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A Comprehensive Approach to Off-line Advanced Error Troubleshooting in Intelligent Manufacturing Systems

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Abstract: The errors recovery in the production systems will be always an open issue. Therefore, the FMSs have to be endowed with tools and techniques allowing an automatic recovery of errors. The objective of this work consists in proposing an off-line version of the software framework for error troubleshooting in a flexible manufacturing system [1]. The main difference between the on-line and off-line version is that the error database is stored on the mobile device and the frame marker device is connected directly to the FMS components without the need of the PC.). Our framework system is designed to solve the failures in the functioning of the FMS and to generate self-training from previous experience.
Keywords: frame maker, FMS(flexible manufacturing system), error, troubleshooting, advanced decision systems.

1 Introduction

To improve their products quality, many companies used the Six Sigma approach to capture measureand eliminate the defects in manufacturing process in last years.

Nowadays, in flexible manufacturing systems, smart products and FMSs components (equipped with embedded smart devices) are wirelessly networked and remotely monitored in a real-time, using for this intelligent control systems.

Consequently, using these systems, we can achieve real time data gathering, remote monitoring and analysing the results acquired from smart product and FMS components, the purpose being: to control the manufacturing quality and to detect quality degradation, that will allows assessment of the failure situation and taking of appropriate corrective actions accordingly.

The error handling issue can be observed from two points of views. The former (out-of order) is related to the hole system-level point of view and deals with unexpected events as: FMS's components breakdowns, changes in task priorities, and all others which can be identified by the system's controller. The latter (out-of-ordinary events) is related to the errors at the cell level. Exceptions (differences between the actual and the expected state of the system) in a flexible manufacturing cell can be classified as: (1) unexpected events [2] (like time-out on expected process report or occurrence of unexpected reports), (2) errors [3] (like positioning errors), (3) unpredictable failures [9] (such as resource's out of orders, cameras failures, equipment failures, tool breakages, human errors, material handling problems, collisions, obstructions and handling failures).

The diagnosis issue is widely spread in the FMS research community. The diagnosis task can be split in the following sub-tasks [5], [6], [9]:

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- Detection, the goal of this task is to identify that something is not going as expected;
- Isolation, the goal of this task is to determine the exact location of the disturbance;
- Identification, the goal of this task is to determine the disturbance magnitude and impact;
- Error Diagnosis and Prognosis, that means to identify the responsible for the system degradation and the future degradation consequences;
- Error or Failure Recovery a procedure that allows to restart the error of failure in a way that either eliminates or minimizes it.

From the perspective of the automated control system, real-time status and data gathering of the various FMS components or manufacturing process and information transfer to the manufacturing process control centre or a corrective maintenance intervention upon FMSs components represents the close loop control and management of the manufacturing system (Figure 1).

