SYSTEM, METHOD AND APPARATUS FOR MANAGING RAILROAD OPERATIONS AND ASSETS USING FREQUENTLY ACQUIRED, PATH ORIENTED, GEOSPATIAL AND TIME REGISTERED, SENSOR MAPPED DATA

Abstract
According to the present invention a system and method is provided for managing both fixed and moving railroad assets for increasing payload throughput and operational efficiency, and enhancing public and worker safety. Moreover, according to the present invention, security is providing thereby enhancing operational efficiency and reducing the cost of risk mitigation. The present invention is accomplished through the use of computerized hardware and software utilizing mobile railway platform-acquired, path-oriented, geospatially aligned, sensor mapped multi-phenomena data together with high frequency path monitoring. According to the present invention, augmented reality, spatial awareness and databases may be incorporated along with large scale databases, so that railroad assets, both moving and non-moving, are monitored and compared with historical conditions to ascertain changes indicative of problem states.
FIG. 1

Major Components of Current & Future Railway Systems

- Network Data Services
- NOC
- BOS
- BOS
- CTC & System Integration
- PTC
- 5RS
- Concept Testing
- Spatial Cylinder of Awareness (SCA)
- Hy-Rail & Spec. Equip
- Trains
- Personnel
- Railway Wireless Data Services
- Railroad Track Network (RTN)

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FIG. 3

- Spatial Cylinder of Awareness (or SCA)
- Planar Area of Interest (or PAI)
- Point of Being (or POB)
- Point of Location (or POU)
- 5th Rail or SCA axis

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FIG. 4

The 5RS System Architecture & Major Components

Network Data Services

NOC

5RS RAILWAY SERVICES

Interface to Existing Railway Data Systems

Cloud Based Computation & Storage Services

5RS SCA Database & Analytics Manager

Sensor/Server/User-PAC I/O Manager

Data Flow

EXISTING RAILWAY SYSTEMS

BOS

BOS

CTC & PTC

Spatial Cylinder of Awareness (SCA)

Sensor/Server/User-PAC (SSU-P)

SSU-P

By Rail & Spec Equip

Trains

Personnel

Railway Wireless Data Services

Railroad Track Network (RTN)

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FIG. 5

The 5RS SSU-PAC Architecture & Major Components

![Diagram of the 5RS SSU-PAC Architecture & Major Components](image-url)
The 5RS SSU-PAC Architecture & Major Components

Railway Network Data Services

Railway Wireless Data Services

5RS Sensor-PAC
- Interface to Existing Railway Data Systems
- Server Based Computation & Storage
- SSU-PAC Database & Analytics Manager
- Sensor/Server/User-PAC I/O Manager

5RS Server-PAC

Mobile Platform
FIG. 7

The 5RS SSU-PAC Architecture & Major Components

Railway Network Data Services

Railway Wireless Data Services

5RS Sensor-PAC

5RS Mobile Platform

5RS Server-PAC

5RS User-PAC

Presentation

Actuation

RTN
FOR EXAMPLE:
In-View, Real-Time
Track Status Reporting

Visor Up

Visor Down
Example: Real-Time Track Status Reporting
For Example: See What’s Hidden Before You Dig
FIG. 12

The 5RS SSU-PAC Architecture & Major Components

Railway Network Data Services

Railway Wireless Data Services

5RS Sensor-PAC

5RS Mobile Platform

5RS Server-PAC

Interface to Existing Railway Data Systems

Server Based Computation & Storage

SSU-PAC Database & Analytics Manager

Sensor/Server/User-PAC I/O Manager

RTN

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FIG. 13

The 5RS SSU-PAC Architecture & Major Processes

INCIDENT ENERGY FROM SCA

ACQUIRE SCA IMAGE

Add 5RS 4D Address Data & Sensor-PAC Meta-Data

ENHANCE IMAGE

DETECT CHANGES

AUGMENT IMAGE

Sensor-PAC Controller

User-PAC Controller

5RDB

PRESENT IMAGE

Select Presentation Mode

Process Images

Acquire SCA Data Packets

Server-PAC

5RS RAILWAY CLOUD SERVICES

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FIG. 14

The 5RS Approach to Naming Switch Connections

- POINT OF SWITCH
- 4' 2" CENTERLINE TIE
- 5TH Rail
- SW(N) POL
- SWC1(N+2)
- SWC(T)(N+1)
- SWC(N+3)

- CENTERLINE OF SWITCH
- FOR NUMBER 24 SWITCH
- SWITCH ROD 5'-8" LONG.

