Extending Human Senses to Aid in Entry to Hazardous Environments

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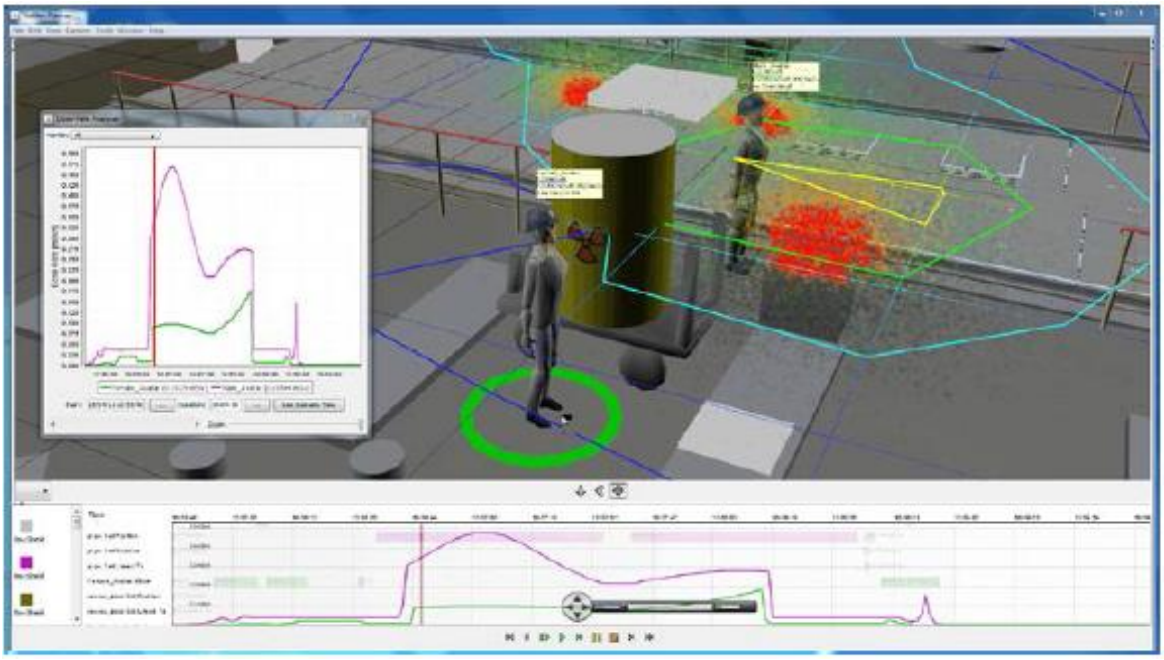
Introduction

Hazard is a word that has a very particular and precise meaning for people who deal in industrial safety: it means any source of energy capable of causing harm if not controlled. The energy may be, for example, electrical, chemical, nuclear radiation or even just the possibility of something falling from a great height and hitting you on the head. So, a hazardous environment is one where there are sources of energy capable of causing harm if uncontrolled. A **dangerous** environment is one in which the sources of energy are not adequately controlled. We also use the work **risk** in a very precise way: it is a measure of the *probability* that harm will occur multiplied by a measure of the *amount of harm*. So, the average risk of death on UK roads is about 1/17,000 per year (much higher than most other risks to which we are exposed, especially for younger people, and young people tend to take more risks on roads so it is even higher than that for most of you).

We reduce risk to acceptable levels by either avoiding the risk or using barriers to prevent accidental release of energy causing us harm. (For example, we can choose not to go rock climbing, and in chemistry laboratories we can wear protective clothing and spectacles.) Sometimes we reduce risk just by reducing the amount of time we are exposed to the hazard. The health risks associated with smoking rise in direct proportion to the amount of time you are exposed to smoke (as well as the concentration of smoking products).

Hazardous environments are created (intentionally or accidentally) by a number of industries. It may surprise you to know that some of the most dangerous work environments for workers are farms (lots of machinery, chemicals, large animals, people working alone etc.), and building (falls from height and getting hit by falling objects). However, the chemical and nuclear industries have to exercise particular care because they manage very large concentrated sources of energy, and if things go wrong it is possible to cause large amounts of harm not only to workers but to the public at large.

