Application Note: Application of KEEL in a distributed diagnostic application in an automobile (09/04/2003)

Objective:

Today's automobiles are becoming very complex. They are no longer simply mechanical structures that use an electrical spark to ignite the gasoline. They are now complex networks of microprocessor controlled devices.

Historically the failure of purely mechanical systems has been relatively easy to detect, and the failure modes have been easily identified. Diagnostic tools were able to isolate the problems. A skilled technician could keep up with changes in technology and could troubleshoot problems with relative ease.

Now, however, the symptoms of failure can be indirect. They can be combinations of failed subsystems, sensors, networks or, as before, some mechanical systems. Now, for optimal performance, sensors throughout the car cause the car to adapt to its environment.

In addition to performance, the automobile is attempting to maintain passenger comfort and provide entertainment while driving.

The automobile is also becoming a place to do business. Not just hauling, but electronic business where the car has integrated business functions.

As automobile companies move to become total system suppliers, they are offering more than just transportation; they are offering constant connectivity with technologies like GPS, integrated telephony and satellite communications. Eventually it will include continuous internet connectivity, tracking and security systems.

At the lowest level, where microprocessors are integrated into the system, they now have the ability to incorporate KEEL technology. Therefore those same microprocessors can begin to take a more active role in the diagnostics process. Subjective decisions can be made about whether to shut down the car (now desirable), to warn the driver (immediately or at optimal times), to record values for the service technician, to record environmental conditions, to synthesize information to keep the car running...

In many of these systems, the sensors will be distributed across several subsystems. Diagnostic evaluations will incorporate elements from each of the subsystems where the data will be networked throughout the car. KEEL technology is architecture independent. Like the human brain that accepts distributed sensors, an automobile will contain multiple "brains", each accepting inputs from distributed sensors and from other "brains" (KEEL engines).

In some cases, diagnostic decisions will include information collected externally from the vehicle. This information could come from the operator, from a service attendant, or from other external equipment or databases.

The car could adapt to the weather forecast, or published changes in gasoline additives. It could adapt to information gathered by the manufacturer through a system like OnStar, or on-board network connectivity.

Because KEEL technology is architecture independent, there is no limit to where the KEEL based diagnostics are executed.

They could be local to the car, where the car accumulates information from distributed microprocessors and sensors in the car, from the operator and service attendant, and from the manufacturer...

They could be executed at local service locations, where the information is collected from the cars and processed at the service location.

They could be executed at various data processing locations with the information collected from whatever the best source was and delivered to the car and or the service location.

Since KEEL just "thinks" and "makes subjective decisions", it just needs to get the information and perform its task.

KEEL engines will be interconnected by direct wire, RF, infrared, the internet, satellite, cellular telephone, and any other interconnection technology developed in the future.

Market:

The market for intelligent subassemblies in automobiles is astronomical. With the plan for drive-by-wire and brake-by-wire systems, there will be more and more microprocessors in the car. Advanced networks will link them together.

Without additional supporting technologies, these cars might spend their lives in service locations, with the only option available for their repair being the mechanic's ability to replace subassemblies in hopes of getting the car back on the road.

No one will be able to spend time troubleshooting the subassemblies because they are too complex.

The market will increase for real time service and support as cars are "always connected" or "periodically connected".

The ability to provide diagnostics on an as-needed basis will provide a better experience for the automobile owner.

IEEE Computer "In-vehicle Networks - Expanding Automotive Electronic Systems" 2002 Page 88 identified a number of services that will be integrated in next generation automobiles. These have been identified as KEEL applications.

Active seat belts - 1980
ABS - 1980
ETC - 1983
EBD - 1994
ESP - 1997
Underfloor concept - 1997

Automatic emergency call - 2000
BAS - 2000
ACC (Distronic) - 2000
ABC - 2002

These have been identified as KEEL applications for both control and diagnostic applications. Any situation where data can be interpreted in an expert fashion is a target application for KEEL technology.
Precrash action - 2003
Road recognition (LDW) - 2004
Environment recognition - 2007
SbW (wb) - 2008
Emergency Brakes - 2010
EMB & EMS - 2012
Platooning - 2015
Smart adaptive controls - 2015
Highway copilot - 2017
Collision avoidance - 2019
Autonomous driving - 2025

Considerations:

Discrete diagnostic solutions that can be added to most microprocessors will require that they reside in limited memory space. Even in distributed applications, space will be important.

If the system is to adapt to problems there will be a need to justify / explain the reasons for actions taken. This is true of discrete diagnostic solutions and distributed solutions.

In some cases the problem will be related to a design problem. To track down the design problem, it will be necessary to use explainable technology. This may exclude some of the conventional AI technologies.

Like Neural Nets.

The subassemblies will have to make judgmental decisions about the types of response to detected problems.

This could mean generating warning data. It could mean generating control adjustments. It could synthesize data; just to keep the car running.

