Multi-agent system for monitoring, diagnosis and forecasting the technical system condition with the car as an example

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Abstract—This paper describes a multi-agent system for monitoring, diagnosis and forecasting the technical system condition with the car as an example. The system consists of four agents: the monitoring agent (collects reports on the condition of the vehicle, handles requests from the user and displays the response), diagnostic agent (reads log files, parses the parameters of the car), forecasting agent (determines the future values of the parameters and diagnoses predicted values), the data collection agent.

Keywords— *diagnosis, forecasting, technical system, multi-agent system.*

I. INTRODUCTION

This paper describes a multi-agent system for monitoring, diagnostics and forecasting the technical system condition on the example of the car.

The object of automation are the processes of monitoring, diagnostics and forecasting technical system on the example of the car.

Diagnostic processes include:

- Collecting data about the current condition of the car (getting values of the ECU (Electronic Control Unit) sensor of the car);
- Analyzing data from the sensors and determine the current condition of the car (finding data which falls into the working range, into the ranges of acceptable and critical deviation).

Forecasting process include:

- Collecting data about the current condition of the car (getting values of the ECU)
- Analyzing data from the sensors and forecasting possible condition of the car, based on of collected data.

Monitoring processes include the timely detection the current and potential troubleshooting, monitoring their progress

and timely notification of failure of staff to develop compensatory measures.

II. DESCRIPTION OF MULTI – AGENT SYSTEM

Figure 1. Description of multi – agent system in AUML notation

Monitoring agent is reflexive agent, it collects data about system condition from the diagnostic and forecasting agent.

Diagnostic agent is reflexive agent too, it requests data from data collection agent, processes it, and decides on the current condition of the system, the result is sent to the monitoring agent.

Data collection agent is also reflexive agent it is a hardware and software that reads data from the sensors, stores them, and sends to other agents if necessary.

Forecasting agent is an intelligent agent. The main task of the agent is to predict the possible condition of the system in the future, according to received information.

III. DATA COLLECTION AGENT

Data collection agent is a reflexive agent. It is a hardware and software submitted to mobile application Torque and Elm adapter respectively.

Elm adapter is a device that allows you to read data from the ECU or the vehicle, using OBD-II (On Board Diagnostics) standard, and transfer it to a computer or mobile phone via Bluetooth, Wi-Fi or a special cable, that plugs directly into the adapter and the device [1].

Torque is a mobile application for the Android OS designed to receive and display diagnostic information about the operation of the engine through the OBD-II interface. To connect you need OBD-II Bluetooth adapter [2].

Agent collects information about the condition of the technical system (in this case a car), writes it to a log file in .csv format and sends data to the selected store.

IV. DIAGNOSTIC AGENT

Diagnostic agent is a reflexive agent. The input which agent receives from the data collection agent is in a .csv format. Data is processed by a specific algorithm and then result is passed to the monitoring agent.

The algorithm of diagnostic agent:

Figure 2. The algorithm of diagnostics agent

To diagnose the condition of the car agent assesses each value of the parameters calculating the number of values, that is out of range, the number of occurrences in the normal range and the number of values within the operating range.

Then the agent calculates percentage of values, which fall within the range of critical deviation and the range of normal deviation, and if the percentage is less than the given (10%) for the critical or more (35%) for normal deviations, the result is bad or normal condition, respectively, otherwise the result is good condition.

V. FORECASTING AGENT

Forecasting agent is an intelligent agent. The main task of the agent is to predict the possible condition of the system in the future according to received information.

At the core of the agent is forecasting time series using Arima method.

Agent's work can be divided into two points:

- The agent reads the values from the log file and predicts future values of the parameters, according to log data and using the Arima method;
- Then, the predicted values are subjected to the diagnosis of the condition and according to it agent generates a report.

After forecasting, the agent sends the result to diagnostic agent, which, together with their results, sends them to the monitoring agent.

VI. DESCRIPTION AND JUSTIFICATION OF THE CHOICE OF FORECASTING AND DIAGNOSIS METHODS.

The method of diagnosis of technical system condition with the car as an example is a step by step analysis of the values of the parameters of the car, calculation the percentage of values falls within the working range, the ranges of acceptable and critical deviation. The method is selected to take into account the entry of parameters in multiple ranges (or range of working values, or in the normal range, or beyond the range of acceptable values), and also take into account that in some very rare cases, the value can go beyond the acceptable ranges even during normal operation system (car), but not to stay permanently.