- LENGTH OF CONNECTING ROD
- 42" WITH 13'-0" HEAD BLOCK TIES

Information Technology (Ref. PROPRIETARY INFORMATION)
Points of Location (POL) for Railroad Switches and Ties

- **POINT OF SWITCH**: 4 1/2" CENTERLINE TIE
- **5TH Rail**: 6'-8"
- **TP POL**: 9'-3"
- **SW POL**: 17" to 20"
- **LENGTH OF CONNECTING ROD**: 42" with 13'-8" HEAD BLOCK TIES

RIGID HEEL

CENTER LINE OF SWITCH CLIPS FOR NUMBER 24 SWITCH ROD, SWITCH ROD 5'-8" LONG.
FIG. 16

The Spatial Cylinder of Awareness (SCA)
Data Packet Format

- Railroad Track Network (RTN)
- Node Connection (SWC)
- Node Connection (SWC)
- Tie (TP)
- Point of Being (POB)
- Point of Time (POT)
- Sensor Channels (SCH)
- Sensor Type (STY) Meta Data
- Image Data

Track Address (TS)
In Planar Area of Interest (PAI)

5th Rail
(5RA)

5th Rail Address
**FIG. 18**

<table>
<thead>
<tr>
<th>Spatial Cylinder of Awareness Data Packer Format:</th>
<th>5th Rail address</th>
<th>Point of Being</th>
<th>Point of Time</th>
<th>Sensor Channels</th>
<th>Sensor Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th Rail Address Format:</td>
<td>Railroad Track Network</td>
<td>Link (SWC&lt;sub&gt;i&lt;/sub&gt;, SWC&lt;sub&gt;j&lt;/sub&gt;)</td>
<td>Tile (1 to N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th Rail Address:</td>
<td>Railroad Track Network</td>
<td>(29,25)</td>
<td>(X)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where Railroad Track Network is: SAN to LAX - BNSF/AMTRAK/NCTO/METRO-LINK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where Link node&lt;sub&gt;i&lt;/sub&gt; is: 28 and Link node&lt;sub&gt;j&lt;/sub&gt; is: 24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point of Being: Location on Planar Area of Interest: RLI eye level @ grade-crossing, E Street, Encinitas, CA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point of Time: 20140413163811 UTC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SENSOR CHANNEL: HD VIS**

**SENSOR TYPE:** iPhone 5s back camera

**Point Of View:** See Sensor X meta-data

**Direction Of View:** See Sensor X meta-data

**Field Of View:** TP(X) to (X+10) where X is TBD

**Scene Of Interest:** Entire data-frame

**Point Of Interest:** NA

**Range Of Interest:** NA
FIG. 19

Spatial Cylinder of Awareness Data Packet Format:

<table>
<thead>
<tr>
<th>5th Rail Address</th>
<th>Point of Being</th>
<th>Point of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Channels</td>
<td>SENSOR DATA</td>
<td></td>
</tr>
</tbody>
</table>

5th Rail Address Format:

Railroad Track Network | Link [SWC, SWC] | Tie (1 to N)

5th Rail Address:

Railroad Track Network | (29,25) | (X) |

Where Railroad Track Network is: SAN to LAX - BNSF/AMTRAK/NCTD/METRO-LINK

Where Link node is: 28 and Link node, is: 24

Point of Being: Location on Planar Area of Interest: RLJ eye level @ grade-crossing, E Street, Encinitas, CA

Point of Time: 20140413152831 UTC

SENSOR CHANNEL: HD VIS
SENSOR TYPE: iPhone 5s back camera
Point of View: See Sensor X meta-data
Direction of View: See Sensor X meta-data
Field of View: TP(X+3) to horizon where X is TBD
Scene of Interest: Entire data-frame
Point of Interest: NA
Range of Interest: NA
SYSTEM, METHOD AND APPARATUS FOR MANAGING RAILROAD OPERATIONS AND ASSETS USING FREQUENTLY ACQUIRED, PATH ORIENTED, GEOSPATIAL AND TIME REGISTERED, SENSOR MAPPED DATA

This application is an original non-provisional patent application claiming the priority benefit of provisional patent application Ser. No. 62/155,114 filed on Apr. 30, 2015, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a mobile, multi-phenomena sensor based computer hardware, software and firmware system that can be used to manage the movement and maintenance of railroad assets. Owners, operators and government regulators of existing and planned railroad infrastructure are searching for ways to use advanced sensor, computer, and network communication technology to increase operational efficiency, to improve safety and security, and to reduce the cost of risk mitigation. An example of this effort is the current US Government mandated system development and integration effort underway known as Positive Train Control.

Current railroad systems are comprised of: a physical network of roadbeds and trackways, rail-and-tie tracks, and switches; and a multiplicity of vehicles (trains and other specialized mobile platforms) which transport material goods, people, and specialized monitoring and maintenance equipment from point to point via the rails of the physical network.

Unlike other transport systems such as aircraft, watercraft and automotive vehicles, the mobile transport assets of a railroad are restricted to forward and reverse motion on the path defined by the rails. As a result, the systems currently used to control traffic on these paths and to assure fixed asset integrity of these paths, dealt with conditions located in a specified proximity of the track path.

Currently, the mapping and monitoring of railroad waybends, roadbeds, and tracks are accomplished using specialized vehicles which gather and process the desired data and then store and forward it to remote systems for processing and evaluation. The frequency of monitoring and mapping specific track path proximity of interest is limited by track availability and the operational cost of specialized vehicles & equipment.

The current system for real time management of railway traffic, Centralized Train Control, uses voice communication between human operators of Mobile Rail Platforms as well as fixed site command and control personnel. This approach suffers from a variety of opportunities for human error and has resulted in the use of machine position-location systems such as Global Positioning System technology in the anticipated Positive Train Control system. These systems are referred to as Positive Train Location sensors. A specific sensor has been developed to combine inputs from several global positioning systems with inputs from inertial guidance and wheel-speed/direction sensors to calculate the position-location. It is expected that this approach will significantly reduce the occurrence of machine position-location errors due to the distortion or denial of satellite positioning system input data. However, there is still a need for a comprehensive system that integrates centralized train control with positive train control using real-time sensor mapping to improve on current railway asset management.

