person game control. Pressing the 'W' button on the keyboard will make the mine worker move forward. Pressing the 'S' button will cause the mine worker to move backward. Pressing the 'A' or 'D' button will make the mine worker move sideways to the left or right, respectively. This simulation game allows the player to interact with certain objects in the virtual mine. The button for interaction is the 'E' button. All this control is managed from a class named MinerPawn.uc. This class extends SimplePawn.The game engine provides UC class. It inherits all the navigation control methods from the super-class. The camera is set to become a third-person camera from this class and the set-up of dynamic lighting for the mineworker and the animset for the mineworker animation.

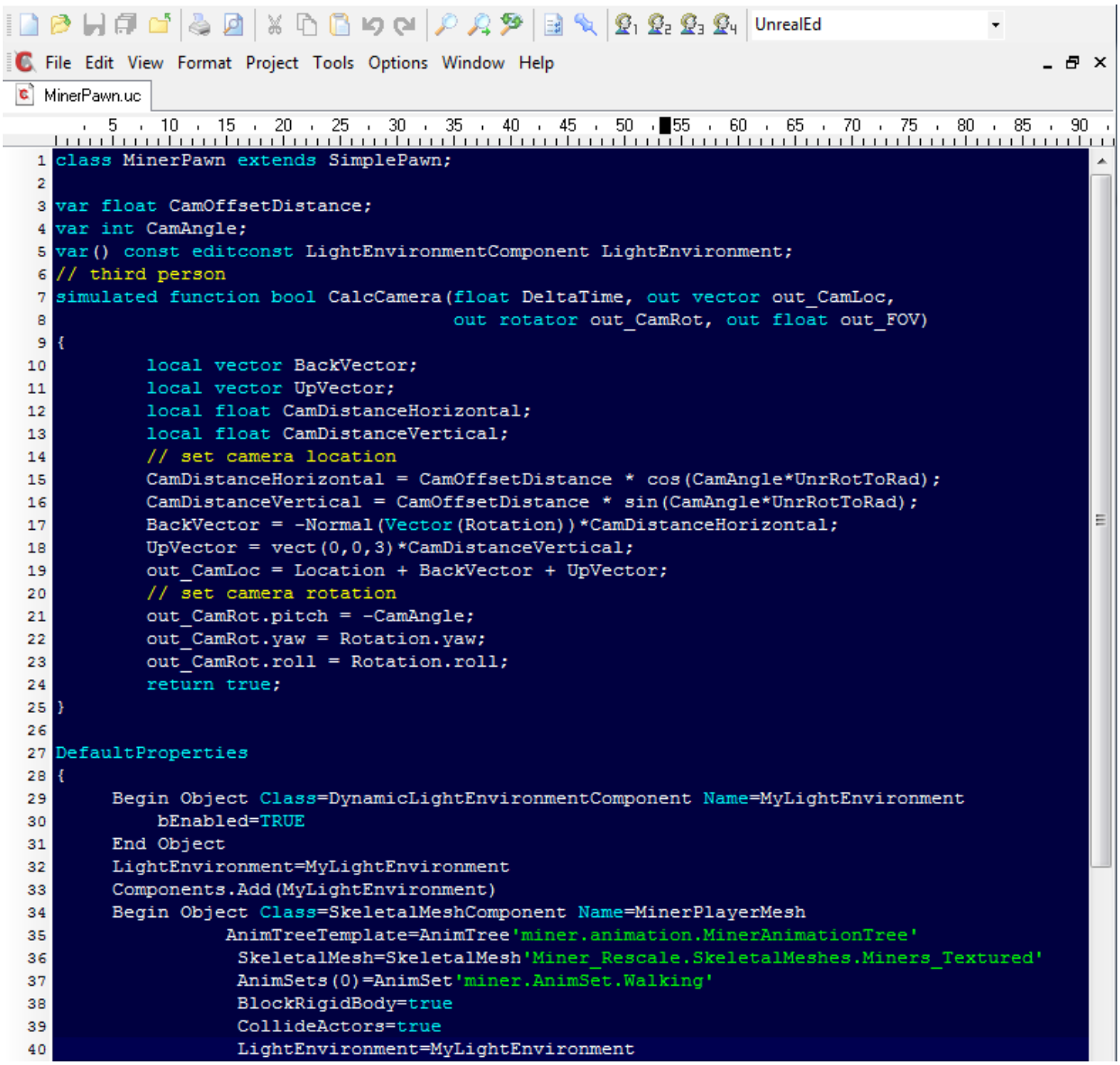

Figure 9. Miner pawn class.

Self-Escaped Simulation Gameplay

The game starts with the miner finding out that the shearer is burning (figure 10a). As he needs to contact the control room, he must find the phone. The phone can be found by following the lifelines toward the phone sign (figure 10b). The player needs to press the 'E' button while standing close enough to the telephone to activate the communicating with the control room sequence. After contacting the control room, the player needs to follow the lifelines to reach the FREEK location (figure 10c and 10d). The player needs to press the 'E' button while standing close enough to the FREEK to change over to a CABA suit. The player needs to follow the lifelines to reach the crew transport vehicle/PJB (figure 10e and 10f).

