Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 22 (2014) 219 – 224

www.elsevier.com/locate/procedia

3rd International Conference on Through-life Engineering Services

Precise vehicle location as a fundamental parameter for intelligent self-aware rail-track maintenance systems

I. Durazo-Cardenas*[a], A. Starr[a], A. Tsourdos[a], M.Bevilacqua[a], J. Morineau[a]

[a]*Cranfield University, Cranfield, Bedfordshire, MK430AL, United Kingdom*

* Corresponding author. Tel.: +44-1234-750-111 ext. 5264; fax: +44-1234-754-605. *E-mail address:* i.s.durazocardenas@cranfield.ac.uk

Abstract

The rail industry in the UK is undergoing substantial changes in response to a modernisation vision for 2040. Development and implementation of these will lead to a highly automated and safe railway. Real-time regulation of traffic will optimise the performance of the network, with trains running in succession within an adjacent movable safety zone. Critically, maintenance will use intelligent trainborne and track-based systems. These will provide accurate and timely information for condition based intervention at precise track locations, reducing possession downtime and minimising the presence of workers in operating railways. Clearly, precise knowledge of trains' real-time location is of paramount importance.

The positional accuracy demand of the future railway is less than 2m. A critical consideration of this requirement is the capability to resolve train occupancy in adjacent tracks, with the highest degree of confidence. A finer resolution is required for locating faults such as damage or missing parts, precisely.

Location of trains currently relies on track signalling technology. However, these systems mostly provide an indication of the presence of trains within discrete track sections. The standard Global Navigation Satellite Systems (GNSS), cannot precisely and reliably resolve location as required either.

Within the context of the needs of the future railway, state of the art location technologies and systems were reviewed and critiqued. It was found that no current technology is able to resolve location as required. Uncertainty is a significant factor. A new integrated approach employing complimentary technologies and more efficient data fusion process, can potentially offer a more accurate and robust solution. Data fusion architectures enabling intelligent self-aware rail-track maintenance systems are proposed.

Peer-review under responsibility of the Programme Chair of the 3rd InternationalThrough-life Engineering Conference

Keywords: vehicle location; uncertainty; data fusion architecture

1. Introduction

The rail industry in the UK is undergoing substantial changes in response to a modernisation vision for 2040. Gradual development and implementation of these changes will lead to a highly automated and safe railway. Real-time regulation of traffic will optimise the performance of the network. In this scenario, trains will run in succession within an adjacent movable safety zone. Enhanced protocols will communicate the location of each train to control centre. Control centre will then command optimised energy and network capacity travel speed. Future rail maintenance will use intelligent trainborne and track based systems. These will provide accurate and timely information for condition based intervention at precise locations, reducing possession downtime and minimising the presence of workers in operating railways. Clearly, the precise knowledge of trains' real-time location is of paramount importance.

The positional accuracy target of the UK future rail is < 2m [1]. In the USA 3.5m has been specified [2]. However, a finer resolution is required for locating faults such as damage or missing parts. A critical consideration of these requirements has been the capability to resolve train occupancy in adjacent tracks, with a high degree of confidence.

Peer-review under responsibility of the Programme Chair of the 3rd InternationalThrough-life Engineering Conference
doi:10.1016/j.procir.2014.07.002

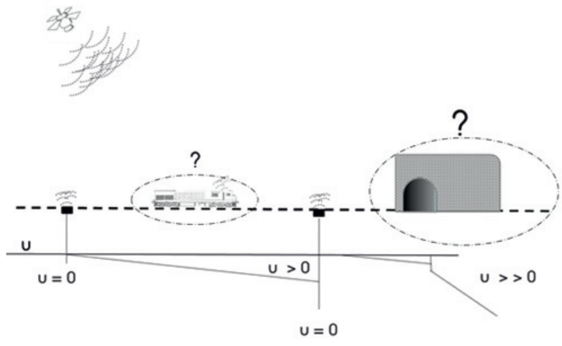

Fig. 1. Train location scenario and illustration of its uncertainty (U).