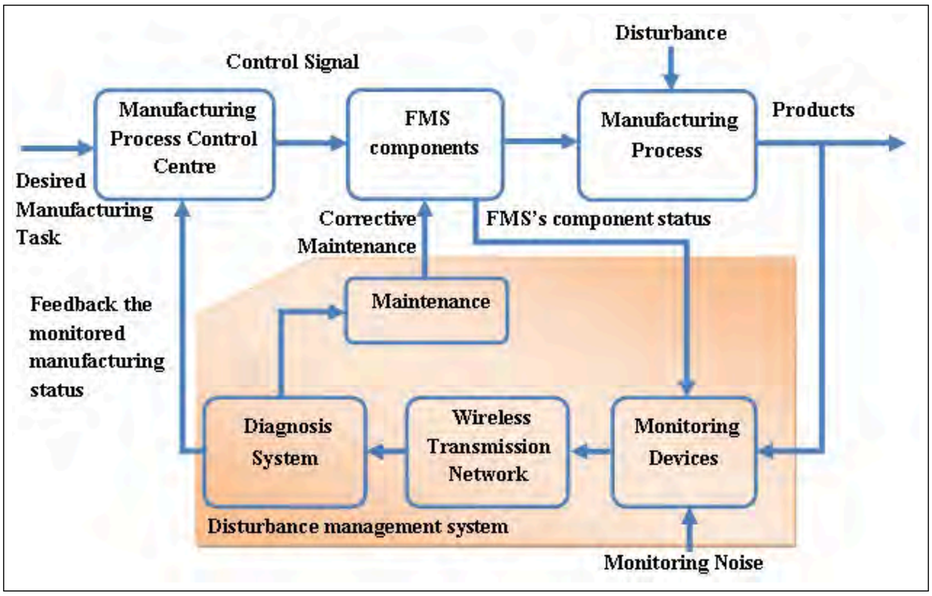

Figure 1: Disturbance management system

Figure 1 illustrates the informational flow in a disturbance management system. The monitoring devices is continuously observe the FMSs component status and manufacturing process, performing a comparison with the existing states and plans to verify if a deviation occurs.

If a deviation is detected, a diagnostic is generated, so the causes for the disturbance are identified; then its dynamics is evaluated, the possible actions to be executed to prevent a dynamic evolution of the disturbances consequences [7] ; all these with the aim to recover the system from this status.

If the diagnostic is generated, the diagnostic system starts a self-repair procedure; if it is not possible, the system requests a corrective maintenance intervention to the maintenance department. In the same time this department generates updates info about occurred disturbances.

In [8] was developed a prototype system, using RFID monitoring system and ZigBee wireless transmission as a close loop, to monitor the manufacturing process for a FMS.

In [9] is presented a new disturbance management system approach, based on ADACOR holonic control architecture [10].

2 System Structure

To monitoring the FMS system developed at the University of Oradea and presented in figure 2, our researchers have conceived and realized an off-line frame marker device for error troubleshooting.

