An early warning system for railways and highways tunnels using artificial neural networks

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Sommario

Il nocciolo di questo articolo proviene da considerazioni in merito ai problemi di miglioramento della security dei trasporti, con un occhio rivolto ai fatti passati (l'Undici Settembre, Madrid 2004 e Londra 2005) e un occhio al concetto di fattibilità (analisi di rischio, studio dell'impatto delle misure, minimizzazione degli aspetti critici come la congestione). In particolare l'attenzione è centrata su come migliorare la security di trasporti e mobilità mediante la protezione delle gallerie. Le gallerie ferroviarie e autostradali rappresentano da sempre il collo di bottiglia della mobilità, considerando sin da subito il caso di incidenti e attacchi terroristici contro treni merci e autocarri che trasportano merci pericolose (HazMat). Le reti neurali artificiali sembrano essere in grado di costruire un sistema intelligente in grado di intervenire in tempo reale in situazioni come questa, in cui sostanze pericolose vengono rilasciate a prescindere da cause dolose o accidentali.

Abstract

The main core of this paper comes from transports security improvement issues, with an eye to the past facts (the Nine Eleven, Madrid 2004 and London 2005 taken as milestones), and an eye to the feasibility (risk analysis, impact of measures, minimization of critical aspects such as congestion). In particular the attention is focused on how to improve transports and mobility security protecting tunnels. Highways and railways tunnels represent an all-along bottleneck of mobility, considering first of all the case of accidents and terrorist attacks against freight trains and trucks carrying hazardous materials (HazMat). Artificial neural networks look to be able to build up an intelligent system which can do real time intervention in cases like these, where hazardous materials are released, regardless malicious or accidental.

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1. Introduction

The idea of this paper takes inspiration from a real application of a complex system, which has been thought and realized on Gran Sasso mountain by the Department of Information, Electronics and Telecommunication Engineering of Sapienza University of Rome [9]. This scientific application consisted (and consists, because it it on use so far) in a technological device, which represents the technical integration of three important aspects: safety, security and communication, and at the same time is able to manage several parameters involved. It is even able to learn and analyze all the critical situations ready to happen. In case of alert conditions, a signal of rapid activation is given, and it is followed by the right procedures to avoid or limit danger situations.

In the following pages it will be discussed and presented the possibility to improve a system like this, based on the use of artificial neural networks (ANN), for protecting highways and railways tunnels from warnings due to accidents. Artificial neural networks represent the useful reproduction of human neural networks; they started to be used about forty years ago mostly for financial and economic statistics [1] [2] [3], nowadays they are actors of various situations and case studies which are enhanced in a very smart way, which itself permits to simulate somehow human sensitivity.

Artificial neural networks are used in different fields, such as electronics (process control, machine vision, voice synthesis, linear and nonlinear modeling, signal analysis), robotics (trajectory control, vision systems, movement controller), telecommunications (image and data compression, noise reduction), medical/bioengineering (e.g. ECG monitoring and early warning nets [6]), transports (flow transports control and monitoring, both roads [5] and railways [7]), security (face recognition, voice recognition, and other biometrics applications, new sensors), defense (weapon steering, signal and image identification, radar and image signal processing, object discrimination and recognition), aerospace, banking, manufacturing and so on.

2. Security risk analysis for railways and highways tunnels: rules, parameters and devices

In this study highways and railways are looked simultaneously, but separately, considering that there are tunnels in both these transport networks, but differences depend on the kind of vehicle which does pass through: trains and cars. The two tunnels require different attentions and security evaluations, because the vehicles they are built for are different and they can provoke or be subject to different kinds of accidents.

2.1 Rules

Inside the risk analysis assessment, the dots which are followed in Italy in order to respect, and try to guarantee tunnels security, respond to very precise governmental laws, first of all the minister decree DM 20.10.2005 for railways tunnels, and the legislative decree DLgs 05.10.2006 for highways tunnels. The picture in figure 1.1 explains the most clearly as possible the difference between highways and railways tunnels security umbrellas.

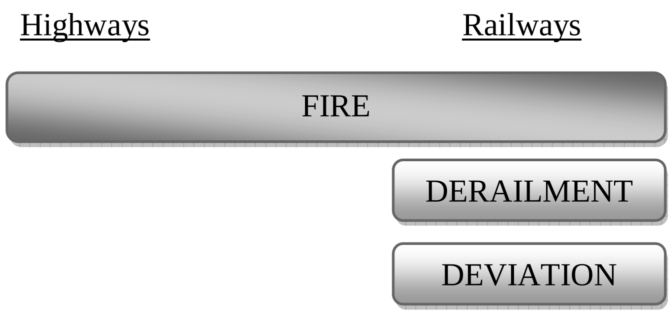

Figure 1.1: Highways and railways tunnels security: what they are protected for

According to this scheme and to Italian rules, railways legislation of tunnels security includes the highways adding two cases of accidents causes typical of the train reality: derailment and deviation.

The risk analysis of tunnels security is the first most important dot to deal with. It is basic to follow that the norms propose, quite specific steps to be respected and which come from experiences inside this area [10]. These are the risk analysis key issues:

- hazard identification: factors and prediction;
- risk based approach;
- identification and description of all possible scenarios;
- costs and benefits evaluation.

Another important aspect not to be dismissed concerns the tunnel's length, in fact long tunnels do not have the same risks level as short ones do. Following the European standards in fact "long tunnel" are longer than 5 km, while tunnels longer than 20 km need special attention and safety investigation.

