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UNIT 2
ARCHITECTURAL STYLES & CASE STUDIES

ARCHITECTURAL STYLES

List of common architectural styles:

Dataflow systems:
- ✓ Batch sequential
- ✓ Pipes and filters

Call-and-return systems:
- ✓ Main program and subroutine
- ✓ OO systems
- ✓ Hierarchical layers.

Independent components:
- ✓ Communicating processes
- ✓ Event systems

Virtual machines:
- ✓ Interpreters
- ✓ Rule-based systems

Data-centered systems:
- ✓ Databases
- ✓ Hypertext systems
- ✓ Blackboards.

PIPES AND FILTERS

- Each components has set of inputs and set of outputs
- A component reads streams of data on its input and produces streams of data on its output.
- By applying local transformation to the input streams and computing incrementally, so that output begins before input is consumed. Hence, components are termed as filters.
- Connectors of this style serve as conducts for the streams transmitting outputs of one filter to inputs of another. Hence, connectors are termed pipes.

Conditions (invariants) of this style are:

- Filters must be independent entities.
- They should not share state with other filter
- Filters do not know the identity of their upstream and downstream filters.
- Specification might restrict what appears on input pipes and the result that appears on the output pipes.
- Correctness of the output of a pipe-and-filter network should not depend on the order in which filter perform their processing.

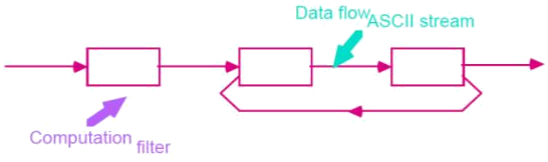


Figure 1: Pipes and Filters

Common specialization of this style includes :

- *Pipelines:*
  Restrict the topologies to linear sequences of filters.
- *Bounded pipes:*
  Restrict the amount of data that can reside on pipe.
- *Typed pipes:*
  Requires that the data passed between two filters have a well-defined type.

Batch sequential system:

A degenerate case of a pipeline architecture occurs when each filter processes all of its input data as a single entity. In these systems pipes no longer serve the function of providing a stream of data and are largely vestigial.

Example 1:

Best known example of pipe-and-filter architecture are programs written in UNIX-SHELL. Unix supports this style by providing a notation for connecting components [Unix process] and by providing run-time mechanisms for implementing pipes.

Example 2:

Traditionally compilers have been viewed as pipeline systems. Stages in the pipeline include lexical analysis parsing, semantic analysis and code generation other examples of this type are.

- Signal processing domains
- Parallel processing
- Functional processing
- Distributed systems.

Advantages:

- They allow the designer to understand the overall input/output behavior of a system as a simple composition of the behavior of the individual filters.
- They support reuse: Any two filters can be hooked together if they agree on data.
- Systems are easy to maintain and enhance: New filters can be added to exciting systems.
- They permit certain kinds of specialized analysis eg: deadlock, throughput
- They support concurrent execution.

Disadvantages:

- They lead to a batch organization of processing.
- Filters are independent even though they process data incrementally.
- Not good at handling interactive applications
  - ✓ When incremental display updates are required.
  - ✓ They may be hampered by having to maintain correspondences between two separate but related streams.
  - ✓ Lowest common denominator on data transmission.

This can lead to both loss of performance and to increased complexity in writing the filters.

OBJECT-ORIENTED AND DATA ABSTRACTION

In this approach, data representation and their associated primitive operations are encapsulated in the abstract data type (ADT) or object. The components of this style are- objects/ADT's objects interact through function and procedure invocations.

Two important aspects of this style are:

- ♥ Object is responsible for preserving the integrity of its representation.
- ♥ Representation is hidden from other objects.

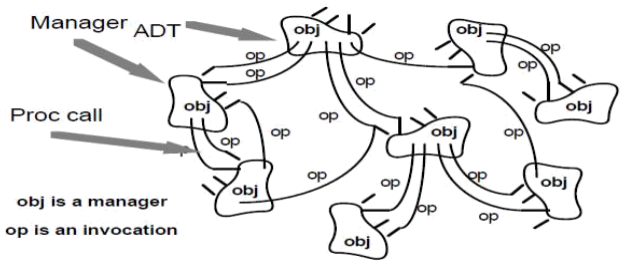


Figure 2: Abstract Data Types and Objects

Advantages

- ✓ It is possible to change the implementation without affecting the clients because an object hides its representation from clients.

- ✓ The bundling of a set of accessing routines with the data they manipulate allows designers to decompose problems into collections of interacting agents.

Disadvantages

- ✓ To call a procedure, it must know the identity of the other object.
- ✓ Whenever the identity of object changes it is necessary to modify all other objects that explicitly invoke it.

EVENT-BASED, IMPLICIT INVOCATION

- ✓ Instead of invoking the procedure directly a component can announce one or more events.
- ✓ Other components in the system can register an interest in an event by associating a procedure to it.
- ✓ When the event is announced, the system itself invokes all of the procedure that have been registered for the event. Thus an event announcement "implicitly" causes the invocation of procedures in other modules.
- ✓ Architecturally speaking, the components in an implicit invocation style are modules whose interface provides both a collection of procedures and a set of events.

Advantages:

- ✓ *It provides strong support for reuse*
  Any component can be introduced into the system simply by registering it for the events of that system.
- ✓ *Implicit invocation eases system evolution.*
  Components may be replaced by other components without affecting the interfaces of other components.

Disadvantages:

- ✓ Components relinquish control over the computation performed by the system.
- ✓ Concerns change of data
  Global performance and resource management can become artificial issues.

LAYERED SYSTEMS:

- ✓ A layered system is organized hierarchically
- ✓ Each layer provides service to the layer above it.
- ✓ Inner layers are hidden from all except the adjacent layers.
- ✓ Connectors are defined by the protocols that determine how layers interact each other.
- ✓ Goal is to achieve qualities of modifiability portability.

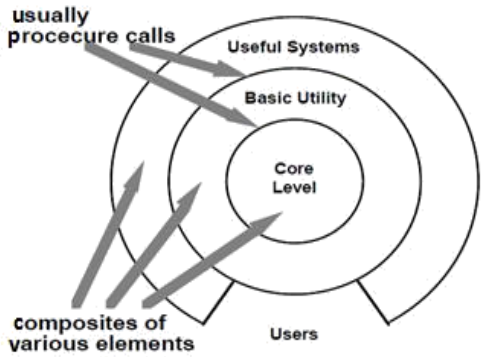


Figure 3: Layered Systems

Examples:

- ✓ Layered communication protocol
- ✓ Operating systems
- ✓ Database systems

Advantages:

- They support designs based on increasing levels abstraction.
- Allows implementers to partition a complex problem into a sequence of incremental steps.
- They support enhancement
- They support reuse.

Disadvantages:

- Not easily all systems can be structures in a layered fashion.

- Performance may require closer coupling between logically high-level functions and their lower-level implementations.
- Difficulty to mapping existing protocols into the ISO framework as many of those protocols bridge several layers.
  Layer bridging: functions is one layer may talk to other than its immediate neighbor.

