Computer Standards & Interfaces 41 (2015) 39–55

Contents lists available at ScienceDirect

Computer Standards & Interfaces

journal homepage: www.elsevier.com/locate/csi

Interoperable architecture for joint real/virtual training in emergency management using the MPEG-V standard

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ARTICLE INFO

Article history:
Received 13 May 2014
Received in revised form 30 November 2014
Accepted 8 February 2015
Available online 17 February 2015

Keywords:
Command and control
Emergency management
Interconnection
MPEG-V standard
Virtual

ABSTRACT

Operatives' training is crucial in emergency management. Traditional exercises to improve procedures interoperability and harmonization between agencies are complex and expensive. Research on command and control systems specifically designed for emergency management and on virtual reality use leads towards enhancing real world applications' capabilities, facilitating management and optimizing resource usage.
This paper proposes a new architecture for a training system based on the interconnection between real and virtual worlds extending the MPEG-V standard; allowing real and virtual units' simultaneous and real-time training using commercial off-the-shelf equipment, and including a novel subsystem for video management from both real and virtual sources.

1. Introduction

A virtual world (VW) is a computer-based simulated environment where users interact through avatars and intelligent agents. The current applications go beyond merely entertaining purposes [1,2] as they have become a powerful tool to enhance the capabilities of real world (RW) applications and have been widely used for training and learning in different areas, including military units; vehicle driving and flight simulators. Trainees can learn and practice how to perform tasks while working toward animated agents that can collaborate with human trainees in the virtual worlds [1]. Furthermore, the capabilities of traditional virtual systems can be enhanced and extended if a hybrid system is implemented including data from real sources [3,4].

In the case of crisis management, the use of virtual reality to create immersive training exercises for human beings allows personnel to operate with modern computer equipment; respond rapidly to unforeseen events in situations under stress, and to perform joint exercises with a significant reduction on costs and complexity. However, the interaction of real and virtual worlds with new standards (i.e., MPEG-V), allowing data streaming between both worlds and using commercial off-the-shelf (COTS) equipment, has not yet been exploited and means going a step further in the state of the art.

This paper presents a new architecture for emergency management training that connects virtual worlds and command and control systems operating in the real world. An innovative and key feature is the use of the MPEG-V standard, which has been extended to develop a middleware, called "interconnection gateway", where different applications can interoperate, contributing to an extendable and scalable solution.

Another significant contribution is the inclusion of a subsystem for streaming, displaying and recording video flows from both real world cameras and virtual world live streams.

A continuous training in a virtual environment based on the proposed architecture helps the staff that intervenes in real crisis resolution enhance their actuation protocols, considerably reduce the response time in the case of an emergency, and improve their effectiveness. Any user can gather information about its state through sensor values, video streaming or specific messages. Any actions performed in the real world are represented in the virtual world (and vice versa).

The main technical challenges and goals are:

- Represent the reality with high fidelity for crisis managers and *first responders* (those who first assist in an emergency situation) in order to help develop actuation strategies and homogenize procedures.
- Enable collaboration among teams of users, software agents and avatars. Crisis management personnel from different organizations and locations should be able to collaborate in developing strategies.
- Provide interoperability, interaction and overlapping between real and virtual worlds using the MPEG-V standard to stream real data in a virtual world and vice versa. It is necessary to make an extension of the standard to fit the particularities of the project and the tools used.

The paper is structured as follows: first, in Section 2, the related work core concepts and literature gaps are summarized. The system

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http://dx.doi.org/10.1016/j.csi.2015.02.007
0920-5489/

architecture is described in Sections 3 and 4; Section 5 contains the data model, and video insertion is explained in Section 6. A performance evaluation is carried out in Section 7. Finally, in Section 8 the conclusions from the study and future work will be commented.

2. Related work

Research related with the ongoing work can be divided into three main topics: use of virtual worlds (VW) for training, command and control systems, and the MPEG-V standard.

2.1. Use of virtual worlds for training

This addresses several areas.