Currently track circuits, axle counters and balise transponders are the primary technologies employed for train location [1, 3]. However, these systems only provide location within discrete track sections. Although they can be accurate at the point of register, location uncertainty of moving trains rapidly escalates. Resolution is even poorer in rural sections of the track, where the length of track between these wayside systems can be of several km.

A relatively small number of trains are currently fitted with standard Global Navigation Satellite Systems (GNSS), primarily employed for basic fleet management and passenger information purposes. However, standard GNSS is not capable of precisely and reliably resolving the demanding location requirements of the future train [4]. Figure 1 illustrates the location case scenario studied.

This work starts by reviewing technologies currently used for train location, in the context of the needs of the future rail. While a number of reviews have been published before [5, 6]; these either are out of date or not consider the demands of the future rail. Location uncertainty sources are discussed. Previous literature integrated location systems and their data fusion architectures are discussed. Finally data fusion architectures are proposed to assist the decision making process in intelligent self-aware rail-track maintenance systems that use location as a fundamental parameter.

2. Technologies for rail track vehicle location systems

Future rail-vehicle track location systems have stringent requirements resulting from enhanced safety, increased network capacity requirements and optimized traffic control. Traditionally, signaling systems have been used to broadly estimate the position of trains [5]. Because track coverage varies largely from urban to rural areas, location and occupancy certainty cannot always be reliably resolved. Location systems are generally classed as follows [7, 8]:

2.1. Global Navigation Satellite System (GNSS).

GNSS uses a constellation of orbital satellites that transmit positional data to a vehicle receiver. A very accurate time-stamp and a trilateration algorithm permit precise computation of its location, usually within a few meters. Standard GNNS alone, however, does not provide enough accuracy [4] for the location needs of the train of the future.

Augmented GNSS, most commonly in the form of differential global positioning system (DGPS), is used to enhance rail positional accuracy, usually to within 2-3 m [9, 10]. DGPS employs accurately positioned fixed point receivers that provide a correction factor for the computation of location [7]. A higher grade DGPS train-location system with < 20 cm resolution has been recently investigated in the USA [11].

Convenience and the ability to provide the highest-accuracy currently available have resulted in GNSS technology rapidly becoming commonplace for rail track applications. However, GNSS main shortcoming for this application lies in its reliability. Ingress to tunnels, dense forests, tall buildings and passage through deep and narrow track openings significantly degrade or even prevent reception temporarily [12]. Given the speed at which trains run, even a few seconds signal blackout adds to substantial uncertainty.

An increasing number of railway applications using GNSS as part of an integrated location system have been investigated in recent years. These include route mapping for railway asset management [13], rail track profiling [10], train navigation [14] and automated train control [11]. Naturally, the number of patents issued related to GNSS train applications shows a steady growth [15].

2.2. Radiolocation

Radiolocation methods locate vehicles by directly measuring time of radio signals traveling between the vehicle and a number of fixed stations. As with GNSS, trilateration can be used to compute the vehicle's position [8]. The nominal accuracy of radiolocation is in the order of 30 m. However, interference and atmospheric conditions often increase uncertainty up to 400 m [7]. Asset management of trains based on the global system for mobile communication (GSM) using an integrated location system has been demonstrated in Portugal [16].

2.3. Proximity

In proximity systems, location of a vehicle is given by the relationship between the vehicle and fixed location devices strategically positioned throughout the route. They are extremely accurate at point of register, but uncertainty rapidly increases shortly after. Positional accuracy can be enhanced by the use of an increasing number of devices. This, however, makes it inevitably expensive.

Block occupancy and broad location of trains largely rely on wayside track signalling equipment, such as track circuits and axle counters; which can be classed as proximity devices. Track circuits typically use a low voltage current applied to electrically isolated sections of the track rails. Current flow interruption by train wheels provides indication of train presence [17]. Axle counters are electro-magnetic devices capable of registering the presence of rail vehicles. They are typically used in pairs, and by counting the number of axle sets in-and-out of track sections, are also capable of