REPOSITORIES: [data cantered architecture]

- ✓ Goal of achieving the quality of integrability of data.
- ✓ In this style, there are two kinds of components.
  i. Central data structure- represents current state.
  ii. Collection of independent components which operate on central data store. The choice of a control discipline leads to two major sub categories.
  - ♣ Type of transactions is an input stream trigger selection of process to execute
  - ♣ Current state of the central data structure is the main trigger for selecting processes to execute.
    - Active repository such as blackboard.

Blackboard:

Three major parts:

- **Knowledge sources:**
  Separate, independent parcels of application – dependents knowledge.
- **Blackboard data structure:**
  Problem solving state data, organized into an application-dependent hierarchy
- **Control:**
  Driven entirely by the state of blackboard

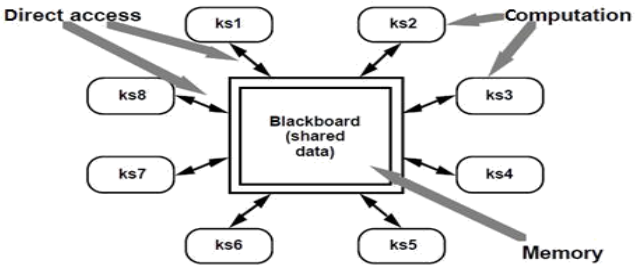


Figure 4: The Blackboard

- ✓ Invocation of a knowledge source (ks) is triggered by the state of blackboard.
- ✓ The actual focus of control can be in
  - knowledge source
  - blackboard
  - Separate module or
  - combination of these

Blackboard systems have traditionally been used for application requiring complex interpretation of signal processing like speech recognition, pattern recognition.

INTERPRETERS

- ✓ An interpreter includes pseudo program being interpreted and interpretation engine.
- ✓ Pseudo program includes the program and activation record.
- ✓ Interpretation engine includes both definition of interpreter and current state of its execution.

1. Interpretation engine: to do the work
2. Memory: that contains pseudo code to be interpreted.
3. Representation of control state of interpretation engine
4. Representation of control state of the program being simulated.
   Ex: JVM or "virtual Pascal machine"

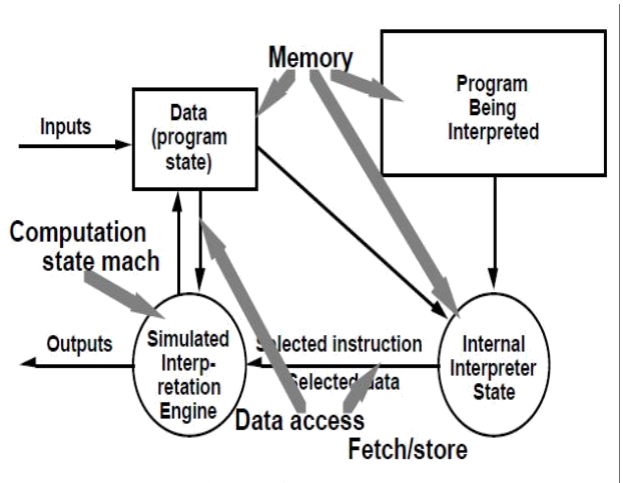


Figure 5: Interpreter

Advantages:
Executing program via interpreters adds flexibility through the ability to interrupt and query the program

Disadvantages:
Performance cost because of additional computational involved

PROCESS CONTROL

PROCESS CONTROL PARADIGMS

Useful definitions:

Process variables → properties of the process that can be measured

Controlled variable → process variable whose value of the system is intended to control

Input variable → process variable that measures an input to the process

Manipulated variable → process variable whose value can be changed by the controller

Set point → the desired value for a controlled variable

Open-loop system → system in which information about process variables is not used to adjust the system

Closed-loop system → system in which information about process variables is used to manipulate a process variable to compensate for variations in process variables and operating conditions

Feedback control system → the controlled variable is measured and the result is used to manipulate one or more of the process variables

Feed forward control system → some of the process variables are measured, and anticipated disturbances are compensated without waiting for changes in the controlled variable to be visible.

The open-loop assumptions are rarely valid for physical processes in the real world. More often, properties such as temperature, pressure and flow rates are monitored, and their values are used to control the process by changing the settings of apparatus such as valve, heaters and chillers. Such systems are called *closed loop systems.*

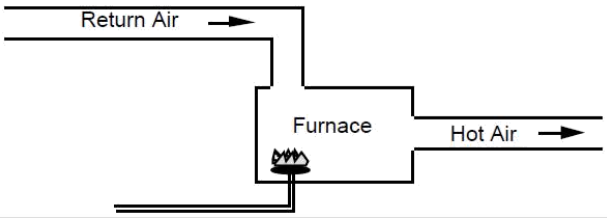


Figure 2.8 open-loop temperature control

A home thermostat is a common example; the air temperature at the thermostat is measured, and the furnace is turned on and off as necessary to maintain the desired temperature. Figure 2.9 shows the addition of a thermostat to convert figure 2.8 to a closed loop system.

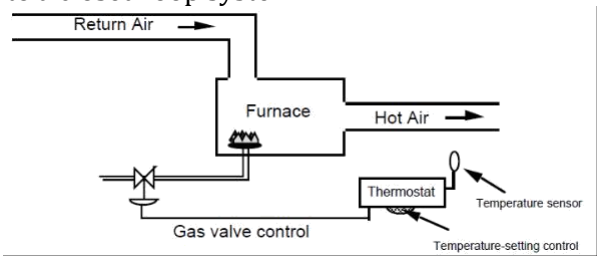


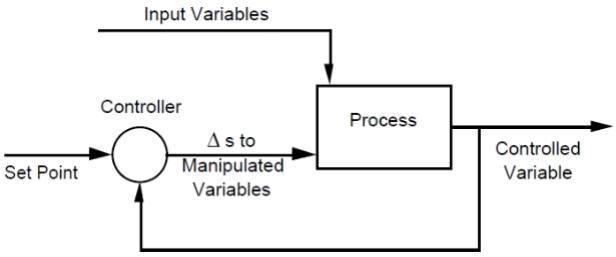
Figure 2.9 closed-loop temperature control

Feedback control:
Figure 2.9 corresponds to figure 2.10 as follows:

- The furnace with burner is the process
- The thermostat is the controller
- The return air temperature is the input variable
- The hot air temperature is the controlled variable

- The thermostat setting is the set point
- Temperature sensor is the sensor

Figure 2.10 feedback control



Feedforward control:

It anticipates future effects on the controlled variable by measuring other process variables and adjusts the process based on these variables. The important components of a feedforward controller are essentially the same as for a feedback controller except that the sensor(s) obtain values of input or intermediate variables.

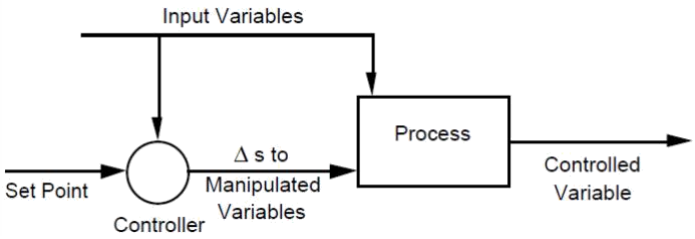


Figure 2.11 feedforward control

- These are simplified models
- They do not deal with complexities - properties of sensors, transmission delays & calibration issues
- They ignore the response characteristics of the system, such as gain, lag and hysteresis.
- They don't show how combined feedforward and feedback
- They don't show how to manipulate process variables.