SUMMARY OF THE INVENTION

The present invention is a system that is designed to be a complementary system overlay, called the 5th Rail System. This system is designed to enhance both the existing Centralized Train Control system as well as the Positive Train Control effort.

The primary embodiment of the present invention is a complementary system overlay, called the 5th Rail System. This system is designed to enhance both the existing Centralized Train Control system as well as the Positive Train Control effort. One of the main features is a system apparatus and software/firmware application intended to acquire and utilize information associated with the geospatial position of the fixed elements of a Railroad Track Network. The system depends upon a precisely defined, geospatial path, whose location runs parallel to the centerline of rails 1 and 2, known as the load bearing rails. Some railroad systems utilize additional rails, 3 and 4, to supply electrical energy to and return electrical current from railroad transport vehicles. The additional rail, designated as a path oriented information rail known as the 5th Rail. A specific geo-spatial location on this path is referred to as a 5th Rail Address.

Another embodiment of present invention uses off-track and on-track railway mobile platforms, to support high frequency recording of the geospatial position and the physical state of Railroad Track Network rails, elements, and other physical features within the proximity of interest, or Spatial Cylinder of Awareness (“SCA”) as defined by the geometrical axis of the 5th Rail. This on-board system uses multi-phenomena sensor arrays and computer servers onboard the mobile platforms. Combined with cloud-based data services, the system can manage the receipt, storage, analysis, augmentation and playback of this railroad path related, multi-phenomena sensor mapped information, resulting in increased mapping resolution and monitoring frequency. The present invention is designed to significantly improve the current methods of managing both fixed and moving railroad assets with the purpose of increasing payload throughput, increasing public and worker safety, and reducing the expense of risk mitigation.

Yet another embodiment of the present invention uses a variety of on-board presentation devices to support various user interface activities, combined with network interface technology, this is the User PAC. Using a variety of cloud based computer processing, storage and network management services to support various system activities such as: Storing and processing the spatial cylinder of awareness data from the Sensor-PAC and Server-PAC; Supporting the development, testing, storage and distribution of software and firmware applications; Path Oriented database systems & software for managing the APPS Library; and image data acquisition and distribution. Using a communication technology network allows the present invention to operate with all existing and planned railway communication, Software Defined Networks and Wide Band Software Defined Radios.

Yet another embodiment of the present invention are the data records (“data-frames”) that compose the maps for a specified railway network link, acquired using an array...
of multi-phenomena sensors (the “Sensor-PAC”). The sensors are located on a mobile platform and mounted at fixed, precisely defined, geo-located positions. Each sensor registers its image data frames in 4D (i.e. 3-space and time) relative to the coordinates of the 5th Rail axis. Each image data-frame includes: a specific network ID; the location co-ordinates or address; a 4 pi radian; a sensor image of the railway track proximity; and the time the image data was registered. In addition to the image data, each data-frame also includes meta-data, such as the sensor type and setting, the railway platform configuration and condition, and other relevant environmental factors.

[0012] An additional embodiment of the present invention is the use of a “path oriented” database approach to store, process and retrieve image data frames, image data packets, and collections (aka maps) in both the Server-PACs and cloud storage to form the collective database. This approach enables highly efficient data access, transfer and processing of image data frames throughout a highly distributed system with a wide variety of legacy components. The “path oriented” nature of the system involves large amounts of storing, processing and streaming blocks of sequential data in the form of videos or movies. The system processing architecture and memory access approach have been designed to accommodate this requirement. Image data can be searched and retrieved from the system memory and viewed in real time, single image or sequential images in variable speeds or time lapse. The image can be enhanced or augmented and stored for future access.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. 1 diagrams the relationship of the major components of current and future railway systems.

[0014] FIG. 2 and FIG. 3 are images displaying the method of defining the spatial cylinder of awareness and the spatial volume of interest along a network of track paths from separate viewpoints.

[0015] FIG. 4 diagrams the general architecture of the distributed system, the primary components of the system, and the network connections between these components.

[0016] FIG. 5 is a diagram of the relationship between the mobile platforms and the Sensor-PAC.

[0017] FIG. 6 diagrams the S sensor-PAC in conjunction with the on-board Server-PAC manages the acquisition, storage, and on-board processing of spatial cylinder of awareness data-frames.

[0018] FIG. 7 diagrams the relationship of the User PAC to the Mobile Rail Platform and the Server-PAC.

[0019] FIG. 8 and FIG. 9 are images of operator display configurations that support Augmented Reality in the locomotive cab (on the mobile railway platform).

[0020] FIG. 10 is an image of a hand-held Display Configuration that Supports Maintenance Planning.


[0022] FIG. 12 diagrams the general case where the User PAC is remotely located from the Mobile Rail Platform.

[0023] FIG. 13 is a diagram of how the 5th Rail System Railway Information Services System uses a variety of cloud based computer processing, storage and network management services to support the various system activities.

[0024] FIG. 14 diagrams the 5th Rail System approach to naming the switch connections.

[0025] FIG. 15 diagrams the Point of Location for railroad switches and ties.

[0026] FIG. 16 diagrams the key components of the information format in the spatial cylinder of awareness data packet.

