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TELE-MAINTENANCE OF INDUSTRIAL TRANSPORT ROBOTS

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Abstract: Mobile transport robots are employed for a flexible flow of materials in industrial production. In order to minimize standstill periods in case of defects, the causes are to be analyzed remotely in order to reduce the time for repair. This paper addresses a telediagnosis infrastructure, allowing a remote service center to receive the crucial sensor data, to submit control commands to the vehicle for tests and to initiate the repair process. The control electronics and the software implementation for this generic telemaintenance approach via Internet will be reviewn, as well as experiences in its industrial use. *Copyright© 2002 IFAC*

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1. INTRODUCTION

In modern lean production mobile transport robots are a key element in the factories to establish a flexible flow of materials between the different steps in the production process (Schilling and Daum, 1999). Therefore a very high availability of such Autonomously Guided Vehicles (AGVs) is to be guaranteed, in order to avoid standstill of production. Thus in order to increase efficiency, it is of interest to reduce the reaction time in case of defects by performing telediagnosis, instead of sending maintenance personal physically to the AGV. This way travel time can be avoided and in a significant percentage of cases, advice on repair processes can be passed to workers in the factory. In more complicated situations, the remotely based maintenance people can select, according to the analyses of the received sensor data, the most probable replacement parts to take with them, when departing for the repair.

Similar telematics techniques have been applied in tele-robotics applications for space and for dangerous environments (Jamshidi and Ecker, 1993, Sheridan, 1992). Due to the improved telecommunication and data processing infrastructure at low prices, the use in commercial tele-service applications is rapidly increasing (Schilling and Roth, 2001).

This paper introduces in chapter 2 a typical AGV system, described in the following as exemplary application. Chapter 3 provides details about the teleservice interface hardware. In chapter 4 the software and operational aspects of this tele-automation infrastructure for maintenance are discussed.

Fig. 1: An AGV coupled with a trailer, performing transport tasks in manu-facturing.

2. THE AGV SYSTEM

Modern industrial production demands increasing flexibility, in order to manufacture according to customer needs small lots of different goods. The necessary flexible logistics for the transport of materials in the production process is often realised by autonomously guided vehicles (AGVs). Currently a new generation of more flexible AGV systems is entering the factories, based on advanced sensor systems requiring only a minimum of external navigation landmarks (cf. Salichs and Halme (eds.), 1998).

The generic telemaintenance aspects are here discussed in the specific example of low-cost AGVs of the company dpm. These AGVs consist of the following components: control unit, safety devices, optical track identification unit and driving mechanism. Specific modular handling devices can be integrated according to production needs in order to support manual and automatic loading, transport of pallets, tractive tasks (cf. Fig. 1) or the AGV's use as a mobile mounting platform. The vehicles are equipped with optical track identification, consisting of a line camera integrated into the drive motor unit. Depending on the manufacturing environment, navigation of the AGV is supported by an optical guiding stripe, which is glued or lacquered on the floor (cf. Fig. 1, Fig. 2). This way a guidepath infrastructure is quickly created and can easily be changed.

The AGV control unit provides the functionalities to deal with a range of complexity for the needed path system, from intersection-free circular courses to a more complex branched path system (cf. Fig.2).

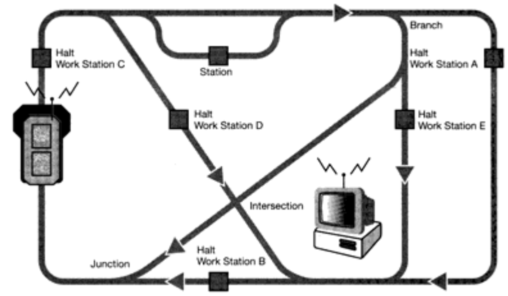

Fig. 2: Typical path system interconnecting several work stations in production.

For the coordination of multiple AGVs, a radio or infrared communication link between each AGV and the central control computer is established. From the fixed central control computer a standard modem or internet connection can be set up to the remote service center.

Thus telediagnosis of each vehicle can be performed from the remote AGV manufacturer's facility. By remote sensor data acquisition methods (cf. Schilling and Roth, 1999) the data, characterizing the AGV status and the factory environment, can be transferred and analyzed in the service center (cf. Fig. 3). Thus by this quick reaction capability stand-still periods in production can be reduced and often quick advice for repair actions can be passed to the workers in the factory.