A SOFTWARE PARADIGM FOR PROCESS CONTROL

An architectural style for software that controls continuous processes can be based on the process-control model, incorporating the essential parts of a process-control loop:

- **Computational elements**: separate the process of interest from the controlled policy
  - *Process definition*, including mechanisms for manipulating some process variables
  - *Control algorithm*, for deciding how to manipulate variables
- **Data element**: continuously updated process variables and sensors that collect them
  - *Process variables*, including designed input, controlled and manipulated variables and knowledge of which can be sensed
  - *Set point*, or reference value for controlled variable
  - *Sensors* to obtain values of process variables pertinent to control
- **The control loop paradigm**: establishes the relation that the control algorithm exercises.

OTHER FAMILIAR ARCHITECTURES

- **Distributed processes:** Distributed systems have developed a number of common organizations for multi-process systems. Some can be characterized primarily by their topological features, such as ring and star organizations. Others are better characterized in terms of the kinds of inter-process protocols that are used for communication (e.g., heartbeat algorithms).
- **Main program/subroutine organizations:** The primary organization of many systems mirrors the programming language in which the system is written. For languages without support for modularization this often results in a system organized around a main program and a set of subroutines.
- **Domain-specific software architectures:** These architectures provide an organizational structure tailored to a family of applications, such as avionics, command and control, or vehicle management

systems. By specializing the architecture to the domain, it is possible to increase the descriptive power of structures.

★ **State transition systems:** These systems are defined in terms a set of states and a set of named transitions that move a system from one state to another.

HETEROGENEOUS ARCHITECTURES

Architectural styles can be combined in several ways:

- One way is through hierarchy. Example: UNIX pipeline
- Second way is to combine styles is to permit a single component to use a mixture of architectural connectors. Example: "active database"
- Third way is to combine styles is to completely elaborate one level of architectural description in a completely different architectural style. Example: case studies

CASE STUDIES

KEYWORD IN CONTEXT (KWIC)

This case study shows how different architectural solutions to the same problem provide different benefits.
Parnas proposed the following problems:

> ***KWIC index system accepts an ordered set of lines. Each line is an ordered set of words and each word is an ordered set of characters. Any line may be circularly shifted by repeated removing the first word and appending it at the end of the line. KWIC index system outputs a listing of all circular shifts of all lines in alphabetical order.***

Parnas used the problem to contrast different criteria for decomposing a system into modules.
He describes 2 solutions:

a) Based on functional decomposition with share access to data representation.
b) Based on decomposition that hides design decision.

From the point of view of Software Architecture, the problem is to illustrate the effect of changes on software design. He shows that different problem decomposition vary greatly in their ability to withstand design changes. The changes that are considered by parnas are:

1. **The changes in processing algorithm:**
   Eg: line shifting can be performed on each line as it is read from input device, on all lines after they are read or an demand when alphabetization requires a new set of shifted lines.
2. **Changes in data representation:**
   Eg: Lines, words, characters can be stored in different ways. Circular shifts can be stored explicitly or implicitly

Garlan, Kaiser and Notkin also use KWIC problem to illustrate modularization schemes based on implicit invocation. They considered the following.

3. **Enhancement to system function:**
   Modify the system to eliminate circular shift that starts with certain noise change the system to interactive.
4. **Performance:** Both space and time
5. **Reuse:**
   Extent to which components serve as reusable entities

Let's outline 4 architectural designs for KWIC system.

SOLUTION 1: MAIN PROGRAM/SUBROUTINE WITH SHARED DATA

- Decompose the problem according to 4 basic functions performed. ○ Input
  - Shift
  - Alphabetize
  - output
- These computational components are coordinated as subroutines by a main program that sequence through them in turn.
- Data is communicated between components through shared storage.
- Communication between computational component and shared data is constrained by read-write protocol.

Advantages:

- Allows data to be represented efficiently. Since, computation can share the same storage

Disadvantages:

- Change in data storage format will affect almost all of the modules.
- Changes in the overall processing algorithm and enhancement to system function are not easily accommodated.
- This decomposition is not particularly support reuse.

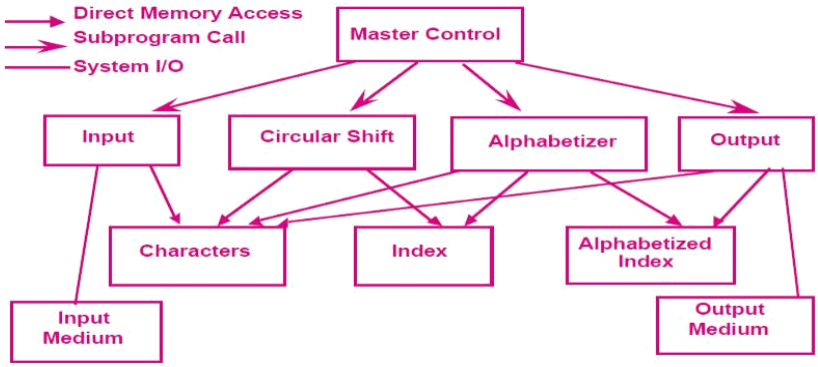


Figure 6: KWIC – Shared Data Solution

SOLUTION 2: ABSTRACT DATA TYPES

- Decomposes The System Into A Similar Set Of Five Modules.
- Data is no longer directly shared by the computational components.
- Each module provides an interface that permits other components to access data only by invoking procedures in that interface.

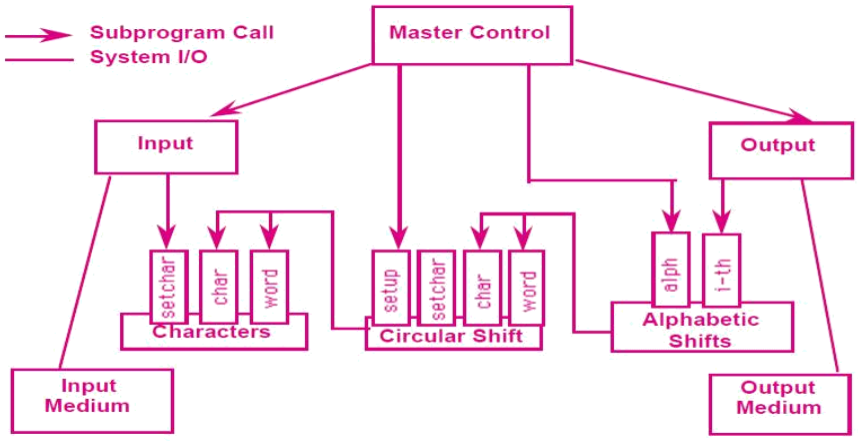


Figure 7: KWIC – Abstract Data Type Solution

Advantage:

- Both Algorithms and data representation can be changed in individual modules without affecting others.
- Reuse is better supported because modules make fewer assumption about the others with which they interact.

Disadvantage:

- Not well suited for functional enhancements
- To add new functions to the system
- To modify the existing modules.

SOLUTION 3: IMPLICIT INVOCATION

- Uses a form of component integration based on shared data
- Differs from 1st solution by these two factors
  - Interface to the data is abstract
  - Computations are invoked implicitly as data is modified. Interactions is based on an active data model.

Advantages:

- Supports functional enhancement to the system
- Supports reuse.