[0027] FIG. 17 is an image showing a case where the 5th Rail or Spatial Cylinder of Awareness axis is parallel to and coincident with the centerline between the bottoms of rails 1 and 2 (i.e. on the top surface of the ties).

[0028] FIG. 18 is an image diagram showing the front of Train 5th Rail address Spatial Cylinder of Awareness Centerline Forward & Down.

[0029] FIG. 19 is an image diagram showing the front of train 5th Rail address Spatial Cylinder of Awareness Centerline Forward to Horizon.

[0030] FIG. 20 is an image of the method that uses image data matching of fixed assets and/or fixed critical features in the Spatial Cylinder of Awareness to determine the position-location of Railroad Track Network Mobile Rail Platforms.

[0031] FIG. 21 is an image of the method that uses fixed assets and/or fixed critical feature counting in the Spatial Cylinder of Awareness to determine the position-location of Railroad Train Network Mobile Rail Platforms.

PREFERRED EMBODIMENT

[0032] FIG. 1 diagrams major components of the current and future railway systems as well as the integration of the present invention into the current railway system. The present invention, the 5th Rail System (“5RS”) encompasses the Spatial Cylinder of Awareness (“SCA”) that is made up of trains or mobile railway units, the railroad track network, rail specialized equipment as well as rail personnel. The SCA is integrated into railway wireless data services, which can communicate with network data services that include the Network Operations Center (“NOC”) and the Back Office System (“BOS”) through 5RS. The communication of data is then integrated into existing Positive Train Control (“PTC”) and Centralized Train Control (“CTC”) systems.

[0033] FIG. 2 and FIG. 3 are images displaying the variations in the “proximity of interest” along the path. This geospatial volume of interest can be viewed as a “Spatial Cylinder of Awareness” (or SCA) in which a track path (the 5th Rail) defines the geometrical axis. At any point along this path, a variable length, variable angle radial vector R_{CA} whose origin remains on and orthogonal to this axis, maps out a Planar Area of Interest (or PAI). A Cylindrical Volume of Interest (or CVI) can then be obtained by integrating the planes of interest along the Spatial Cylinder of Awareness axis.

[0034] The 5th Rail System is distributed sensor, computer, and network based information system structured to support the acquisition, storage, retrieval, analytic processing, augmentation and playback of path oriented and position located sensor-mapped data associated with the management of fixed and mobile assets of railroad networks. The unique aspects of the 5th Rail System are associated with the components, methods, apparatus, and software/firmware used in this design. FIG. 4 diagrams the general architecture of the distributed system, the primary components of the system, and the network connections between these com-
ponents. The present invention, the 5th Rail System ("5RS") provides services that seamlessly share data in real time with the Network Operations Center ("NOC") and Back Office System ("BOC"), the existing railway systems of Centralized Train Control ("CTC") and Positive Train Control ("PTC") and the data being collected in the Railroad Track Network ("RTN") within the Spatial Cylinder of Awareness ("SCA"). The present invention allows the data to be collected, managed, analyzed and stored through one integrated system that combines the three main departments of Railroad asset management.

In FIG. 5, mobile platform sensors are mounted so that their 3D position relative to the 5th Rail of a Railroad Track Network ("RTN") is precisely known at all times. An assembly or array of mobile sensors along with the associated platform mounting apparatus is referred to as the Sensor-PAC or sensor payload. The system uses a variety of on-board and person-carried computer servers to support a variety of data processing, storage and communication activities. These mobile servers and the associated network interface technology are referred to as the Server-PAC. The Sensor-PAC in conjunction with the on-board Server-PAC manages the acquisition, storage, and on-board processing of Spatial Cylinder of Awareness ("SCA") data-frames. The 5th Rail System Sensor-PAC/Server-PAC ("SRS SSU-PAC") combination is designed to acquire and store all of the multi-spectral data frames and associated meta-data during a single traverse of a track path or link by a single Railroad Track Network ("RTN") mobile platform. Benefits that result from using this approach include but are not limited to:

1. Increasing payload throughput and reducing the cost of monitoring the Spatial Cylinder of Awareness.

2. By attaching this equipment to the FOT and EOT of trains providing both scheduled freight and passenger service, it is expected that significant improvements can be achieved in the areas of payload throughput and the cost of monitoring the Spatial Cylinder of Awareness.

Current systems that acquire multi-spectral data do so one channel per traverse via specially designed High-Rail vehicles and maintenance equipment. This approach creates additional traffic on the rails thus reducing track availability and it requires additional capital equipment. By using scheduled trains, the data can be taken on every traverse of the Spatial Cylinder of Awareness without incurring the capital, maintenance and operational costs of using a specialized fleet of mobile platforms.

2. Increasing the efficiency of processing and storing sensor data-frames

Additional system level benefits are also anticipated in the area of post processing the multi-spectral data. Since the entire array of data acquisition sensors are carried on the same mobile platform, tasks requiring time, location and data registration of the data-frames will be significantly reduced since data from the various spectral channels are “time and location aligned” as they are acquired and stored.