In a distributed system, one KEEL engine might recommend an action by another KEEL engine. A dialog could take place between them to determine the best overall solution.

The system architect will be responsible for determining the hierarchy for KEEL decisions, just like a supervisor is responsible for organizing the decisions of a business.

In some cases it will have to explain the problem and actions taken to a service technician or to a higher level controller.

In distributed systems we are dealing with a distributed command and control system. Elements will operate independently when appropriate and will require confirmation for actions when that is appropriate.

It cannot take so long to develop the diagnostic that it slows down the delivery of the product to the market.

Because KEEL engines can operate independently, their deployment in a distributed system can be staged over time.

In many cases discrete KEEL engines will operate autonomously, but will accept commands / tuning from higher level command systems.

It must be non-intrusive and interrupt normal operation of the vehicle when it is in normal operating mode.

The system designer is responsible for architecting the distributed system. This is the case today in the automobile.

It will be possible to use KEEL engines to manage the diagnostic traffic.

It may be possible to put the car in diagnostic mode to assist in the problem isolation.

In a distributed system, portions of the car may be put in diagnostic mode while leaving other segments in normal operation.

In some architectural situations, where KEEL is running remotely, this may not be necessary.

It may be possible to re-allocate processing resources under certain circumstances.

This might allow more intensive diagnostics at certain times.

In some cases the car and the driver (potentially manufacturer) may jointly decide on a course of action. The driver could override the decision of the car.

The KEEL engines will pursue a diagnostic approach that is in line with the model created at the factory. This model may be tuned by the driver or potentially by the automobile manufacturer if remotely connected. The driver may accept some additional risk if a prognostic indicated a forthcoming problem and the vehicle. This could be a safety issue or some other emergency condition.

The chain of authority would be built into the KEEL design.

KEEL technology may not be appropriate for all solutions. It may, however, play a partner role.

In some cases Neural Nets may be deployed in diagnostic and prognostic roles. KEEL technology can be used to train Neural Nets. KEEL can quickly generate patterns that could be used for training.

Additionally, neural nets may process some inputs and feed KEEL to interpret how to respond to certain situations. In this case it may be an add-on.

Description:

For a distributed diagnostic solution in a vehicle, one or more KEEL engines will be used.

Each KEEL engine will be responsible for a separate evaluation of information.

In a distributed system, an overall architecture will be developed. The system design will determine where diagnostic processing will be performed and how and when information needed to perform the diagnostics will be collected. A loosely coupled solution will be used in highly distributed situations.

The outputs of the KEEL engine will be developed. These will be the triggers for external events, or control signals that cause the automobile to adjust its performance.

The inputs to the KEEL engine will be developed. These will be the sensors and other data sources (queues, localized databases, and potentially the operator of the automobile). Eventually it could include data from the automobile manufacturer.

The relationships between inputs and outputs and system variables will be developed.

Each KEEL engine will be tested within the KEEL toolkit before porting to the automobile or distributed test environments where it will undergo additional testing.

KEEL General:

This section identifies the needs that could be addressed with a KEEL based solution.

Human experts are required to interpret information to make the best decisions or take the most appropriate actions

Devices must operate autonomously and make judgmental decisions on their own

Devices can make control decisions when human operators are not present

Human experts may take too long to make judgmental decisions

Applications where the judgmental decisions must be explained

Complex situations where it is uneconomical to develop and maintain straight line code (IF, THEN, ELSE)

Situations where the environment is dynamic and the importance of information changes and the system must react to change

Situations where there is an advantage to be able to create one design and execute it on multiple platforms: device, software simulation, web

When the small memory footprint of a KEEL engine is an advantage

Where architectural issues may prohibit other solutions (KEEL technology is architecture independent: localized, distributed, web based, multiprocessor...)

Summary:

Deploying KEEL cognitive engines in each microprocessor in the automobile will allow the microprocessor to take corrective action on its own, to identify problem areas to the service technician, or to stop or control the car in safety situations.

Distributed KEEL engines will allow the judgmental decisions to be made locally AND remotely; whichever is most appropriate.

The use of KEEL engines in each microprocessor will be just like having an expert technician embedded into each microprocessor. Should the KEEL engines be deployed remotely, it will be like having access to the expert technician when needed.

Networks of microprocessors supported with KEEL engines will be able to communicate for the overall good of the automobile.

There will be several business models for handling distributed diagnostics. KEEL can support all of them, because KEEL engines do not care where they get their information.

In distributed systems the quality of the data will be very important. The quality of data is external to the KEEL diagnostic engine, but could be "observed" with KEEL engines as part of a data integrity issue. There will also be security issues associated with what data is collected and how it is used.

Disclaimer

This application note suggests the potential for KEEL technology to respond to certain market needs. The end users are totally responsible for assuring that the technology performs as expected.

The application note may also assume that certain external technology exists to support the KEEL engine in an effective manner. This may or may not be accurate in all cases.