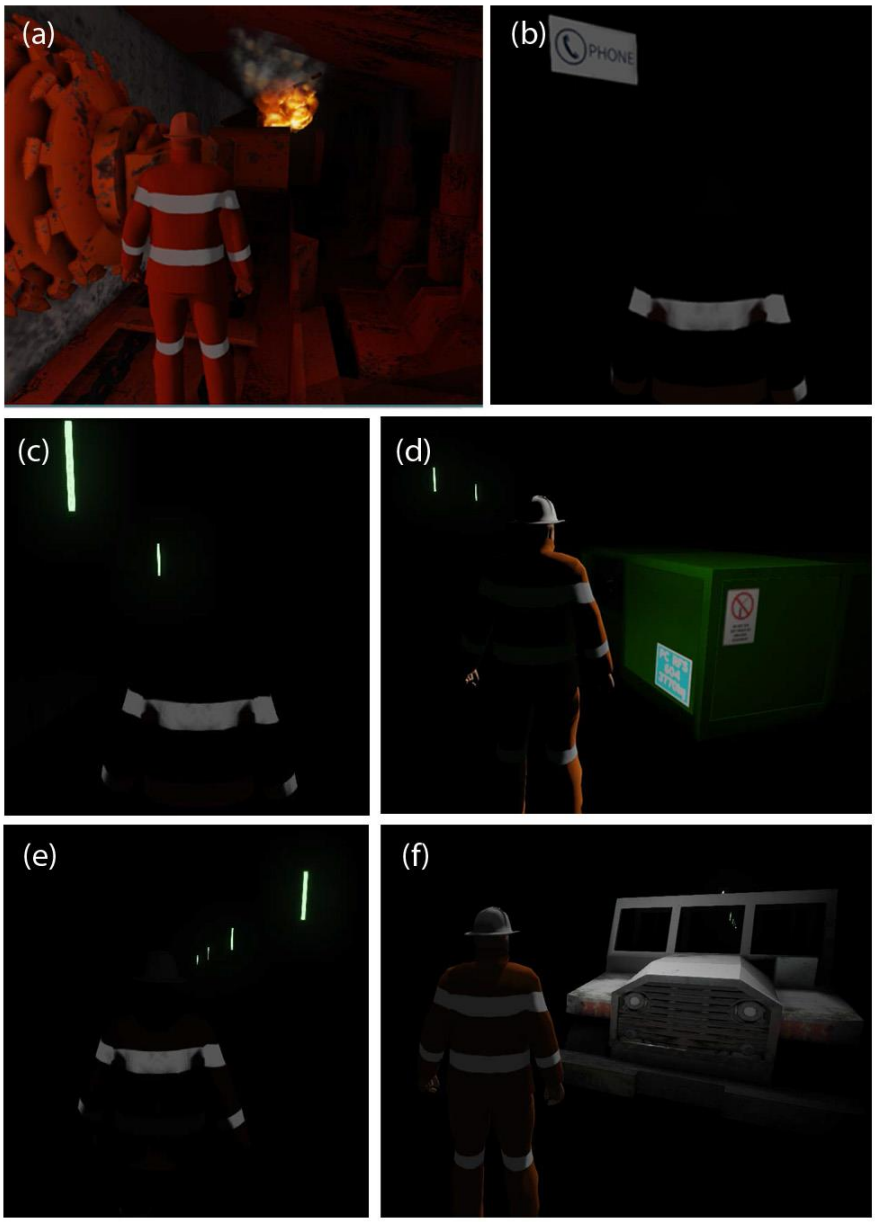

Figure 10. Self-Escaped simulation gameplay; (a) player finds out that the shearer is burning, (b) player reach the phone location, (c) player follows lifelines to reach the FREEK, (d) player reach the FREEK, (e) player follows lifelines to reach the PJB location, (f) player reach the PJB.

Discussion

Based on the results, this game can implement systematic self-escape plans and procedures in mining emergencies as conducted by Kowalsky, et al. This project involved 4 software: 3ds Max 2011, Photoshop ConText, and Unreal editor. Each software needs a significant amount of time to master. Because of the limited time available to finish this research, other miners besides the player, SCSR, and CABA suit are not modeled; the switch to CABA suit mode is not animated. To indicate that the player uses the CABA suit, a text box will appear on the monitor, saying 'CABA suit: Active'.

Most of the reference image for models in this simulation game is from internet and photographs, so there might be a slight problem with the size of objects created. The length, width, and height ratio of the 3D model objects may differ from the length, width, and height ratio of the real objects. As most of the subjects used for the reference do not have photographs that view it from every angle, it isn't easy to model the 3D objects to look very realistic.

Since this simulation game is developed via a laptop, it doesn't include smoke, which is a significant part of self-escape. With a more powerful computer, it is possible to have smoke in the simulation game for

further development. Smoke in the game engine uses the particle effect system. It takes a lot of memory as particles are generated and make the video card work more since the smoke is partially opaque.

Conclusion

A computer simulation game as a training tool for underground coal mine self-escaped has been successfully created by using Unreal Engine 3 game engine. Mine self-escape simulation game can improve a trainee's learning rate as it involves interaction between the player and the environment. It can replicate an underground mine, making a trainee feel familiar with the environment where he is working. All the objects that were implemented into this simulation game are visually representative of the real objects. The main advantage of using such a game as a training tool is that it allows the trainee to experience a dangerous situation while not being put in danger.

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