In case of urgent emergencies, highly reliable and expensive direct broadband communi-cation links are to be used, but for standard maintenance work it is of utmost economic interest to employ inexpensive links. Here the disadvantages related to

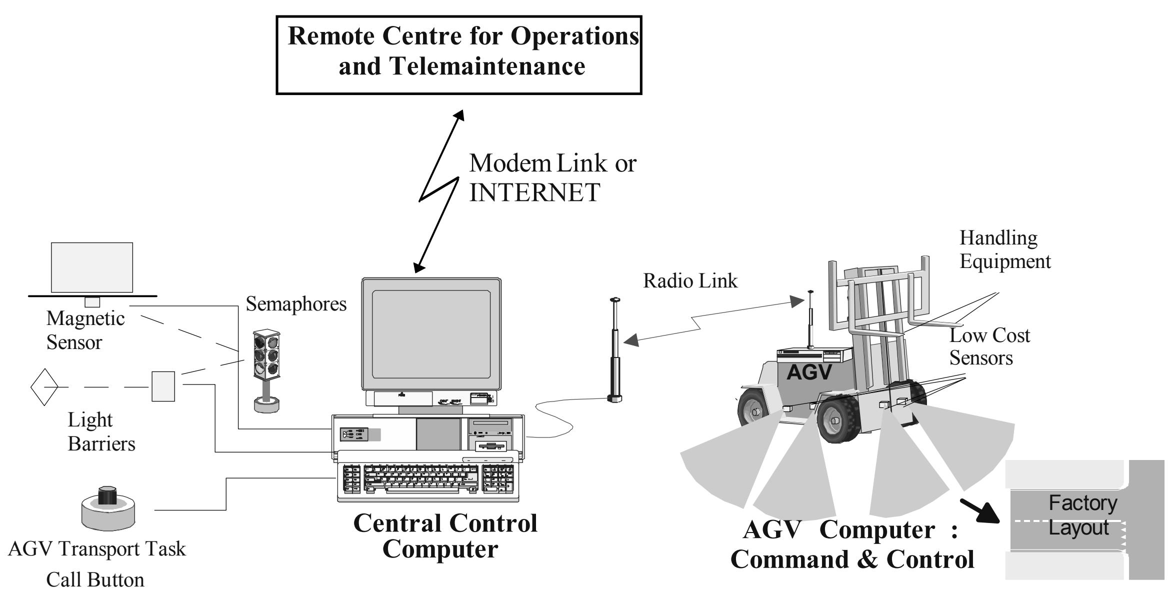

Fig. 3: Typical infrastructure for a factory information system, including an AGV, which is accessible via the central control computer from remote stations.

- delays in data transfer due to limited bandwidth and
- disturbances due to noise during transmission

are to be taken into account.

Countermeasures are addressing data compression and packetizing technologies, as well as the investigation of decentralized control concepts in order to reduce the amount of data to be transferred, including sensor data pre-processing and autonomous reaction capabilities of the control system at the remote site.

3. THE TELESERVICE INTERFACE

For the tele-servicing task onboard the AGV, dedicated electronics are required for the telemetry functions to acquire and transfer sensor data characterizing the AGV status and its working environment in real time. This Telematic Unit collects particular sensor data from

- the ultrasonic range measurement system, providing for fixed directions the distances to objects in the working environments,
- the motion unit, including encoder data from the wheels and status information on brakes,
- the tracking unit based on gray scale images of a line camera to detect the optical guideline, the AGV is following.

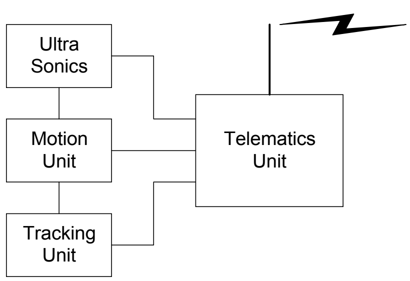

Fig. 4: Block diagram of the telematics unit on-board the AGV

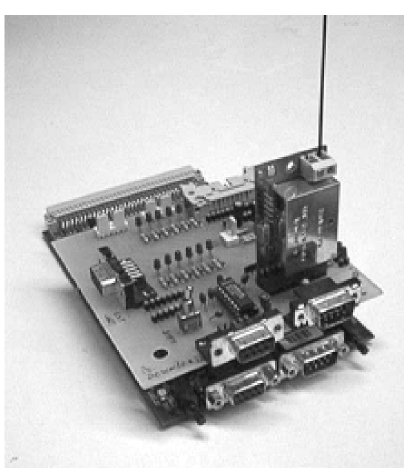

Fig. 5:Telematics unit installed on the AGV

This Telematics unit is based on a 80C167 micro-controller with a 16-Bit architecture providing features like UART and CAN communication interfaces, ADC, PWM, battery buffered real timer clock, FLASH ROM combined with an on-chip bootstrap loader providing an easy code upgrade, and several I/O lines.

To establish communication between AGV and the base station PC, a half duplex Radio Packet Modem is used. This unit operates at the UHF band and transfers small data packets at a baud rate of 40 kbps. It includes a built-in self-test, diagnostics, status LED's and power save mode.