2.2 Parameters and devices to be considered

The parameters to control and the devices to be used to protect tunnels require to be listed. They are basic for this study, apart from the intentionality or fortuity of a certain events happening. Here they are taken into consideration effects and consequences certain events can have, in order to guarantee the tunnel security, since a GPL release may happen accidentally or because someone tampered with the valves, the results this fact can have on all that is around does not vary. Then the consequences are those an artificial neural network system here proposed may prevent, avoiding. "How" is explained in the following paragraph.

According to the tunnels' length the following things to be controlled vary and have different weights [10]: the frequency of the initiator events; the number of trains potentially involved in a tunnel fire; the length of the egress path; the time a fire has got to reach significant HRR values and to break fire barriers; the complexity of rescue intervention and of intervention of the fire brigade; the robustness of the boundary conditions. On the other side the parameters which must be monitored, such as the temperature reached inside/immediately outside the tunnel according to the part of the day and of the year (temperature measured vs. temperature expected); presence of HazMat released inside the tunnel (dust, gas, liquid); presence or not of people walking on the road/railways inside the tunnel, and so on.

A complex system of tunnel protection is composed by many parts which must cover both safety and security side simultaneously:

- enlightening system;
- CCTVs (video surveillance);
- snow alarm system;
- fire alarm system;
- intrusion alarm system;
- ways of accesses control system;
- railroad switches heater (in railways);
- HazMat detectors (multipoint detectors);
- temperature detectors (multipoint heat detectors).

According to the study conducted, the ANN brain for early warning system might be able to manage the parameters to control and detect and all the operating devices. The more parameters there are, the more complex the code is, because so many lists and numbers to deal with, model and train, and as many as weights to multiply.

3. Artificial neural networks as brain for early warning system devices

In this paragraph it is explained how the ANN would work in order to prevent or limit the consequences an any-kind-of-accident might have inside a tunnel. As it has been already seen, first of all they must be defined the parameters that should be controlled inside the tunnel. These parameters are the basis of this ANN, whose aim is to recognize as soon as possible (as an early warning system is supposed to do) unexpected and/or "oversized" values of the parameters themselves.

The more different input parameters and the more complexity of the net. Since quite limited resources are supposed to be used, it is required to reduce as more as possible the complexity of the net (less computational duty, but more speeder).

In the pictures (figures 2.1 and 2.2) it is represented a typical (even if simplified) scheme of a net that should be used in this case of study, where the visible layers are two: the first layer accepts as input the single values of the parameters to work as an early warning system and a second layer, whose neurons accept as inputs all the outputs of the first layer, and where only one neuron at once activates and gives an output as a function of the warning that must be generated, then the first layer works as predictor and the second one as classifier. The first layer of the neural net has to learn the temporal behavior of a certain parameter, so that it can predict its future value as consequence of the previous ones, while the second layer classifies the critical situations activating only neurons corresponding to critical situations.

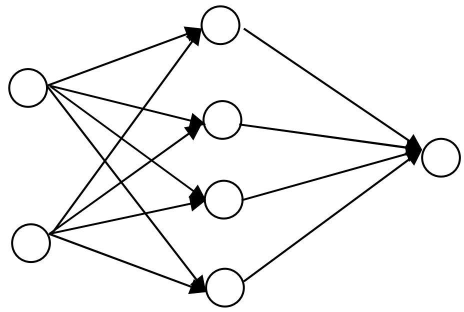

Figure 2.1: Scheme of a common ANN

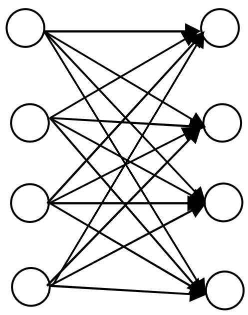

Figure 2.2: The two layers net: predictive and classifier

An example of functioning might be the following: the brain of the ANN system is claimed to control, and, in case, have a reaction of alarm when the temperature inside a tunnel overpasses a value which has been defined and, at the same time, can vary according to the kind of accident (up to 1000°C if explosions happen). In this case temperature is the parameter under control by ANN, which lets the alarm to switch on. It is required to put attention at the parameters to control, because some of them do not appear so practical either representative of efficacy. Doubts should emerge, especially at the light of the experience of people in charge, for instance measuring the dust inside a tunnel is not so smart as it could look like, and it is motivated because of the presence of the ballast in railways and draining gases in highways, this means that confusions can be done and situations can appear as false warning.

4. Conclusions

The purpose of this paper is to identify the potential applications of a system of artificial neural networks, planned in the aim to improve the existent systems of warning installed inside the tunnels, ready to intervene in case of fires post accidents, HazMat release, and so on. Taking it for granted ANN functioning, nothing can be started without taking into consideration laws and rules concerning the analysis of risk inside the tunnels (apart from their typology). This cannot be left out of consideration.

The study proceeds considering the parameters, which could be measured, then put under control by the budding system and the attention goes on the measurement into the tunnels of temperature and dust, the first is a good parameter to be measured in accordance with the used combustible, the way the fire is set, potential explosions, etc.), the second is not so easy to be measured because of the coexistence of various kinds of dusts inside the tunnels. This means that the choice of the right parameters must be done carefully.

The application of ANN brain on Gran Sasso mountain security and safety central system shows the possibility to enhance a system like this, but not all the cases are similar and if on one side it is true that the artificial neural networks are fast and work with almost zero errors, it is as well true that an a priori choice must be done, trying to evaluate if such a system can do better and more than that is done nowadays through the normal and common systems of control which protect from fire, intrusions, etc. The doubt exists in terms of expenditures: indeed improving security has a cost and it is to assess its amount.

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