NETWORK COMMUNICATION NOTE TO ASSIST BACKHOE OPERATORS AND DUMP TRUCK DRIVERS FOR EARTHWORK

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ABSTRACT

Network communication note is a cloud system for an earthwork project. It enables backhoe operators and dump truck drivers to monitor their own works in progress currently and performed up to the present, and to have opportunity to reflect on their own bearings in the earthwork operations, and then could increase their situational awareness to the actual work conditions. First, this paper presents problems and purpose. Secondly, the configuration of the network communication note is reported. Thirdly, examples of communications enhanced by the network communication note are shown. Finally, remarks are described.

KEYWORDS

Earthwork process, Points on construction, Operator assist, Driver assist, Actual operation rate, Haul road monitoring, Early alarm, Proximity warning

INTRODUCTION

Network communication note (hereafter called NeCo Note) is a cloud system for an earthwork project, which supports to control field operations in an earthwork process. We call this system NeCo Note from the old Japanese proverb "*neko no te*", which means that "we are so busy and short-handed, and so we will take any help we can get, even cat's paws." The NeCo Note is composed of Points on Construction (hereafter called POC) system and ICT-based work management system at a data center. The POC aims to collect data of events occurred in an earthwork process automatically in real time. The ICT-based work management system is a comprehensive, web-enabled, Windows-based system to support construction work management. First, this paper presents problems and purpose. Secondly, the configuration of the NeCo Note is reported. Thirdly, are shown examples of communications enhanced by the NeCo Note. Finally, remarks are described.

PROBLEMS AND PURPOSE

An earthwork process is separated into several works that are sometime independently and at other time interactively performed by different workers. For examples, road construction includes a series of discretely repetitive operations such as excavating, loading, hauling, dumping, grading, compacting, etc., which are performed by different operators, drivers and other workers, who are belonging to different subcontractors. Consequently, it becomes difficult to gather field data concerning each operation, to grasp situations of their own operations in progress on real time basis, and to understand the "Do's" and "Don'ts" in the whole earthwork process.

To overcome the problems of those, focusing on day-to-day operations from viewpoint of an earthwork process, we have been and are trying to build the NeCo Note that aims to:

- Enable operators and drivers to get intelligences relevant to their own operations in progress on real time basis,
- Give them opportunities to reflect on their own bearings, and

- Give the persons concerned a construction profile to guide or instruct the workers under their control with objective of increasing earth work efficiency, improving safety and achieving ecological earthwork in a cooperative manner, where the construction profile is defined as a set of data to vision characteristics of phenomena being generated along with construction in progress and indexes to show their patterns.

CONFIGURATION

The graphical illustration of the NeCo Note applied to an earthwork process is shown in Figure 1. As noted earlier, the NeCo Note consists of the POC system and the ICT-based work management system at a data center. The POC utilizes a number of communication nodes, active tags, cameras, GPS receivers, cellular phone, three-axis accelerometer, three-axis gyroscope, electromagnetic compass, barebone PC, tablet PC, and so on. The ICT-based work management system aims to support the persons concerned by generating and visualizing construction profile of earthwork process and providing remotely real-time monitor to display current situations of the earthwork process remotely on timely basis.