4. TELEDIAGNOSIS FOR THE AGV

The generic telemaintenance structure is summarized in Fig. 6. On-board the AGV the local control system processes sensor data for autonomous obstacle avoidance (e.g. ultrasonics, bumpers) and guide path following (e.g. grayscale line camera). Other sensors characterize the AGV status (e.g. batteries, brakes) and location (e.g. odometry). These are monitored for further reactions to the central control computer in the factory (cf. Fig. 3). The data of all AGVs are collected and monitored by the local operator (e.g. to recharge the AGV batteries in time and to perform smaller routine checks).

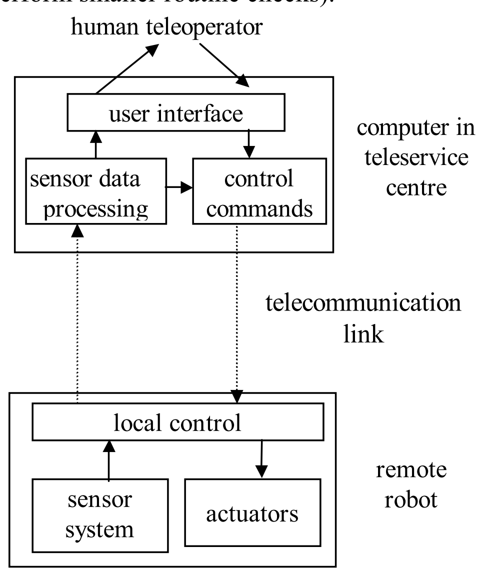

Fig. 6: The information flow between teleoperator and remote robot

More detailed AGV checks can be performed by the remote specialists in the teleservice center, on the basis of the data stored on the factory's central control computer. For the data transfer between both computers (the one in the service center and the factory's central control computer) usually the Internet is used due to cost aspects. Here a distributed system implementation approach based on dynamical webpages by JAVA applets and servlets has been applied (cf. Comer, 1997). Before the data transfer occurs, data encoding is performed for security reasons and for compression of camera pictures. The telemaintenance specialists take advantage of more extended computer resources, such as knowledge bases for defects. Drive commands can be send to the AGV, allowing assessment of the AGV performance in predefined tests and supporting the localization of defects.

In case of detected failures, according to the autonomous reaction strategy implemented, there can be switching initiated to redundant units at different levels (cf. Fig. 6) by

- the AGV's local control,
- the computer in teleservice center,
- the human teleoperator.

A typical user interface for the teleoperator is displayed in Fig. 7. Here in the upper left corner, the data of the grayscale line camera are displayed (with the guideline currently placed at position 32 (no reflection) and reflection areas to the left and right of it). Below, the AGV status data can be seen. In the upper right corner the ultrasonic data, representing the distances in the specific given pointing direction of each sensor are displayed. In addition camera data, providing a view of the AGV in the factory can be requested by the tele-operator. Thus he can observe on-line the changes in sensor data, while he sees the vehicle driving in the factory. The nominal data profiles to be expected have been obtained earlier during AGV installation and serve now as reference for comparisons.

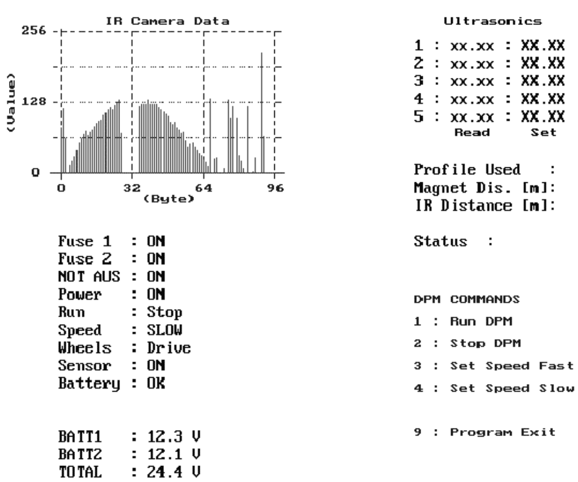

Fig. 7: User interface for the remote operator

5. CONCLUSIONS

Modern telematics methods offer an huge application potential in the teleservicing of automation systems in factories. This article discussed specific solutions for the concrete example of transport robots. Here a generic sensor data interface was developed, allowing the transfer of even high-data-rate sensor information safely via Internet or modem connection. In direct reaction to these sensor data, the remote human operator can send commands to adapt the sensors or to steer the robot. Similar telemaintenance schemes can be directly transferred to other applications in automation engineering, in particular for teleoperations and telemaintenance of machines, as well as telemonitoring of remote sites.

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