FIG. 6 diagrams how each sensor in the Sensor-PAC samples or images its respective phenomena on a time and/or location clock basis, forms a data payload word consisting of: a frame of sensed data and; the associated meta-data generated by the specific sensor for that specific sample or image. This data payload word is then communicated to the associated Server-PAC and stored in 5th Rail Database section of memory. This data word can then be further processed by the Server-PAC and/or communicated to the 5th Rail System ("5RS") Cloud Services section of the 5th Rail database for further processing and archive storage. The Server-PAC contains processors and memories suitable for receiving, storing, and processing real-time raw sensor payload data words as well as post processed, path oriented baseline data maps from the 5th Rail System Cloud Services section of the 5th Rail Database. On-board processing functions such as image enhancement, differencing and matching would be supported in real-time with results being presented to on-board operators via the User-PAC and communicated to Cloud based Network Operations Center and Back Office System services. Forwarding specified raw and processed data to and receiving data from on-board operators, remote data processing/storage centers, and remote operators is accomplished via both existing and anticipated railway data communication assets and systems located on-board the mobile platforms, wayside data communication assets, and railway system-wide communication Network Operations Center and Back Office System services.

The 5th Rail System uses a variety of on-board and person-carried computer servers to support a variety of data processing, storage and communication activities. These mobile servers and the associated network interface technology are referred to as the Server-PAC. FIG. 6 diagrams a mobile railway platform with both the server-PAC and sensor-PAC onboard. The Sensor-PAC in conjunction with the on-board Server-PAC manages the acquisition, storage, and on-board processing of Spatial Cylinder of Awareness data-frames. The 5th Rail System Sensor-PAC/Server-PAC ("SRS SSU-PAC") combination is designed to acquire and store all of the multi-spectral data frames and associated meta-data during a single traverse of a track path or link by a single railroad track network mobile platform. This method results in the following system improvements:

1. Increasing payload throughput and reducing the cost of monitoring the spatial cylinder of awareness ("SCA"): By attaching this equipment to the front ("FOT") and back ("EOT") of trains providing both scheduled freight and passenger service, it is expected that significant improvements can be achieved in the areas of payload throughput and the cost of monitoring the Spatial Cylinder of Awareness. Current systems that acquire multi-spectral data do so one channel per traverse via specially designed High-Rail vehicles and maintenance equipment. This approach creates additional traffic on the rails thus reducing track availability and it requires additional capital equipment. By using scheduled trains, the data can be taken on every traverse of the spatial cylinder of awareness without incurring the capital, maintenance and operational costs of using a specialized fleet of mobile platforms.

2. Increasing the efficiency of processing and storing sensor data-frames: Additional system level benefits are also anticipated in the area of post processing the multi-spectral data. Since the entire array of data acquisition sensors are carried on the same mobile platform, tasks requiring time, location and data registration of the data-frames will be significantly reduced.
since data from the various spectral channels are “time and location aligned” as they are acquired and stored. 

[0045] (3) Increasing the update frequency of baseline sensor data maps: By using this approach, the baseline sensor data maps used to monitor the fixed assets of the railway path can be updated automatically and on a daily basis. This will improve the ability to accomplish early identification of changes that may provide “an early warning” relative to potential infrastructure failures or obstructions.

[0046] FIG. 7 diagrams the fixed site and Mobile Railroad Platform user consoles consist of standard existing and anticipated human/computer interface devices such as desk and console mounted workstations, displays (alpha-numeric and graphic), audio out and actuation devices (e.g. keyboards, buttons, switches, mouse & track pad and audio). Person carried, hand held User-PAC configurations consist of existing and anticipated user displays, keyboards and other ancillary devices packaged in handheld and/or wearable format, e.g. smart phones, pads, laptops, watches and other similar configurations. The data from the 5th Rail System User-PAC can be accessed on both a fixed interface system or on portable, hand-held devices.

[0047] The following set of images shows four different utilizations of 5th Rail System sensor based technology through various operator display configurations that support augmented reality in a locomotive cab, hand-held and remote control environments. FIG. 8 shows an example of real time track status reporting using a movable visor display configuration that supports virtual signaling and safety alerts. Using the 5th rail system visor screen, the railway track ahead highlights and defines various important assets that could otherwise be overlooked. FIG. 9 is an example of a heads-up display configuration that supports virtual signaling and safety alerts, with more information about the track ahead regardless of obstructions or weather conditions that might impede visibility. FIG. 10 is an image of a hand held display configuration tool that supports maintenance planning by allowing the user to see beyond the limitations of objects. This system allows the user to see through objects using 5th rail system sensor based technology. By combining certain features of Augmented Reality systems with the 5th Rail System allows users and/or sensors to “point at objects” and request related data. Similarly, this combination will allow users and/or autonomous vehicles to be “pointed to” or shown a path that will lead to a destination. FIG. 11 shows an image of the command and control display console configuration that supports mobile railway platform using enhanced imagery and augmented reality.

[0048] The 5TH Rail System supports use cases where a User-PAC can be located remote from its associated Mobile Railway Platform. FIG. 12 illustrates the general case where the User-PAC is remotely located from the MRP. These cases include but are not limited to the following: Front and back of a locomotive; on and off track high-rail vehicles; analysis and maintenance equipment; remotely operated vehicles; autonomous vehicles; and dismounted persons.