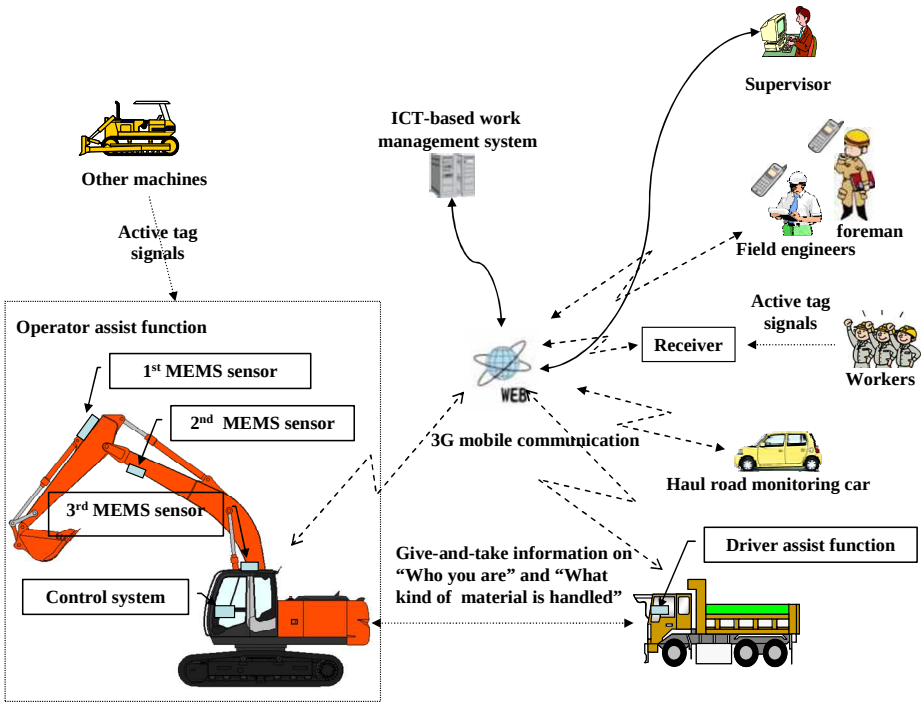

Figure 1 – Graphical illustration of NeCo Note application

Points on Construction

The POC consists of five sorts of principal functions, which are (1) event detection function, (2) operator assist function, (3) driver assist function, (4) functions of attendance control and collision avoidance, and (5) haul road monitoring function.

(1) Event detection function

The event detection function that is capable of indentifying events occurred in the earthwork process and the positions within a mount of short time. In this study, an event is defined as a significant occurrence or activity related to digging, loading hauling, dumping, spreading, and compacting, which are operations in an earthwork process. There are two event detection approaches to identify the events through the earthwork process. One is a sensor-based event detection that utilizes wireless sensor medium

to detect a significant occurrence or activity automatically. The other is an operator intervention approach to recognize it manually. If possible, the beginning and end of occurrence could be automatically detected by wireless sensor medium, and otherwise recognized by a button pressed event, that is, pushing predetermined function key by operator.

(2) Operator assist function

The operator assist system consists of MEMS sensors and a control system. The control system receives and stores data from the MEMS sensors. Based on the data, it automatically generates predefined quantitative indexes, for examples, positions of endpoint of the stick, number of machine relocations, work volume performed, actual production rate, and so forth. It displays ID of dump truck that is approaching to load and early alarm to avoid collisions. Also, it shows poses, orientations, and positions of the backhoe in real time, and also periodically displays the quantitative indexes.

The operator's bearing evaluation indexes and the actual operation rate are automatically and periodically generated based on time series of three-axis acceleration responses. The bearing evaluation indexes means operator's motor skills and attitude of remote control tasks at hand. (Nishigaki et al 2013). The actual operation hours are automatically and periodically calculated by finding change points in means and variances through time series of the three-axes acceleration responses (Killick&Eckley, 2011). And then, the actual operation rate and the actual production rate would be automatically generated.

(3) Driver assist function

The driver assist function in driver's seat consists of a tablet PC with GPS unit and a receiver to receive signals from active tags. Dump truck drivers are helped by displaying information on the screen of the driver assist system in the driver's seat. The information includes ID of the backhoe, type of materials being loaded, tonnage hauled up to the present, and driver's bearing evaluation indexes, early alarm to avoid collisions, and early proximity warning to crossings, school zones, densely inhabited districts, and so on. The information could be periodically and automatically updated as they might work.

(4) Functions of attendance control and collision avoidance

Every worker carries an active tag as a vade mecum while working. Here, the Media Access Control address of the active tag designates the worker's ID. Receivers for the active tags are placed at entrance or egress of the construction site, and boarded on the construction machines and the dump trucks. The receiver has the radio range that is something of the order of 100m. It could successively receive signals from the active tags within the effective range. The first detection time of the signals is regarded as the beginning time when the workers came into the effective radio range. The last time of the signals identified is regarded as the end time when the workers went away from the effective radio range. These first and last time stamps are utilized for the attendance control for workers. For collision avoidance, when the in-cab and in-vehicle receivers get signals from the active tags, the in-cab and in-vehicle tablet PCs show early alarm concerning other machines or other workers that are coming close to.