Disadvantages:

- Difficult to control the processing order.
- Because invocations are data driven, implementation of this kind of decomposition uses more space.

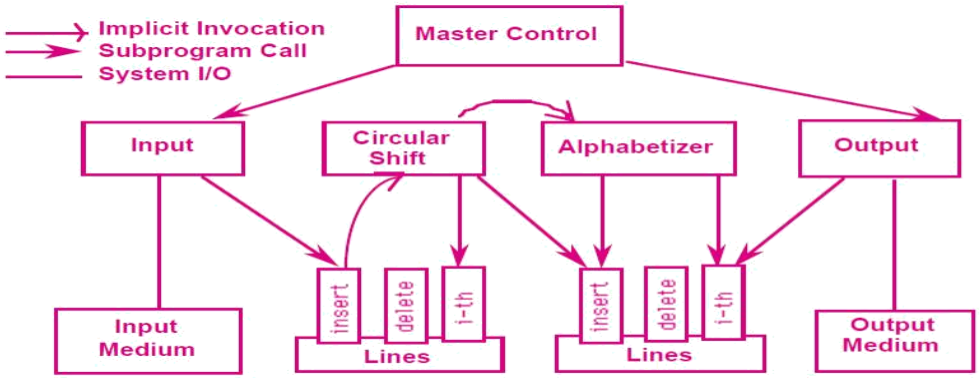


Figure 8: KWIC – Implicit Invocation Solution

SOLUTION 4: PIPES AND FILTERS:

- Four filters: Input, Output, Shift and alphabetize
- Each filter process the data and sends it to the next filter
- Control is distributed
  - Each filter can run whenever it has data on which to compute.
- Data sharing between filters are strictly limited.

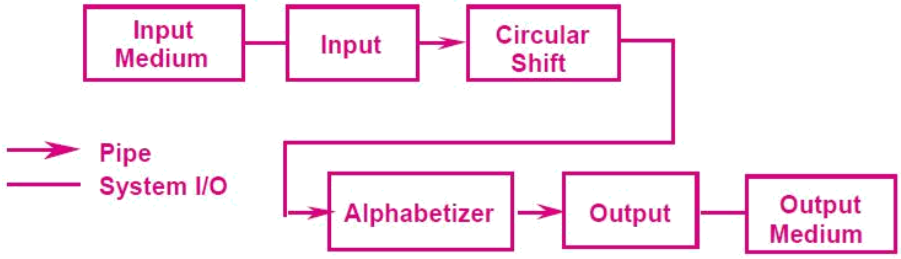


Figure 9: KWIC – Pipe and Filter Solution

Advantages:

- It maintains initiative flow of processing
- It supports reuse
- New functions can be easily added to the system by inserting filters at appropriate level.
- It is easy to modify.

Disadvantages:

- Impossible to modify the design to support an interactive system.
- Solution uses space inefficiently.

COMPARISONS

	Shared Memory	ADT	Events	Dataflow
Change in Algorithm	–	–	+	+
Change in Data Repn	–	+	–	–
Change in Function	+	–	+	+
Performance	+	+	–	–
Reuse	–	+	–	+

Figure 10: KWIC – Comparison of Solutions

INSTRUMENTATION SOFTWARE:

- Describes the industrial development of software architecture.
- The purpose of the project was to develop a reusable system architecture for oscilloscope
- Oscilloscope is an instrumentation system that samples electrical signals and displays pictures of them on screen.
- Oscilloscope also performs measurements on the signals and displays them on screen.
- Modern oscilloscope has to perform dozens of measurements supply megabytes of internal storage.
- Support an interface to a network of workstations and other instruments and provide sophisticated user interface, including touch panel screen with menus, built-in help facilities and color displays.
- Problems faced:
  - Little reuse across different oscilloscope products.
  - Performance problems were increasing because the software was not rapidly configurable within the instrument.
- Goal of the project was to develop an architectural framework for oscilloscope.
- Result of that was domain specific software architecture that formed the basis of the next generation of oscilloscopes.

SOLUTION 1: OBJECT ORIENTED MODEL

Different data types used in oscilloscope are:

- ✓ Waveforms
- ✓ Signals
- ✓ Measurements
- ✓ Trigger modes so on

There was no overall model that explained how the types fit together. This led to confusion about the partitioning of functionality. Ex: it is not clearly defined that measurements to be associated with types of data being measured or represented externally.

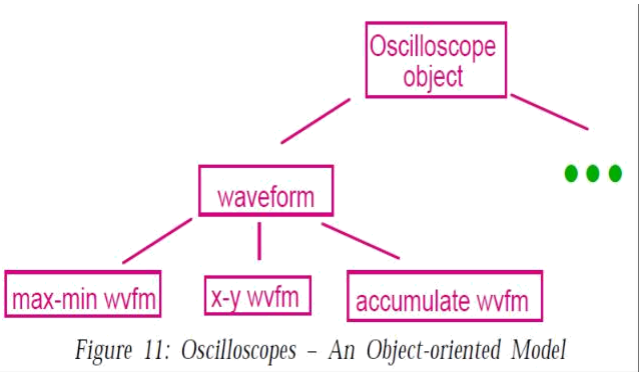


Figure 11: Oscilloscopes – An Object-oriented Model

SOLUTION 2: LAYERED MODEL

- To correct the problems by providing a layered model of an oscilloscope.
- Core-layer: implemented in hardware represents signal manipulation functions that filter signals as they enter the oscilloscope.
- Initially the layered model was appealing since it partitioned the functions of an oscilloscope into well defined groups.
- But, it was a wrong model for the application domain. Because, the problem was that the boundaries of abstraction enforced by the layers conflicted with the needs for interaction among various functions.

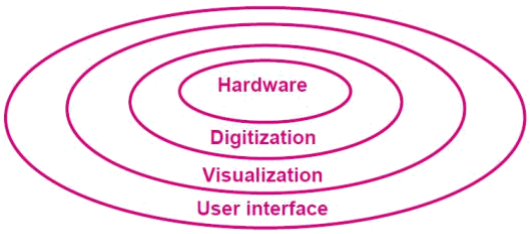


Figure 12: Oscilloscopes – A Layered Model

SOLUTION 3: PIPE-AND-FILTER MODEL:

- In this approach oscilloscope functions were viewed as incremental transformers of data.
  - Signal transformer: to condition external signal.
  - Acquisition transformer: to derive digitized waveforms
  - Display transformers: to convert waveforms into visual data.
- It is improvement over layered model as it did not isolate the functions in separate partition.
- Main problem with this model is that
  - It is not clear how the user should interact with it.

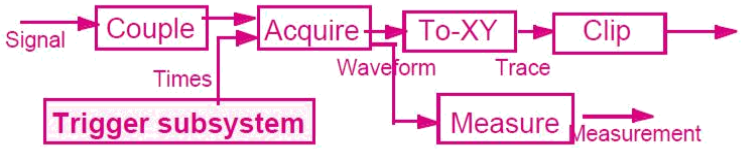


Figure 13: Oscilloscopes – A Pipe and Filter Model

SOLUTION 4: MODIFIED PIPE-AND-FILTER MODEL:

To overcome the above said problem, associate control interface with each filter that allowed external entity to set parameters of operation for the filter.
Introduction of control interface solves a large part of the user interface problem

- ✓ It provides collection of setting that determines what aspect of the oscilloscope can be modified dynamically by the user.
- ✓ It explains how user can change functions by incremental adjustments to the software.