[0049] The 5RS Railway Information Services System consists of four primary segments: a fleet of 5RS SSU-PACs aboard specific MRPs; 5RS Railway Cloud Computer Services; Railway data network and wireless data services, and; the distributed 5RS Data Base. The primary function of this system is to use existing and emerging computer, communication and sensor technology to: frequently acquire the RTN SCA “relevant reality” data; create and store the spatial cylinder of awareness data maps in the RDB for further analysis, processing, and application; distribute and present these maps and analytic results “anytime . . . anywhere” in response to customer queries using existing and anticipated railway data communication channels and user interfaces equipment. FIG. 13 diagrams how the 5th Rail System Railway Information Services System uses a variety of cloud based computer processing, storage and network management services to support the various system level activities. These activities include but are not limited to:

[0050] 2 Storing the Spatial Sensor of Awareness sensor data maps acquired by and pre-processed by a Sensor-PAC and its associated Server-PAC.

[0051] 3 Post processing Spatial Sensor of Awareness sensor data maps for to support operational, maintenance and management functions.

[0052] 4 Supporting the development, testing, storage and distribution of software and firmware applications.

[0053] 5 Path Oriented database systems & software for managing APPS Library.

[0054] 6 Image data processing, archiving & data distribution (5TH Rail Data Base).

[0055] FIG. 14 is a diagram of present invention’s approach to naming switch connections. A railroad switch is technically a mechanical router that determines the path of a railroad transport vehicle when it traverses the switch. In the 5th Rail System, assigning the “handedness” connection numbers for a specific switch (“SW”) is accomplished as follows: Stand on the Link (“TS”) that is connected to the “Facing connector” or SWC(ID)=SW(ID)+1; (2) the “Trailing Left connector” or SW (ID)=SW(ID)+2; and (3) the “Trailing

[0056] A specific Switch (“SW”) ID names a unique switch in the Railroad Track Network (“RTN”). Each named switch has three uniquely named Switch-to-Link (“SWL” to “TS”) connectors. They are named the (1) the “Facing Connector” or SWC(ID)=1; the “Left Connector” or Switch(ID)=1; and the “Trailing Right Connector” or SWC(ID)=3. A switch can support only four types of vehicle motion: (1) from SWL to SWL; (2) from SWL to SWL; (3) from SWL to SWL; and (4) from SWL to SWL. Motions (1) and (3) are called converging and (2) and (4) are called diverging. Vehicle motions that are not allowed are (5) from SWL to SWL; and (6) from SWL to SWL. To support a converging motion it is required that the switch be set into one of two possible diverging states. To support a converging motion, a specific switch state is generally not required. It is possible to combine a “switch name with a connector name” in a manner that results in the use of a single address field by adding the ID of a specific switch to one of its switch connector ID’s (1, 2 or 3). For example, if SW ID’s are chosen to be only decimal numbers that are a multiple of 4, a combined ID can be generated to designate a unique switch and a unique connector on that switch as shown below. This approach uses the term node connection (“SWC”) ID to designate both a unique switch and a specific connector on that switch.

[0057] SWC ID’s are generated as follows: (1) the “Facing connector” or SWC(ID)=SW(ID)+1; (2) the “Trailing Left connector” or SWC(ID)=SW(ID)+2; and (3) the “Trailing
Right connector” or \(SW_1(ID) = SW(ID) + 3\) where the SW ID’s are decimal numbers that are multiples of 4.

Example

\[SW(ID) = 20\]

[0059] \(SWC(21)\) identifies the “Facing connector” of SW(20).

[0060] \(SWC(22)\) identifies the “Trailing Left connector” of SW(20).

[0061] \(SWC(23)\) identifies the “Trailing Right connector” of SW(20).

[0062] To resolve the SW(ID) from a given SW(ID), divide the SW(ID) by 4 and subtract the remainder from the SW(ID). Using this scheme, the planned and actual path or route that a railroad transport vehicle takes when moving from a point of origin to a point of destination in an RTN can be described by the sequential series of SWC ID’s that the vehicle traverses in going from an origin to a destination.

[0063] A unique TS address can be generated by using the double field address comprise of the two switch connections associated with the TS, e.g. \(SWC(ID_1),SWC(ID_2)\). This can also be written as TS Address=\(ID_1-ID_2\). Thus, if one calls out a specific TS address or ID, it can be used to resolve the identity of the corresponding SW and SWC connections. In this approach, the sequence of the SWC addresses in the combined address field provides an indication of the direction of traverse. The first ID is the “from” SWC (or SWC) and the second ID is the “to” SW (or SWC).

[0064] Each TS contains a uniformly spaced series of tyes or tie positions throughout the length of the path. The total number of ties contained within a specific TS is dependent on the length of the TS and the tie spacing standards used during the construction of the TS. In this element addressing scheme, a TP(ID) names a unique tie within a specific TS(ID). In general, the TP(IDs) are numerical and run sequentially in increasing or decreasing order from one end of the TS to the other end of the TS.

[0065] To write the address or ID of a specific tie or tie position in the railroad track network, one use a triple field address format. The addresses or ID names left to right are (1) the "from" SWC, (2) the "to" SWC, and (3) the specific TP within the TS specified by double field address (1) and (2).

In summary, all elements of a railroad track network are given unique network addresses or ID’s using the following protocol:

[0066] SW Address=1A decimal number which is a multiple of 4!