(5) Haul road monitoring function

A survey car with the haul road monitoring function periodically runs on the haul road to find the specific locations that have a number of shock points. The haul road monitoring function consists of a three-axis accelerometer and a tablet PC. It is assumed that shock points could have strong jerks derived from the 1st difference of acceleration responses. The strong jerks means jerk values that lie beyond 1.5 times IQR (interquartile range) of the jerk distribution. If a significant number of shock points might be found around a specific location, there might be sever unevenness and ruts at that location in the haul road, and accordingly harsh jolts and severe jars would occur there. The persons concerned should watch number of and changes in shock points, because it might show haul road deterioration progression by haulage operations.

COMMUNICATIONS ENHANCED

Image of communications enhanced between mobile entities in the NeCo Note application is shown Figure 2.

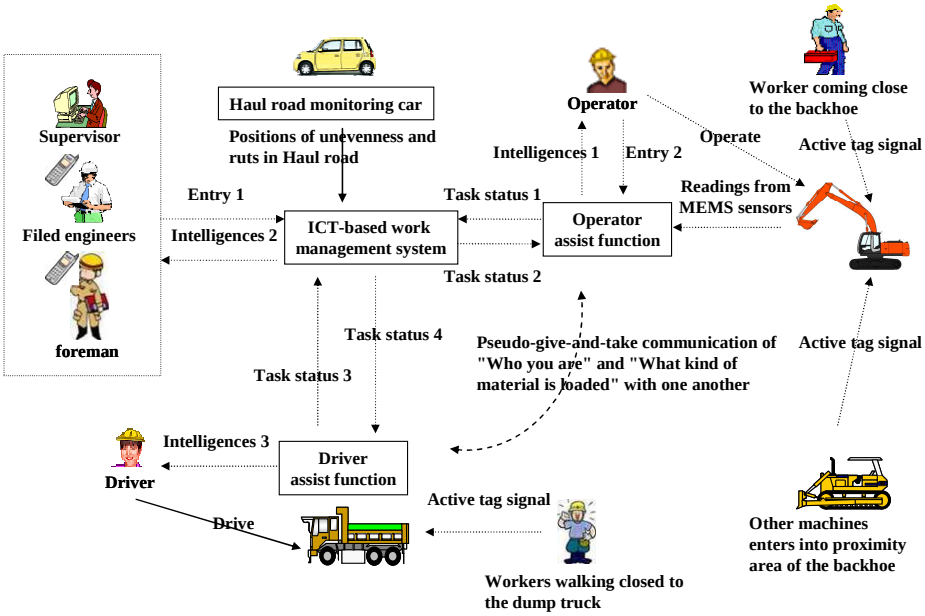

Figure 2 – Image of communications enhanced between mobile entities

Entry 1

Field engineers, a supervisor, or foremen input instructions regarding works under their control into the ICT-based work management system. Examples of the instructions include:
- Start, suspension or stoppage of the works,
- Positions of digging, loading, and dumping
- Alteration or modification of the works,
- Evacuation from the work site, and
- Crossings, school zones, and densely inhabited districts to be watched in the haulage road.

Entry 2

Operator presets the planned work range at the day and a max mobile scope of the backhoe at that position, and inputs type of material being handled during the operation into the operator assist function.

Task status 1

The operator assist function automatically calculates and stores the quantitative indexes based on the readings from the MEMS sensors. These calculations are automatically conducted at the noon and the evening. Examples of the quantitative indexes include:
- Cumulative operation hours, idling hours, driving hours and actual operation hours,
- Actual operation rates (in the morning, the afternoon and the whole day),
- Work volume performed concerning digging and loading,
- Production rates (in the morning, the afternoon and the whole day),
- Position trails of digging, loading and driving,

- Number of repositions of backhoe, and
- Operator's bearing evaluation indexes in a day.