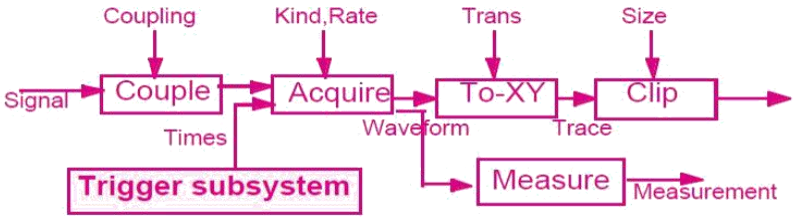


Figure 14: Oscilloscopes – A Modified Pipe and Filter Model

FURTHER SPECIALIZATION

The above described model is greater improvement over the past. But, the main problem with this is the performance.

a. *Because waveform occupy large amount of internal storage*
   It is not practical for each filter to copy waveforms every time they process them.
b. *Different filters run at different speeds*

It is unacceptable to slow one filter down because another filter is still processing its data.
To overcome the above discussed problems the model is further specialized.
Instead of using same kind of pipe. We use different "colors" of pipe. To allow data to be processed without copying, slow filters to ignore incoming data.
These additional pipes increased the stylistic vocabulary and allowed pipe/filter computations to be tailored more specifically to the performance needs of the product.

MOBILE ROBOTICS

- **Mobile Robotic systems**
  - Controls a manned or semi-manned vehicle ○ E.g., car, space vehicle, etc
  - Used in space exploration missions
  - Hazardous waste disposal
  - Underwater exploration
- **The system is complex**
  - Real Time respond
  - input from various sensors
  - Controlling the motion and movement of robots
  - Planning its future path/move
- **Unpredictability of environment**
  - Obstacles blocking robot path
  - Sensor may be imperfect
  - Power consumption
  - Respond to hazardous material and situations

DESIGN CONSIDERATIONS

- **REQ1:** Supports deliberate and reactive behavior. Robot must coordinate the actions to accomplish its mission and reactions to unexpected situations
- **REQ2:** Allows uncertainty and unpredictability of environment. The situations are not fully defined and/or predicable. The design should handle incomplete and unreliable information
- **REQ3:** System must consider possible dangerous operations by Robot and environment
- **REQ4:** The system must give the designer flexibility (mission's change/requirement changes)

SOLUTION 1: CONTROL LOOP

- **Req1:** an advantage of the closed loop paradigm is its simplicity → it captures the basic interaction between the robot and the outside.
- **Req2:** control loop paradigm is biased towards one method → reducing the unknowns through iteration
- **Req3:** fault tolerance and safety are supported which makes duplication easy and reduces the chances of errors
- **Req4:** the major components of a robot architecture are separated from each other and can be replaced independently

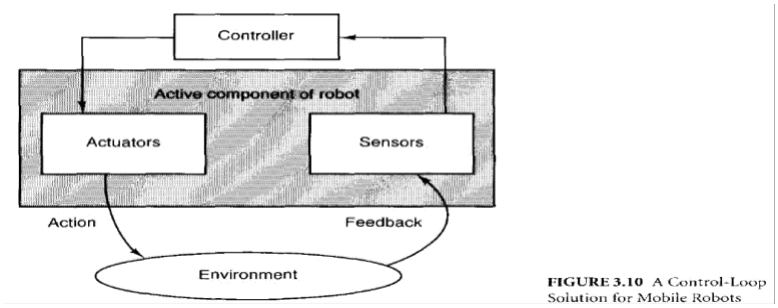
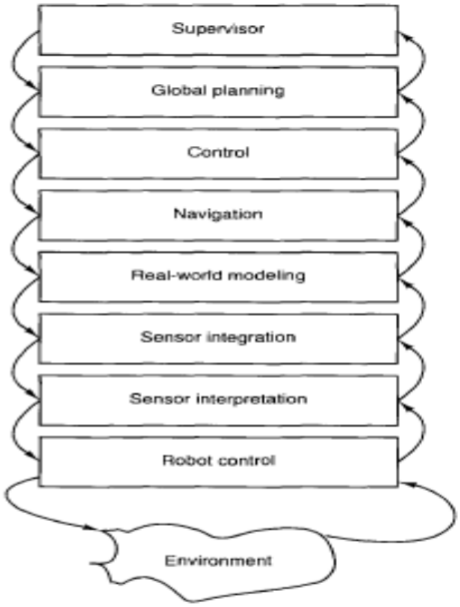


FIGURE 3.10 A Control-Loop Solution for Mobile Robots

SOLUTION 2: LAYERED ARCHITECTURE

Figure shows Alberto Elfes's definition of the layered architecture.
⊕ Level 1 (core) control routines (motors, joints,..),
⊕ Level 2-3 real world I/P (sensor interpretation and integration (analysis of combined I/Ps)
⊕ Level 4 maintains the real world model for robot
⊕ Level 5 manage navigation
⊕ Level 6-7 Schedule & plan robot actions (including exception handling and re-planning)
⊕ Top level deals with UI and overall supervisory functions



- **Req1:** it overcomes the limitations of control loop and it defines abstraction levels to guide the design
- **Req2:** uncertainty is managed by abstraction layers
- **Req3:** fault tolerance and passive safety are also served
- **Req4:** the interlayer dependencies are an obstacle to easy replacement and addition of components.

SOLUTION 3: IMPLICIT INVOCATION

The third solution is based on the form of implicit invocation, as embodied in the Task-Control-Architecture (TCA). The TCA design is based on hierarchies of tasks or task trees

- Parent tasks initiate child task
- Temporal dependencies between pairs of tasks can be defined
  - A must complete A must complete before B starts (selective concurrency)
- Allows dynamic reconfiguration of task tree at run time in response to sudden change(robot and environment)
- Uses implicit invocation to coordinate tasks
  - Tasks communicate using multicasting message (message server) to tasks that are registered for these events

TCA's implicit invocation mechanisms support three functions:

- **Exceptions:** Certain conditions cause the execution of an associated exception handling routines
  - i.e., exception override the currently executing task in the sub-tree (e.g., abort or retry) tasks
- **Wiretapping:** Message can be intercepted by tasks superimposed on an existing task tree
  - E.g., a safety-check component utilizes this to validate outgoing motion commands
- **Monitors**: Monitors read information and execute some action if the data satisfy certain condition
  - E.g. battery check

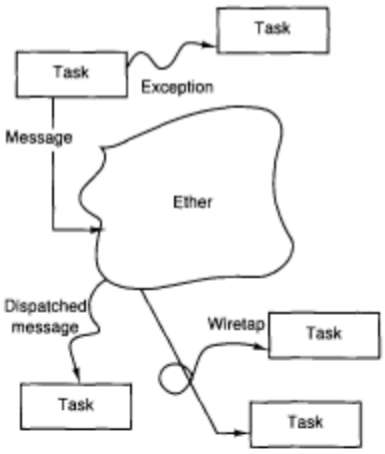


FIGURE 3.12 An Implicit Invocation Architecture for Mobile Robots

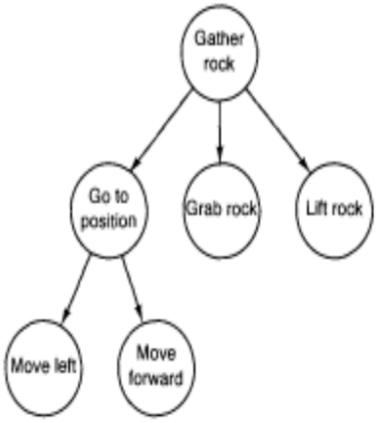


FIGURE 3.13 A Task Tree for Mobile Robo

- **Req1:** permits clear cut separation of action and reaction
- **Req2:** a tentative task tree can be built to handle uncertainty
- **Req3:** performance, safety and fault tolerance are served
- **Req4:** makes incremental development and replacement of components straight forward