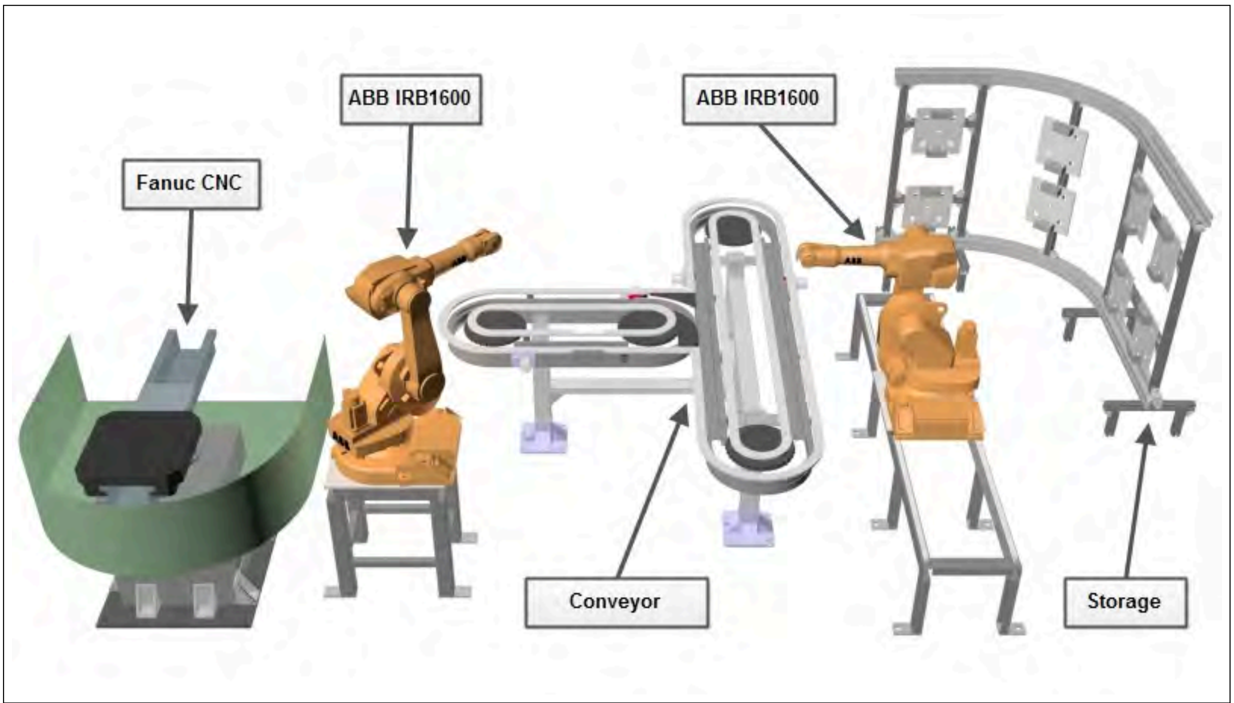

Figure 2: FMS structure

The main components of the FMS are: the 5-axis machine-tool TMA AL 550 equipped with Fanuc CNC, two ABB IRB 1600 robots with SCHUNK PNG 100 grippers, an ASRS (to storage pallet with work-piece, finite product and tools) and a conveyor.

3 Frame Maker Device

The starting point in using frame markers to detect errors in FMS is the ease of recognition of their patterns fiducial markers by Vuforia SDK Frame Marker software which can run on any smart phone. These fiducial markers (called frame markers) present a very predictable and specific pattern and are generated by Frame Marker Device (FMD) realized by authors.

The frame marker's ID, used to recognize the marker in its environment by the camera during run-time, is generated by FMD which has three zones as follows: a continuous outline black square, an area with light and dark blocks which follow the outline border and the last one - the inside area - a black square (figure 3). The position and arrangement of blocks from second zone are distinct, offering possibility to develop a computer vision algorithm for frame markers detection. The ID is encoded four times (on each edge of the frame) using a different base pattern of dark and light blocks. This redundancy increases the robustness of marker in detection and tracking.

To realise the code generator device of the FMD two major components were used::

- LED stripe with 36 LEDs individually addressable;

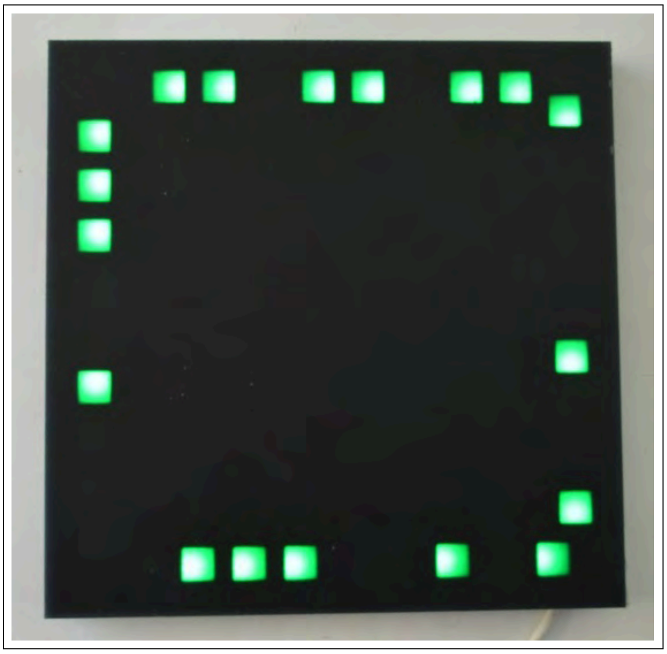

Figure 3: Frame Marker Device

- as signal generator for LED stripe was used an ATmega 1280 micro-controller .

Each LED is powered separately because of the high energy consumption. If all 36 LEDs are set to white colour the consume should be around 12 Watts (2.5 Amps and 5 Volts) Each LED is provided with an control chip (shift register) which uses one pin for input and one for output. From this reason the used protocol is very timing-specific and the micro-controller has to work with high repeatability (100nS timing precision) and at least on 8MHz. For each LED, the colour can be set with 8-bit PWM precision (24-bit colour / LED).

The ATmega 1280 micro-controller can be programmed with the Processing/Wiring open source programming language and the integrated development environment (IDE). The programming language is built on Java but uses a simplified syntax.

4 Structure of the off-line error troubleshooting system

The structure of the off-line error troubleshooting system is presented in figure 4.

The Frame Maker Device is connected through Factory Server to each FMS component's control module, and also receive information about the FMS's components status directly from the monitoring devices.