Selected method of the forecasting is based on the prediction of time series (the Arima method) and it was chosen due to the fact, that it does not require the marked sample data for learning (such as methods, based on the use of neural networks, which is, of course, are more accurate method of forecasting).

VII. DESCRIPTION OF RANGES OF PARAMETERS OF THE TECHNICAL SYSTEM WITH THE CAR AS AN EXAMPLE

This section describes the parameters of the technical system with the car as an example that are subjected to the diagnosis and prediction.

TABLE I. TABLE OF RANGES OF PARAMETERS OF THE TECHNICAL SYSTEM ON THE EXAMPLE OF CAR [3]

Parameter	Units	The operating range	The range of normal deviations	The range of critical deviations
CO2 (the average value of CO2 emissions of the engine)	Gram(g) / Kilometer (km)	Less than 130	About 130	More than 130
Fuel trim bank 1 sensor 1	%	[-5, 5]	[-15, 15]	Other values
Fuel trim bank 1 sensor 2	%	[-5, 5]	[-15, 15]	Other values
Fuel rail pressure	Kilogram(kg)/centimeter ² (cm)	[2.5, 3.5]	[2.2, 4]	Other values
The pressure in the intake manifold	kP	[0, atmosphere pressure]	More than pressure	atmosphere
Fuel pressure	Atmosphere (atm)	[2, 4]		Less than 2 or more than 4
Longitude	%	[-20, 20]		Less than -20 or more than 20
Latitude	%	[-10, 10]		Less than -10 or more than 10
Voltage (control module)	Volt (V)	Battery voltage	Battery voltage – 0.5 V	Other values
Volumetric efficiency (rated)	%	[80, 100]	[50, 100]	Less than 50
Throttle Position (Manifold)	%	Less than 2	For 2 to 4	More than 4
Air Fuel Ratio		14:1	[13:1, 18:1]	Less than 13:1 or more than 18:1
Intake air temperature	Degree Celsius (°C)	25	[20, 30]	-
Catalyst temperature	Degree Celsius (°C)	[230, 300]	[230, 800]	Less than 230 or more than 800
Engine oil temperature	Degree Celsius (°C)	[80, 100]	[50, 150]	Other values
Engine coolant temperature (when the engine is operating)	Degree Celsius (°C)	[80, 90]	[50, 110]	More than 110
Transmission temperature	Degree Celsius (°C)	[80, 100]	[Environment temperature, 250]	More than 250

VIII.RESULTS

The system has been tested on a real car Ford C-Max. Figure 3 shows the piece of data that have been collected by data collection agent within 30 minutes of using the car:

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ude,GPS Speed (Meters/second), Horizontal Dilution of Precision, Altitude, Bearing, G(x), G
3.25600004,-0.27700001,9.45199966,-0.02871418,-0.78125,37.85542297,14.93888664,37.85542297,
3.25600004,-0.27700001,9.45199966,-0.02871418,-0.78125,18,14.93888664,18,0,-,1.06200004,0,
3.25600004,-0.27700001,9.45199966,-0.02871418,-3.90625,18.25,14.93888664,18.25,0,1.42236435,
3.25600004,-0.27700001,9.45199966,-0.02871418,-3.90625,19.79999924,14.93888664,19.79999924,
3.25600004,-0.27700001,9.45199966,-0.02871418,2.34375,21.5,14.93888664,21.5,0,16.89045334,-,
3.25600004,-0.27700001,9.45199966,-0.02871418,5.46875,22.8571434,14.93888664,22.8571434,0,1,
3.25600004,-0.27700001,9.45199966,-0.02871418,0,25.33333397,14.93888664,25.33333397,0,12.77:
3.25600004,-0.27700001,9.45199966,-0.02871418,0,27,14.93888664,27,0,12.77318382,-,7.1310000:
3.25600004,-0.27700001,9.45199966,-0.02871418,1.5625,27.66666603,14.93888664,27.66666603,0,:
3.25600004,-0.27700001,9.45199966,-0.02871418,-5.46875,29.0714283,14.93888664,29.0714283,0,!
3.25600004,-0.27700001,9.45199966,-0.02871418,-11.71875,30.5625,14.93888664,30.5625,0,10.95'
3.25600004,-0.27700001,9.45199966,-0.02871418,-7.03125,31.94444466,14.93888664,31.94444466,
3.25600004,-0.27700001,9.45199966,-0.02871418,-7.03125,32.5263176,14.93888664,32.5263176,0,:
3.25600004,-0.27700001,9.45199966,-0.02871418,-13.28125,33.52381134,14.93888664,33.52381134,
3.25600004,-0.27700001,9.45199966,-0.02871418,-16.40625,34.26086807,14.93888664,34.26086807,
3.25600004,-0.27700001,9.45199966,-0.02871418,-22.65625,34.54166794,14.93888664,34.54166794,
3.25600004,-0.27700001,9.45199966,-0.02871418,-25.78125,35.03845978,14.93888664,35.03845978,
3.25600004,-0.27700001,9.45199966,-0.02871418,-18.75,35.42856979,14.93888664,35.42856979,0,-
3.25600004,-0.27700001,9.45199966,-0.02871418,-19.53125,35.55172348,14.93888664,35.55172348,
3.25600004,-0.27700001,9.45199966,-0.02871418,-22.65625,35.80644989,14.93888664,35.80644989,
3.25600004,-0.27700001,9.45199966,-0.02871418,-16.40625,35.90625,14.93888664,35.90625,0,3.4!
```

Figure 3. Some collected data

The first row contains the names of all parameters. All subsequent lines contain the value of each parameter, if the parameter is not supported, the value is a symbol “-“. All parameter names and values separated by a comma.

In our case, we have a file which contains about 1200 lines, which means that we have about 1200 values for each supported parameters.

The system has four operating modes:

1) Help mode, it means that system can display the usage message