Unfortunately, the best safety management practices are not universal, and there are places that now suffer from past neglect, and dealing with the problem requires people to enter hazardous environments. These include places which are chemically contaminated from poor disposal of waste products. It has, for example, recently been discovered that the Italian Mafia around Naples controlled the business of disposing of hazardous materials, burying chemical waste in unprotected holes from which it is now leaking and probably causing illness to local people. Even worse, during the Cold War, the Soviet Union had a large programme of building nuclear submarines, but made no plans for decommissioning them. After the collapse of the Soviet Union, Russia could neither afford to keep the fleet maintained, nor could it afford the expense of safe decommissioning. As a result, on the Kola Peninsula in Northern Russia (close to the border with Finland) there are sites, such as Andreeva Bay which are heavily contaminated with both chemical and radioactive wastes. Many of the records of what was stored where have been lost (or were never created in the first place). So, for example, there are building holding drums that may contain relatively innocuous chemicals, and others that hold material both radioactive and chemically toxic. Which is which? Some buildings have parts of decommissioned submarine reactors that are highly radioactive. You might walk down a warehouse corridor surrounded by steel objects providing lots of shielding and turn a corner into a high gamma field. This figure shows one attempt to tackle this issue (red- danger, green OK).



We cannot ignore this problem, or leave it just to Russia, because of the possibility of waste leaking into ground water, and from there to the Barents Sea, will contaminate the Arctic and this is a cause of real concern to both the Scandinavian countries and the USA (currents will carry radioactivity, and fish such as Salmon migrate from the Barents Sea around the Artic, potentially causing problems for the Alaskan Salmon fisheries). We know that at least one Russian nuclear submarine has already sunk in that area, and could also release contamination at some point in the future.

It is now necessary for people to enter and work in these contaminated locations, and we need to make that work as safe as possible. Unfortunately, these types of hazards are mainly invisible and that makes them more dangerous. Smelly chemicals such as hydrogen sulphide may be poisonous, but they are usually not classified as dangerous, because you smell and get out before they reach a toxic concentration. The really dangerous chemicals are those without smells, such as carbon monoxide. Radioactivity cannot be seen and does not have a smell, though it is relatively easy to detect with instruments at levels much less than those that cause harm.

We protect against chemicals using protective clothing (and sometimes with face masks). There are three ways to protect against radioactivity cause harm: time, distance, and shielding. Do not stay in a radioactive environment for very long, keep away from radioactive sources, or put something that the radiation cannot penetrate between you and the source. There are three basic types of radioactivity, and you will need to understand the properties of each to decide which strategies work best. You will also need to understand that some places might be dangerous because there are high fields of radiation (e.g. gamma rays) and others because they are covered in radioactive dust emitting alpha rays, which becomes harmful if you breathe it in or swallow it, but which you might be able to get very close to without harm (why?). You will need to understand something of the effect of radiation on people.

However, the shielding option probably does not help much in places like Andreeva Bay. We need to go in and move around. Hence, we would like to know where the problems are likely to be, to detect problems before we get close to them, and to be able to plan our work so that we do it as efficiently and as quickly as possible. Traditional ways of going about this type of work are very time consuming, e.g. using radiation detectors on long poles (detect before you get close), careful sampling, and making detailed plans of every movement before entry to the hazardous environment.

However, modern technology is now offering exciting possibilities to tackle problems like this much faster, and also be much safer. In particular, we would like you to consider the ways in which we can use technology to extend human senses so workers can operate in the field with much higher awareness of the hazards that surround them. Imagine, for example, holding up an iPhone with its camera active, and superimposed on the image of the surrounding could be a visual representation of the levels of radioactivity. Imagine wearing a Google Glass and just looking at a chemical drum, or a machine would access information about what might be going on inside (perhaps accessing historical records as well as recently gathered data).

This project is about the use of existing technology and science to solve a real problem. (That is, you cannot assume that you have invented a super-efficient light-weight shield against gamma rays. Current scientific knowledge says that this will never be possible (why?)). What you can assume is that the same type of technology used to build Martian Rovers could be used to build scouting robots feeding information to the workers. However, we expect you to research how an “enhanced” man, or a robot can detect radiation or chemical contamination. Or do we just use robots and a virtual reality environment for the human operator? Are there some things that we just cannot do without a real human present? (No one has ever made a manipulator as good as the human hand yet – or maybe it has just happened – find out.) However, modern robots are coming in all sorts of sizes and shapes, from the Curiosity Rover, to “snakebots”, “octobots” or small, cheap flying robots the size of insects.

We are looking for imaginative but practical applications of science and technology, especially imaginative combinations of things we know that work in other contexts. You will get credit for researching the science underlying your proposals and explaining why you think they will work. Good engineering also has a certain simplicity and elegance (think of the bicycle) so we will also prefer the most economical solutions to those that are overly complex. You will also get credit for showing how you understand the way that people and technology interact with each other. In modern engineering it is essential to understand something about human psychology – the limitations of senses and the capacity of the human brain – and how our abilities can be enhanced, rather compromised by, for example, information overload.