The above indexes are automatically sent after the calculation to the ICT-based work management system. In addition, current positions of the backhoe and the type of material being handled are sent on real time basis to the ICT-based work management system.

Task status 2

From the ICT-based work management system, the operator assist function receives the instructions described at the Entry 1, and also the IDs of the dump trucks that is going to approach to load.

Intelligence 1

The operator assist function displays the 1st and 2nd task statuses on the screen of the tablet PC in the cabin. Especially, is shown in real time on the screen the ID of dump truck that will be approaching to load and also given early alarm to avoid collision, when other machines or other workers entered into the proximate area of 100m range from the backhoe's position, and if the backhoe's arm should attain the mobile scope bounds.

Task status 3

The driver assist function sends GPS readings of its own current positions in real time to the ICT-based work management system.

Intelligence 2

Based on inputted instructions and data of task statuses received from the operator assist function and the driver assist function, the ICT-based work management system automatically generates or updates quantitative indexes as follows:
- Positions and foot trails of backhoes and the dump trucks,
- Operator's and Driver's bearing evaluation indexes,
- Work volume performed by backhoes
- Material volume hauled by dump trucks,
- Productivity as mentioned earlier,
- Locations where harsh jolts and sever jars occur,
- Cutting and filling records and so on.

Task status 4

From the ICT-based work management system, the driver assist function receives the instructions described at the Entry 1, and also the ID of the backhoe to which the dump truck is going to come close and the material type being loaded on the truck bed. When approaching to crossings, school zones, or densely inhabited districts, early proximity warnings are automatically given to the driver. In addition, the driver gains early alarm to avoid collision, when other machines or other workers entered into the proximate area of 100m range from the dump truck's position.

Intelligence 3

Examples of haulage and driving records, proximity warning, and driver's bearing indexes are shown in Figure 3.

The driver assist function displays the task status 4 on the screen of the tablet PC in the driver seat. Especially, are displayed in real time on the screen the ID of the backhoe, the type of the material being

loaded, the early proximity warning, and the early alarm to avoid collision. Moreover, the driver's bearing indexes and the work volume performed by the driver are displayed on demand.

Pseudo-give-and-take communication

Figure 4 sows image of the pseudo-give-and-take communication between an operator and a driver via the ICT-based work management system. As it were direct communication with one another, the operator could check the ID of the dump truck that is going to approach for loading, and, on the other hand, the driver could confirm the ID of the backhoe to which the driver is going to approach and the type of the material being loaded on the truck bed.

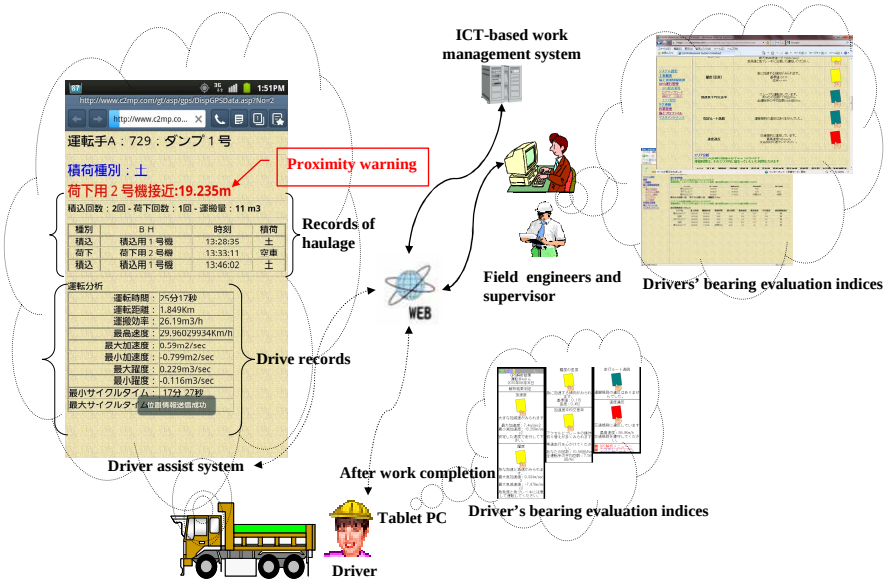

Figure 3 – Examples of haulage and driving records, proximity warning, and driver's bearing indexes