```
-----Help-----
--Use flag -f to get full information about condition of each params.
--Use flag -s to get just information about car condition (good, normal, bad)
--Use flag -c to work with car's configuration params
--.....Use 'get' after '-c' flag to print all conf params.
--.....Use 'set' after '-c' flag to set values of params.
--Use flag -p to predict information of car.
--Use flag -h to get help.
```

Figure 4. Usage message

2) Short diagnostics mode. It means, that system can display short diagnostics information about condition of the car. We'll get one of the three possible condition of the car:

- Bad
- Normal
- Good

In our case we got a normal condition of the car. It means that one or more parameters are normal, while other parameters are good.

3) Full diagnostics mode. It means, that the system also can display detailed diagnostic information about condition of the car.

```

Condition is good by Fuel trim bank 1 sensor 1
Fuel trim bank 1 sensor 2 contain incorrect value. Mybe symbol '-'
Condition is good by Intake Manifold Pressure(psi)
Condition is good by Fuel Trim Bank 1 Long Term(%)
Condition is good by Kilometers Per Litre
Condition is good by Fuel Trim Bank 1 Short Term(%)
Condition is good Engine Load(%)
Condition is good by Voltage (Control Module)
Condition is good by O2 Volts Bank 1 sensor 1(U)
Condition is good by O2 Volts Bank 1 sensor 2(U)
Condition is good by Air Fuel Ratio(Commanded)<:1)
Condition is good by Intake Air Temperature(°C)
Condition is normal by Intake Air Temperature(°C)
Condition is good by Engine Coolant Temperature(°C)

```

Figure 5. Detiled diagnostics information about condition of the car

Thus we see that all the car parameters are in good condition, except for Intake Air Temperature. This parameter is in normal condition.

4) Prediction mode. The system display detailed (just detailed) information about predicted condition of the car.

The result will look very similar to the diagnosed information:

```

Condition is good by Air Fuel Ratio(Commanded)<:1)
Condition is good by Engine Coolant Temperature(°C)
Condition is good Engine Load(%)
Condition is normal by Fuel trim bank 1 sensor 1
Condition is good by Fuel Trim Bank 1 Short Term(%)
Condition is good by Intake Air Temperature(°C)
Condition is normal by Intake Air Temperature(°C)
Condition is good by Intake Manifold Pressure(psi)
Condition is good by Kilometers Per Litre
Condition is good by O2 Volts Bank 1 sensor 1(U)
Condition is good by O2 Volts Bank 1 sensor 2(U)
Condition is good by Voltage (Control Module)

```

Figure 6. Predicted information

According to predicted information we see, that all the car parameters are in good condition, except for Intake Air Temperature and Fuel Trim Bank 1 Sensor 1. These parameters are in normal condition. Parameter Fuel Trim Bank 1 Sensor 1 has a good condition in diagnostic (current condition), but according to predicted information this parameter may be out from operating range, that possible indicates incipient faults.

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