SOLUTION 4: BLACKBOARD ARCHITECTURE

The components of CODGER are the following:

- Captain: overall supervisor
- Map navigator: high-level path planner
- Lookout: monitors environment for landmarks
- Pilot: low-level path planner and motor controller
- Perception subsystems: accept sensor input and integrate it into a coherent situation interpretation

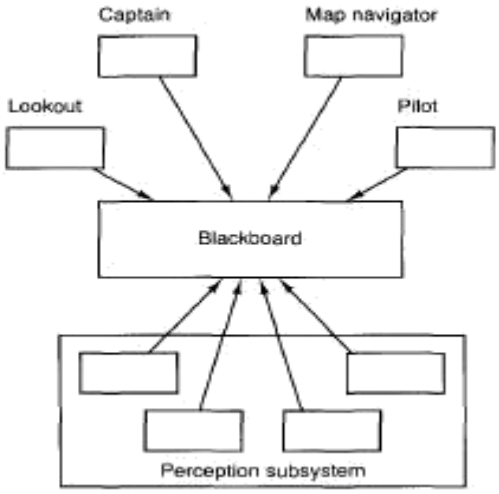


Figure: blackboard solution for mobile robots

The requirements are as follows:

- **Req1:** the components communicate via shared repository of the blackboard system.
- **Req2:** the blackboard is also the means for resolving conflicts or uncertainties in the robot's world view
- **Req3:** speed, safety and reliability is guaranteed
- **Req4:** supports concurrency and decouples senders from receivers, thus facilitating maintenance.

COMPARISONS

	Control Loop	Layers	Impl. Invoc.	Black Board
Task Coordination	+–	–	++	+
Dealing with Uncertainty	–	+–	+–	+
Fault Tolerance	+–	+–	++	+
Safety	+–	+–	++	+
Performance	+–	+–	++	+
Flexibility	+–	–	+	+

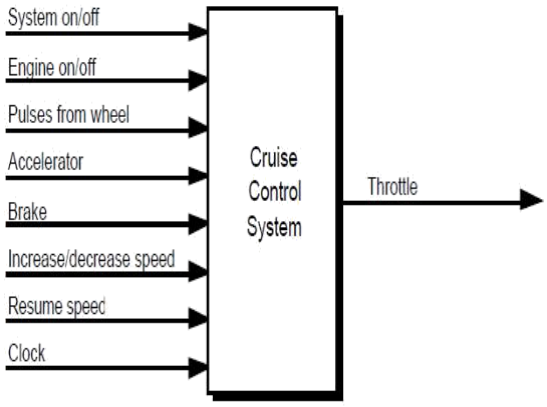
Table 2.2.1. Strengths and Weaknesses of Robot Architectures

CRUISE CONTROL

A cruise control (CC) system that exists to maintain the constant vehicle speed even over varying terrain.

Inputs:

System On/Off: If on, maintain speed
Engine On/Off: If on, engine is on. CC is active only in this state
Wheel Pulses: One pulse from every wheel revolution
Accelerator: Indication of how far accelerator is de-pressed
Brake: If on, temp revert cruise control to manual mode
Inc/Dec Speed: If on, increase/decrease maintained speed
Resume Speed: If on, resume last maintained speed
Clock: Timing pulses every millisecond



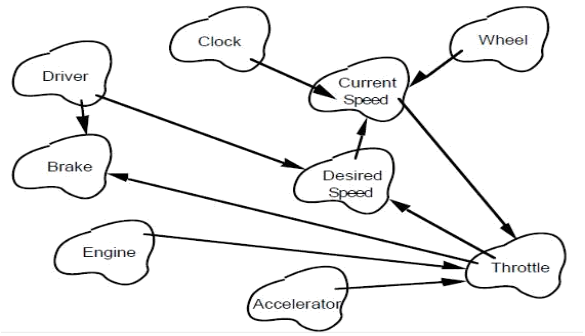
Outputs:

Throttle: Digital value for engine throttle setting

Restatement of Cruise-Control Problem

Whenever the system is active, determine the desired speed, and control the engine throttle setting to maintain that speed.

OBJECT VIEW OF CRUISE CONTROL



⊗ Each element corresponds to important quantities and physical entities in the system
⊗ Each blob represents objects
⊗ Each directed line represents dependencies among the objects

The figure corresponds to Booch's object oriented design for cruise control

PROCESS CONTROL VIEW OF CRUISE CONTROL

- **Computational Elements**
  - ✓ *Process definition* - take throttle setting as I/P & control vehicle speed
  - ✓ *Control algorithm* - current speed (wheel pulses) compared to desired speed ○ Change throttle setting accordingly presents the issue:
    - ○ decide how much to change setting for a given discrepancy
- **Data Elements**
  - ✓ *Controlled variable:* current speed of vehicle
  - ✓ *Manipulated variable:* throttle setting
  - ✓ *Set point:* set by accelerator and increase/decrease speed inputs
    - system on/off, engine on/off, brake and resume inputs also have a bearing
  - ✓ *Controlled variable sensor*: modelled on data from wheel pulses and clock

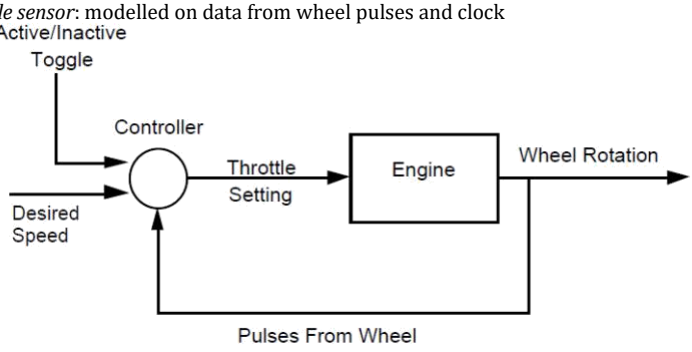


Figure 3.18 control architecture for cruise control

The active/inactive toggle is triggered by a variety of events, so a state transition design is natural. It's shown in Figure 3.19. The system is completely off whenever the engine is off. Otherwise there are three inactive and one active state.