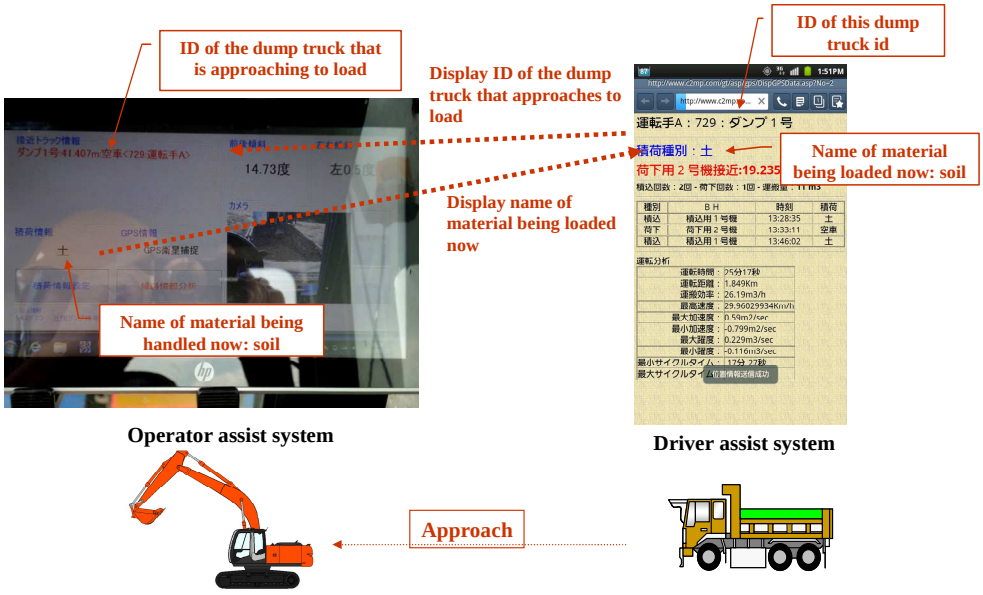

Figure 4 - Image of the pseudo-give-and-take communication

REMARKS

The machine guidance system focuses on backhoe movements and construction accuracy. By contrast, the NeCo Note watches not only backhoe movements but also behaviours of workers and a fleet in a whole earthwork process. The NeCo Note holds many fortes as follows:
- Giving workers the opportunities to reflect on their own bearings facing their works at hand, and
- Taking timely and quickly correct actions based on detailed visibility of appearances and motions in a whole earthwork process.

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REFERENCES

Killick, R., Eckley, I. A. (2011). Optimal detection of changepoints with linear computational cost, Retrieved from http://arxiv.org/pdf/1101.1438.pdf

Nishigaki, S., Sugiura, H., Takamura, T., Ogura, H., & Hatori, K. (2005). Study on framework of construction profile for collaboration and intelligent construction, Journal of Applied Computing in Civil Engineering, Vol.14, pp. 287-298.

Nishigaki, S., Saibara, K., Matsuda, F., Ogura, H. (2008). Points on construction, 25th ISARC, pp. 796-803.

Nishigaki, S., Saibara, K., Kitahara, S., Satoh, H., Hasegawa, M., Ogura, H., Matsuda, F. (2010). LHD remote monitoring and management based on delay/destruction tolerant network, 27th ISARC, pp. 326-335.

Nishigaki, S., Saibara, K., Kitahara, S., Iwasaki, H., Yamada, K. (2011). ICT-based work management to support unmanned construction for post-disaster Restoration, 28th ISARC, pp. 508-513

Nishigaki, S., Saibara., K., Kitahara, S., Fujino, K. (2013).Quantitative indexes to evaluate operator's bearing to remotely control backhoe, being submitted to 30th ISARC.

Saibara, K., Nishigaki, S. (2011). Driving bearing evaluation system to achieve ECO first haulage work, 28th ISARC, pp. 520-525.