If any error appears in FMS (e.g. failure at any FMSs component, or at the FMS control modules or at the communications level) the error troubleshooting system will try to solve this problem searching in the error database for a possible solution. If the error can be manage automatically by the system it will be solve by FMS software. If not, the code generator maker of the frame marker device will generate and deliver an error code to the FMD and the operator will be notified about the need of troubleshooting the error through a visual and sound alarm.

The error ID can be read, from the frame maker device, using a portal device CCD camera, which should be directed toward the FMD (figure 5). The image acquired by CCD camera is decoded by Vuforia SDK to an error ID. On the portable device screen will appear an error message, with a brief description (which corresponds to that error ID figure 6).

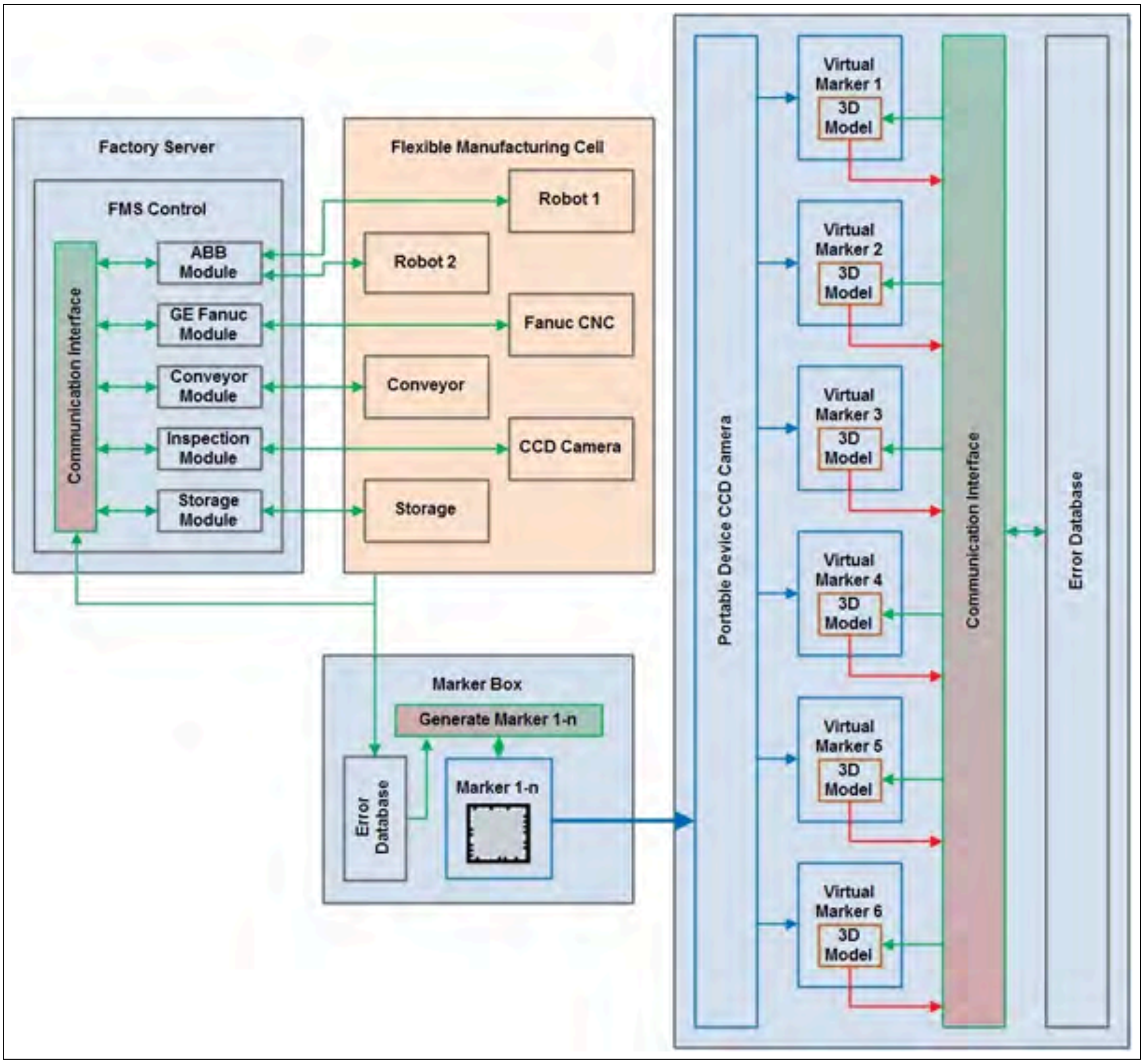

Figure 4: Structure of the off-line error troubleshooting system

Errors types for different cases of failures is presented in figure 7 (with red for ABB IRB robot, with blue for ASRS system, with purple for conveyor).