[0067] SWC Address=1SW Address+1SW connector No. (1, 2 or 3)

[0068] TS Address=1SWC Address1SWC Address1

[0069] TP Address=1SWC Address1SWC Address1Tie No. 1-N1

[0070] Each element of a railroad track network has the potential of being geo-located within the associated spatial sensor of awareness using a variety of precision surveying schemes. In many cases where the location coordinates for a specific element have been acquired and are available, they can be stored in the meta-data field associated with that element. The format most commonly used is the WGS 84 reference frame. Since many of the elements have irregular shapes and dimensions that are much larger than the precision of geo-location, a Point of Location ("POL") on the element (or object) is specified on the data map image. FIG. 15 shows an image of a fixed primary POL that can be identified on or within the platform. The platform POL is used to spatially reference the POL’s of all the sensors on the platform. This approach allows a mobile platform sensor Point Of Being ("POB") to be calculated using an spatial cylinder of awareness axis POL and the platform primary POL.

[0071] FIG. 16 diagrams the key components of the 5th Rail System ("5RS") spatial cylinder of awareness ("SCA") data-frames (or data records) that make up the 5RS SCA multi-phenomena data maps for a specified Railroad Track Network ("RTN") link are acquired using an array of multi-phenomena sensors or Sensor-PAC. The Sensor-PAC is mounted on a Railroad track network mobile platform that traverses the Spatial Cylinder of Awareness paths of a Railroad Track Network. The individual sensors that comprise a Sensor-PAC are mounted at fixed, precisely defined, geo-located positions on or within the mobile platform. This allows each sensing element in the array to precisely reference (or address/register) each of its image data frames in 4D (i.e. 3-space and time) relative to the coordinates of the 5th Rail (or Spatial Cylinder of Awareness axis) at the time of data acquisition. A Sensor-PAC supports a variety of sensor technologies. These sensors support spatial cylinder of awareness views that include but are not limited to: Wayside, roadbed & track view (forward and rear); downward view of the switch, rail and tie; side views and (upward) ceiling views.

[0072] The system and associated methods, apparatus and software/firmware applications acquire and utilize information associated with the geo-spatial position of the fixed elements of a Railroad Track Network. To support this requirement, the system depends upon a precisely defined, geospatial path, shown in FIG. 17, where the location runs parallel to (but not necessarily coincident with) the centerline of rails 1 and 2. Rails 1 and 2 are the load bearing rails of all past, currently existing, and planned Railroad Track Networks. Some railroad systems utilize additional rails, noted as 3 and 4, to supply electrical energy to and return electrical current from railroad transport vehicles. To support the features of the 5th Rail System, design this additional rail has been designated “a path oriented information rail” and is referred to as the 5th Rail. A geo-spatial location on this path is referred to as a 5th Rail Address.

[0073] Examples of image data packet formats are shown in FIGS. 18 and 19 in two different viewing angles on the Mobile Railroad Platform. The various sensors input the data relevant to the image in the Spatial Cylinder of Awareness. The geographical fixed assets (or elements) of the physical track system (roadbed paths and waysides, ties, rails and switches) can be represented by a network graph of interconnected nodes (the switches), links (the track segments that connect two switches), and tie positions associated with each link. FIG. 18 and FIG. 19 show how each Switch, link, and tie are given a unique network address or name, i.e. an element ID. Using this approach and terminology, any specific physical Railroad Track Network can be represented by creating a network graph using the specifically identified set of geo-spatially fixed nodes, links and ties that support the movement of mobile assets on that specific system.
[0074] FIGS. 20 and 21 are images that display the method that uses fixed assets and/or fixed critical feature counting in the Spatial Cylinder of Awareness to determine the position/location of Railroad Train Network Mobile Rail Platforms. Using a Sensor Type at the Point Of Being such as illustrated in FIGS. 20 and 21, a sequential series of data frames for a specific Link are acquired, 5th Rail Address addressed, formatted into a data map, and stored in the 5th Rail Data Base. This data map, which is referred to as a spatial cylinder of awareness base-line map, is acquired so that an image of each sequential tie (a fixed asset) in the link is included. This can be accomplished with a sensor that captures an image every 2.5 inches less (the inter-tie spacing) as it traverses the link from the point of location of switch_s to the point of location of switch_t. Specifically in the data map shown in FIG. 21, a count of the tie addresses or ID's associated with the specific link is established and recorded. In the data map shown in FIG. 20, a fixed assets location clock can be created and then used during subsequent traverses of the link to trigger a spatial cylinder of awareness image data frame comparison process.

[0075] In a subsequent traverse of this Link shown in FIG. 21, a sensor at the same Point Of Being on a Mobile Rail Platform will acquire sequential image data frames that include each individual Tie. Using a software/firmware light intensity spot photometer to examine each image as it is acquired in real time, each Tie can be counted and identified (from 0 to N) as the Link is traversed. Using this as a real time Tie counter, the position-location of a Mobile Rail Platform’s SOL is known in terms of a specific Tie location or 5th Rail Address. The light intensity vs. time output of the spot photometer can also be recorded during a traverse. In the 5th Rail System this data stream or graph when plotted as light intensity vs. location is referred to as a Tie Location Clock.