2.1.1. Representation of virtual environments

Models for virtual world representation describe the worlds in such a manner that browsers can efficiently visualize the geometry of the worlds and, in some cases, support low level interactivity. However, in order to support richer interactions, and to improve agent reasoning [5], a high level representation model including semantic information [6,7] is desirable, as well as the use of ontologies to model such information. A possible way to address these issues is to use the MPEG-V standard [8], which, besides aiming at interoperability, sets a base data model to represent information and define interactions with virtual entities. We will be discussing more about MPEG-V throughout the paper.

There are also several studies on how to reconstruct scenes and users from the real world to create a real-time full 3D representation that can be placed inside a shared virtual world [4,9,10], and even with a focus on tactical information [11].

2.1.2. Architectures

Different holistic architectures have been used to test semantic models. Normally a middle layer has been used as an interface between the agents and the virtual world and it models the world through a semantic representation built by instantiating a set of ontologies. This kind of architecture is reusable and allows decoupling the graphical representation from the semantic representation of the environment; thus, agents can interact directly with the semantic layer and process the semantic representation of the virtual world [6]. Others [1] propose an architecture with separate components running in parallel and which communicate by exchanging messages through a dispatcher, increasing modularity.

However, architectures going beyond representation, and aiming to allow direct interaction between the real and virtual worlds are much fewer, and even more if the focus is emergency management. We intend to fill this gap, and propose a layered architecture and a middleware connecting a command and control system from the real world, currently used in emergency management, with a virtual world representing the same operation field.

2.1.3. Navigation guidance and support

Users often experience difficulties and can easily become disoriented or lost for a variety of reasons, including those common to real world environments (e.g., getting trapped inside a building), as well as some problems unique to virtual worlds such as lack of landmarks and reduced level of detail [6]. Many methods and techniques may be combined to solve these issues depending on the application; for instance, animated agents can serve as navigation guides preventing users from becoming lost [1]; or social network analysis may be used to adjust the level of detail to represent an avatar based on its interactions with other entities [12].

Authors in [6] deepen further on this matter and provide a summary of techniques for navigation support. We have implemented artificial intelligence algorithms to determine the best possible path to go from one point to the other and preventing agents from getting lost.

2.1.4. Addition of life to the environments

The addition of life (populate the environment with autonomous agents that behave in a life-like manner [6], such as humans and animals) improves the user experience and realism of the simulation. Authors in [13] developed semantic applications that model the real world by associating ontology concepts with objects and locations. Also, augmented reality is another interesting field of research; it

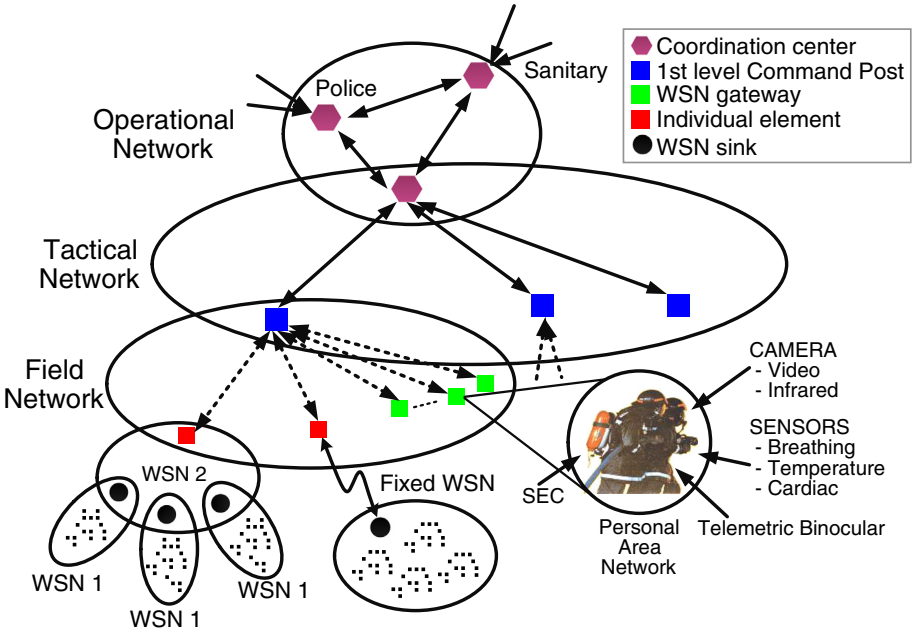

Fig. 1. SIMACOP architecture.