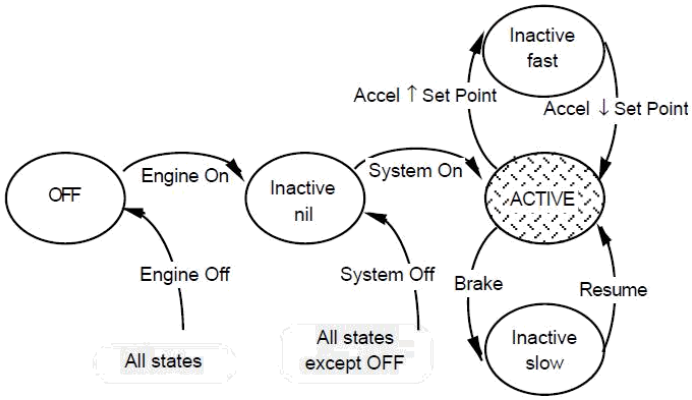


Figure 3.19 state machine for activation

Event	*Effect on desired speed*
Engine off, system off	Set to "undefined"
System on	Set to current speed as estimated from wheel pulses
Increase speed	Increment desired speed by constant
Decrease speed	Decrement desired speed by constant

We can now combine the control architecture, the state machine for activation, and the event table for determining the set point into an entire system.

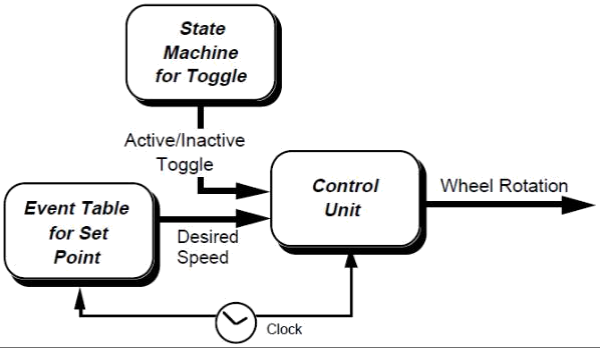


Figure 3.21 complete cruise control system

ANALYSIS AND DISCUSSION

[Interested students can refer text book since this has not been asked in exam till date]

THREE VIGNETTES IN MIXED STYLE

A LAYERED DESIGN WITH DIFFERENT STYLES FOR THE LAYERS

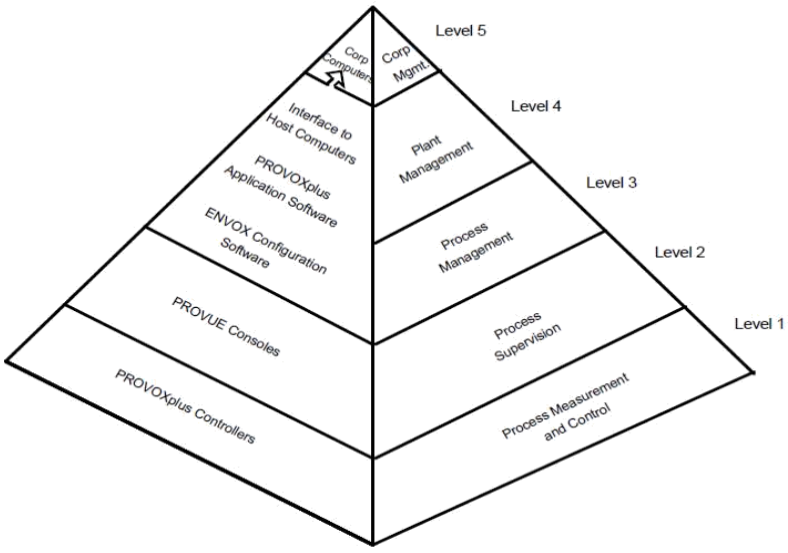


Figure 19: PROVOX – Hierarchical Top Level

Each level corresponds to a different process management function with its own decision-support requirements.

- **Level 1:** Process measurement and control: direct adjustment of final control elements.
- **Level 2:** Process supervision: operations console for monitoring and controlling Level 1.
- **Level 3:** Process management: computer-based plant automation, including management reports, optimization strategies, and guidance to operations console.

- **Levels 4 and 5:** Plant and corporate management: higher-level functions such as cost accounting, inventory control, and order processing/scheduling.

Figure 20 shows the canonical form of a point definition; seven specialized forms support the most common kinds of control. Points are, in essence, object-oriented design elements that encapsulate information about control points of the process. Data associated with a point includes: Operating parameters, including current process value, set point (target value), valve output, and mode (automatic or manual); Tuning parameters, such as gain, reset, derivative, and alarm trip-points; Configuration parameters, including tag (name) and I/O channels.

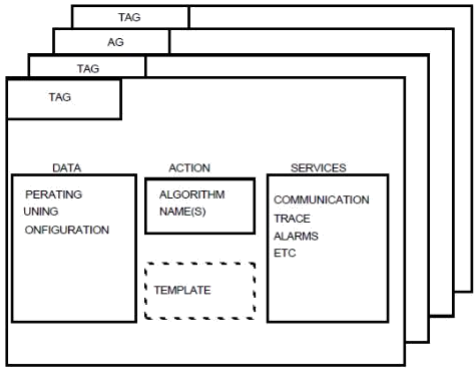


Figure 20: PROVOX – Object-oriented Elaboration

AN INTERPRETER USING DIFFERENT IDIOMS FOR THE COMPONENTS

Rule-based systems provide a means of codifying the problem-solving knowhow of human experts. These experts tend to capture problem-solving techniques as sets of situation-action rules whose execution or activation is sequenced in response to the conditions of the computation rather than by a predetermined scheme. Since these rules are not directly executable by available computers, systems for interpreting such rules must be provided. Hayes-Roth surveyed the architecture and operation of rule-based systems.

The basic features of a rule-based system, shown in Hayes-Roth's rendering as Figure 21, are essentially the features of a table-driven interpreter, as outlined earlier.

- The *pseudo-code* to be executed, in this case the knowledge base
- The *interpretation engine,* in this case the rule interpreter, the heart of the inference engine
- The *control state of the interpretation engine,* in this case the rule and data element selector
- The *current state of the program* running on the virtual machine, in this case the working memory.

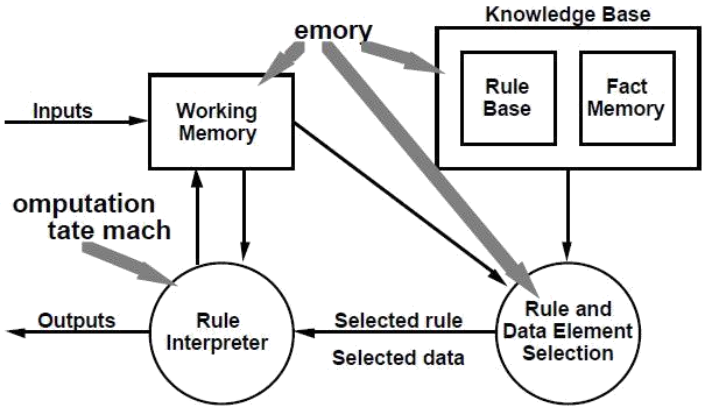


Figure 21: Basic Rule-Based System

Rule-based systems make heavy use of pattern matching and context (currently relevant rules). Adding special mechanisms for these facilities to the design leads to the more complicated view shown in Figure 22.

We see that:

- The knowledge base remains a relatively simple memory structure, merely gaining substructure to distinguish active from inactive contents.
- The rule interpreter is expanded with the interpreter idiom, with control procedures playing the role of the pseudo-code to be executed and the execution stack the role of the current program state.
- "Rule and data element selection" is implemented primarily as a pipeline that progressively transforms active rules and facts to prioritized activations.
- Working memory is not further elaborated.