[0076] The explanation given above is based upon being able to measure the light intensity variation obtained using a HD-VIS video rate sensor. Since Railroad Track Network roadbed conditions can vary due to the presence of snow and/or other debris conditions, the signal-to-noise ratio of a Tie Location Clock obtained with a HD-VIS sensor may not be sufficient to determine an accurate location. In these cases it may be necessary to use one or more alternate sensor technologies that can penetrate the masking material and provide a reliable Tie Location Clock under all operating conditions. In a manner similar to using the Ties, other identified fixed assets or fixed critical features within the Spatial Cylinder of Awareness, that are recorded on Spatial Cylinder of Awareness base-line image data maps, can be used to locate a Mobile Rail Platform relative to a specific 5th Rail Address. A location clock for these assets or features, a Fixed Assets Location Clock, can be established and recorded for each Link in the 5th Rail Database.

[0077] In a subsequent traverse of the Link shown in FIG. 20, a sensor at the same Point of Being on a Mobile Rail Platform will acquire sequential image data frames that include an image of each sequential fixed asset/critical feature in the Link. Using software/firmware image processing algorithms based on the Mobile Rail Platform’s Server-PAC, each new Spatial Cylinder of Awareness image data frame can be compared with the corresponding base-line Spatial Cylinder of Awareness image data frame. The image processing algorithms can support the following functions. These functions include but are not limited to:

[0078] Position-location of the Mobile Rail Platform
[0079] Position-location of a fixed asset/critical feature
[0080] Absence or presence of a fixed asset/critical feature
[0081] Change detection of critical features via image differencing
[0082] Object identification via feature recognition and image matching, e.g. Tie and switch ID’s
[0083] Virtual Signaling (with support of Augmented Reality functions)
[0084] Passenger entertainment (with support of Augmented Reality functions)
[0085] Tie and switch counting
[0086] Velocity of mobile platforms on a railroad path
[0087] Remote controlled and autonomous mobile platforms
[0088] Track, roadbed, and wayside inspection

[0089] Assume that for a specific Link, a tie location clock or fixed asset location clock exists. Since the geo-location of each tie or fixed asset in the link sequence is known and available to the Server-PAC via the baseline tie and/or fixed asset map, analyzing the real-time tie and/or fixed asset sensor input relative to the stored baseline tie or fixed asset map can provide the current speed of the mobile rail platform on the path.

[0090] The 5th Rail System manages sensor data maps by developed an address scheme based on using a Point Of Location ("POL") combined with path-related, pre-existing objects that are fixed in position relative to the earth’s surface (or center) and have a very low probability of moving in 3-space relative to their initial or planned position. In a railroad track network, the rails, ties and wayside are critical features. In path-oriented systems, there are two primary ways to discern a location, (1) traverse the path and periodically use a Global Positioning System ("GPS") to calculate your location, or (2) periodically look at the physical environment around your location and match it to a previously generated map of that physical environment along the path. The map will contain images of unique markers or features along the path and their respective locations in 3-space and relative to neighboring markers or features. Method (1) is in current use by the railroads but is subject to unreliability. However method (2) functions as a more reliable solution by frequently generating appropriate path-oriented, physical environment baseline maps and using these maps to compare the real time imagery being collected by every Mobile Rail Platform during a traverse towards the imagery shown in the data-map.

[0091] The 5th Rail System functions as a multi-purpose media recording, storage and retrieval system. Baseline sensor data maps and real-time image sequences that are generated by the 5th Rail System are displayed as sequential image frames along the path. The data frames are acquired using sensors that are time-base clocked or location-based clocked. In the context of existing systems, these sensor data maps are presented in a motion picture format, and can be played in real time while moving in the direction and space that the data map was first recorded. The database machinery is capable for the efficient storage and retrieval of these data maps based on the need to respond to real-time search algorithm queries needs, to look and behave exactly like the technology being used to currently store and deliver video and audio to the, on-demand consumer market. The organization of the 5th Rail System can take considerable advan-
tage of "big data" machinery designed, developed and used by current on-demand streaming media providers. Many of the software tools used by the entertainment industry to edit and deliver mass quantities of video and sound can be used or adapted for use in the 5" Rail System.

1. A complimentary overlay system for monitoring and controlling the progress and condition of a moving transportation object wherein said system comprises:
   a. one or more sensory data collection devices for gathering information indicative of environmental conditions surrounding said transportation object as it moves through space and time;
   b. a geo-location and time-clock device associated with said transportation object for indicating position and time data relative to said transportation object as it moves through space and time;
   c. a correlation module for combining said sensory data with said position and time data of said transportation object into combined reference data;
   d. a memory storage medium for storing said reference data indicative of a path of motion of said transportation object, including said sensory information and said position and time data, wherein said memory storage medium includes data indicative of said reference data corresponding to a path movement of said transportation between two points without occurrence of any safety concerns that could impact transportation object integrity;
   e. a real time data acquisition monitor associated with said transportation object wherein real time sensory information obtained from said sensory collection device and real time position data obtained from said geo-location device are compared with previously collected said sensory information and previously collected said position data to determine if conditions in the proximity of said moving transportation object have changed between data collection times to an extent whereby an unsafe condition exists whereby said unsafe condition may effect transportation object integrity; and
   f. wherein said combined reference data is subsequently accessed continuously as said moving transportation object moves through space and compared with any of earlier collected said combined reference data to determine if an unsafe condition exists so as to impede movement of said transportation object in a manner without impacting transportation object integrity.