In some cases when the portable device screen is touched, detailed information of the error can be supplied, if exists.

After one error was successfully corrected, the operator should communicate the intervention via WiFi with FMS's Error Database.

Another application was also developed by authors: to check the functional status of FMS components by orienting the portable device towards the marker device; if a message on a green background appears on portable device screen, it means that the FMS component works properly; in case that a message on a purple background appears on screen, it means that the FMS component is off-line.

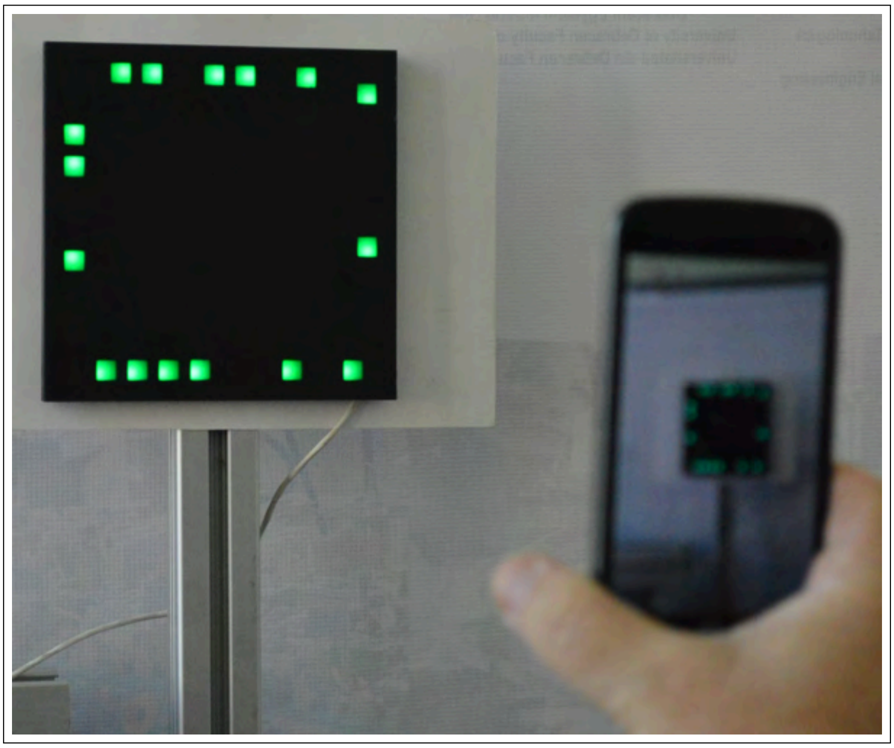

Figure 5: Image acquired by CCD camera

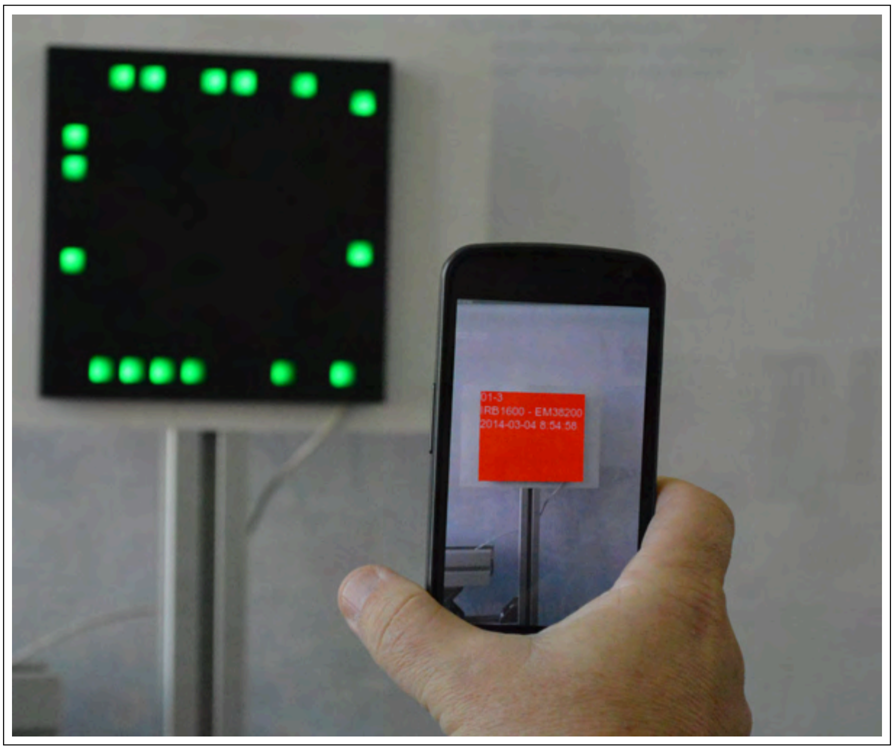

Figure 6: Error message

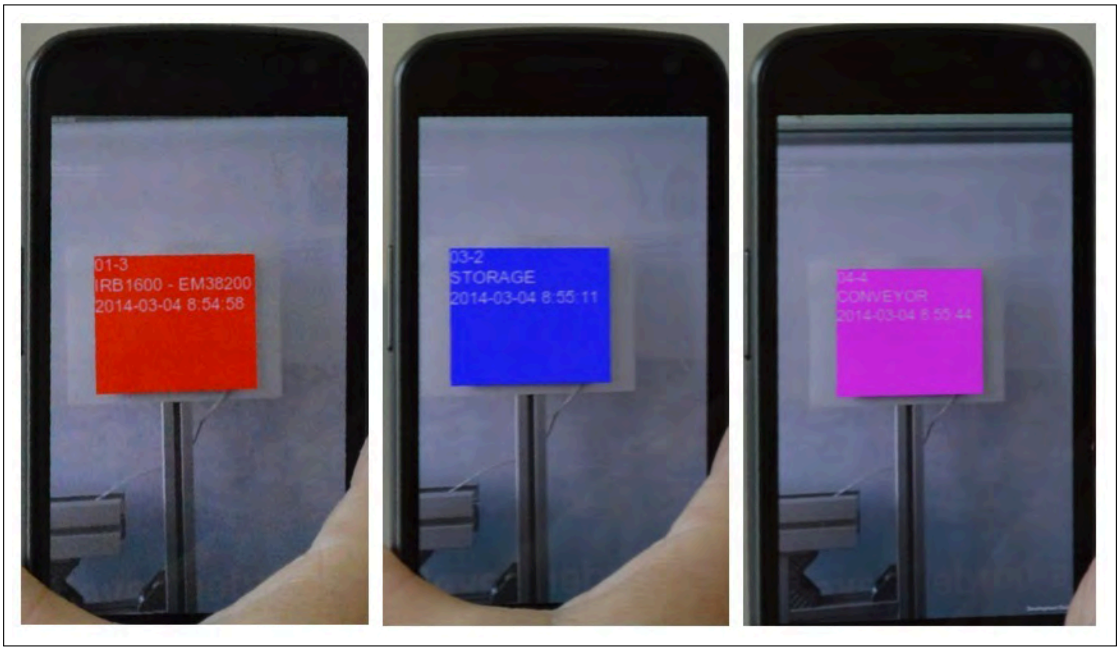

Figure 7: Errors types for different cases of failures

5 Conclusions and Future Works

The contribution of this paper is to propose an off-line version of the software framework using a frame marker device conceived by the authors, which can offer effectiveness control activities in the frame of a disturbance management system. The FMS components status is controlled by the software framework which transfers the information about the need of error troubleshooting from the FMS component to the operator, via a smartphone.

With the off-line error database we can create a more compact and network free error troubleshooting system. The only drawback of the system is the updates are not instant; they can be applied when the mobile system connects to the FMS control software when recharging.

The initial error database can be dynamically extended with new items corresponding to unpredictable errors developed during the manufacturing process.

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