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Player: An open source tool to simulate complex maritime environments to evaluate data fusion performance

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ABSTRACT

In this paper it is presented a new open source tool for evaluating data fusion systems, mainly related to the maritime surveillance domain. This tool provides specific utilities for designing and simulating synthetic maritime environments to assists in the fusion development process, like designing vessels trajectories, placing different types of sensors, simulating vessels dynamics, or simulating sensors detections. This synthetic information can be used to feed a data fusion system to evaluate its response in a reproducible way under different conditions. This tool can be used to optimize the data fusion evaluation process, since testing a fusion system is a quite complex task, as the fusion output depends on the combination of multiple algorithms, configurations, measures, timing, and so on. Then, having reproducible synthetic environments can be quite useful when evaluating fusion results, system performance in dense scenarios, vessel trajectories with different dynamics, sensor coverages, and so on. This tool has been used with success for evaluating different fusion systems, and now it is presented as an open source tool, so it can be easily adapted to different environments, be used by other researchers, or extended by the community. This paper presents how it is built, the underlying algorithms, and presents some example use cases.

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1. Introduction

Maritime Surveillance systems are commonly used for identifying and intercepting threats in seaports, coastal areas, maritime boundaries, maritime platforms, or important installations. Monitoring extensive environments, like the maritime, requires a wide deploy of sensors detecting targets of interest. Common sensors in this domain are the Automatic Identification System (AIS), radar, and Closed-circuit Television (CCTV) [1]. Although most modern systems can use UAVs (Unmanned Aerial Vehicles), and satellite imagery [2,3] as additional data sources. It is common to obtain such distributed information in a common base station and use a Vessel Traffic Service (VTS) for evaluating possible threats in real-time. VTS systems normally include data fusion systems [4] to integrate sensor information in order to provide a more comprehensive representation of the environment state.

In such complex environments, it is quite important to ensure the proper operation of all the underlying components, specially the one related with the fusion system, as many of the services integrated in VTSs are normally built on top of the data fusion. A fusion system is a quite complex software development that includes multiple algorithms for data processing,

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association, filtering, combination, etc., that may work flawlessly in real-time to feed VTS information systems. So, before integrating a fusion system in a production environment it is required to test it extensively covering as many situations as possible.

However, testing a data fusion system can become a complex task, as it is not possible to cover every possible case due to the problem nature, which inherently contains infinite degrees of freedom. There are multiple variables that will condition the execution, like algorithm parameters, sensor observations, sensors noise, vessel dynamics, etc. This way, it is required to evaluate the most significant cases to ensure a proper operation under similar conditions, like vessels crossing so close, vessels moving in parallel, vessels moving along different sensors coverage keeping stable identifiers, vessels doing maneuvers at high speed, etc. It is not practical to evaluate this kind of special situations using only information from a real-world deployment, as they will not happen quite often, exactly as required, or the information is not isolated to debug it easily.

Therefore, this paper describes a recently released open source tool to assist in the process of designing and simulating maritime surveillance scenarios, where the user can easily define sensors, and vessels trajectories by just clicking over a map representation. The description made by the user can be simulated in real-time to generate multi-sensor multi-target detections as they were generated in a real-environment. This simulation can be used to feed a fusion system in order evaluate its behavior under the specified conditions.

There are few alternatives, if any, specifically designed for the purpose of this tool. In [5] it is described a tool to simulate static trajectories with waypoints, making animations, visual effects, and events that can be visualized in the Google Earth tool with a generated KML (Keyhole Markup Language). However, this tool does not generate detections in real-time, cannot be connected to a fusion system, and does not allow design environments in the tool, as it is designed only for scenario representation purposes. There is a more complete approach defined in [6], that describes a fusion architecture that serves as a base for higher-level situation assessment algorithms. It includes a simulation module, but it is tightly coupled in the tool, so it cannot be used with different fusion architectures. Furthermore, none of these tools are available as open source.

There are other general-purpose alternatives that can be used to represent environments and its state, like the Google Earth tool [7], NASA World Wind [8], and in general, any Geographic Information System (GIS) [9]. Nevertheless, this kind of tools lacks all the specific layers covered by the Player tool, like the environment description, edition, simulation, animation, visualization, connection to fusion system, etc. Therefore, the Player tool intends to provide a complete and comprehensive suite for designing and simulating maritime surveillance scenarios for fusion system evaluation. This tool is released under an open source license, so any user can adapt it to their needs, or integrate in commercial projects.

This paper is covering mainly the general Player tool architecture and the models used for simulating both sensors and vessels, while providing also some illustrative results for a better comprehension. The rest of the paper is organized as follows: Section 2 provides a background about data fusion systems and its complexity, and how the tool is integrated in such architectures. Sections 3, and 4, describe the models used both for vessel and sensors simulations. Section 5 describes the final modules developed inside the tool to assist the user while designing synthetic environment. Finally, Section 7 provides some results while using the tool to simulate different uses cases.

2. Background on data fusion in maritime surveillance

The core of maritime surveillance systems are Vessel Traffic Services (VTS), aimed to provide efficient transits and safe navigation for vessels [10–14]. To accomplish this task, technical means should be designed to enhance situational awareness and overcome the limitations of traditional methods such as direct sight and voice communications. There are diverse surveillance sources in maritime areas, which must be integrated to provide real-time decision support to operators. Data from cooperative sources (AIS transponders equipped in vessels) must be correlated with non-cooperative sensors, such as shore radar, high-frequency radars, or video (optical/infrared/satellites). This way, a VTS operator can obtain a more representative picture of the environment, which will support the decision making process in the surveillance task.

Then, a fusion system must process the different sources of information to provide a single fused output for each entity detected in the environment, like vessels. The output typically consists of a set of non-redundant tracks, called global tracks. Each global track represents a single entity in the environment that is normally composed of information describing vessel location and its cinematic: global track ID (unique for each vessel); last update timestamp; geodesic coordinates; speed and course over ground, etc. This type of systems are normally modeled as a distributed system [15,16], where a first layer contains processors for each data source (like sensors), and these mono-sensor tracks are then compared to decide if they can be correlated in the same entity. This process can be decomposed in several steps which are executed periodically in a fusion cycle [17,18], which is represented in Fig. 1.

However, there are many research needs on appropriate architectures and algorithms for multi-sensor fusion in maritime surveillance [4,10,19,20]. The problem is challenging when dealing with large sensor networks and heterogeneous areas such as high-density zones crowded with diverse objects in motion. An important phase of analysis and adjustment of the system is usually necessary to refine the models and raise robust processes to ensure the reliability of the system in real conditions such as presence of inconsistent measures, sensors malfunction, dynamic behaviors, parameter changes, etc [21]. Thus, the proposed tool will assist to properly design and evaluate a data fusion system in maritime surveillance environments, at it will allow simulating multiple sources of information with multiple observable entities.

Fig. 2 presents a general overview that describes how the proposed tool will interact with a fusion system, taking into account the fusion architecture, as described in Fig. 1. The tool will assist on designing synthetic entities like vessels, radars,

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