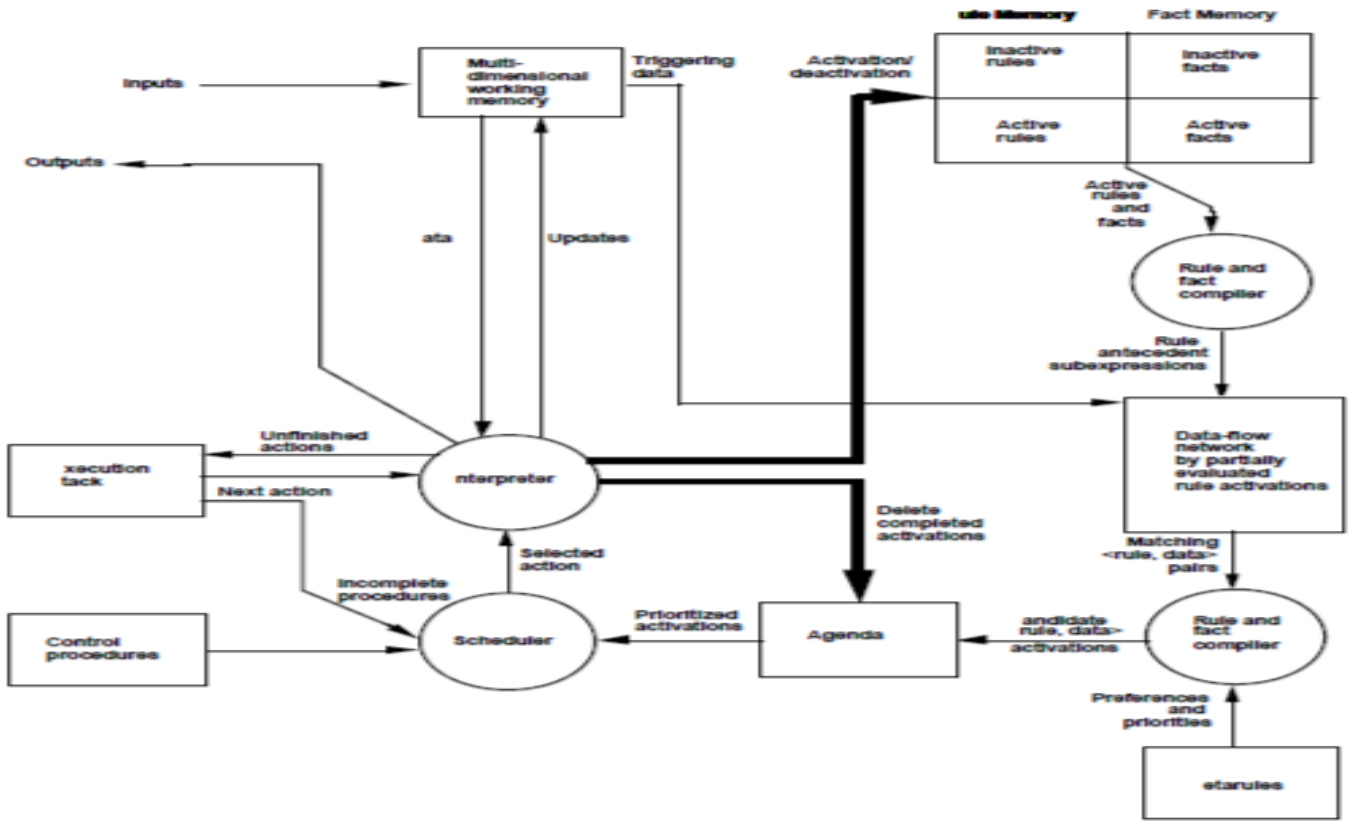


Figure 23: Sophisticated Rule-Based System

A BLACKBOARD GLOBALLY RECAST AS AN INTERPRETER

The blackboard model of problem solving is a highly structured special case of opportunistic problem solving. In this model, the solution space is organized into several application-dependent hierarchies and the domain knowledge is partitioned into independent modules of knowledge that operate on knowledge within and between levels. Figure 24 showed the basic architecture of a blackboard system and outlined its three major parts: knowledge sources, the blackboard data structure, and control.

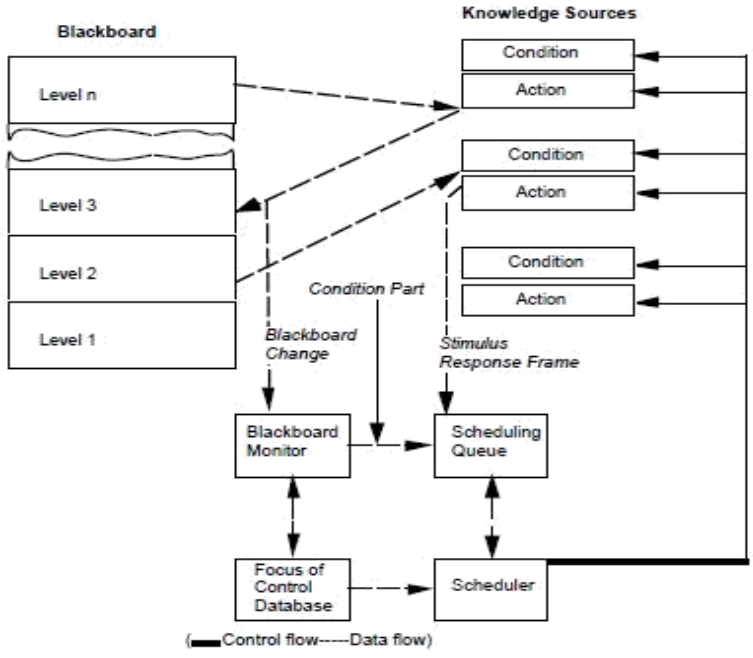


Figure 24: Hearsay-II

The first major blackboard system was the HEARSAY-II speech recognition system. Nii's schematic of the HEARSAY-II architecture appears as Figure 24. The blackboard structure is a six- to eight-level hierarchy in which each level abstracts information on its adjacent lower level and blackboard elements represent hypotheses about the interpretation of an utterance.

HEARSAY-II was implemented between 1971 and 1976; these machines were not directly capable of condition-triggered control, so it should not be surprising to find that an implementation provides the mechanisms of a virtual machine that realizes the implicit invocation semantics required by the blackboard model.

Interested students can refer text book for blackboard and interpreter view of HEARSAY II which is similar to above figure

UNIT 2 – QUESTION BANK

No.	QUESTION	YEAR	MARKS
1	Explain the architecture styles based on: (i)Data abstraction and object-oriented organization (ii)event-based, implicit invocation	Dec 09	10
2	What are the basic requirements for mobile robot architecture?	Dec 09	4
3	Explain the control loop solution for a mobile robot	Dec 09	6
4	Define architectural style. Mention any four commonly used styles	June 10	4
5	Consider the case study of building a software controlled mobile robot. Describe its challenging problems and design considerations with four requirements. Finally give the solution by layered architecture for all the four requirements.	June 10	16
6	Define the following with an example: i)controlled variable ii)set point iii)open loop system iv)feedback control system v)feed forward control system	Dec 10	10
7	State the problem of KWIC. Propose implicit invocation and pipes and filters style to implement a solution for the same	Dec 10	10
8	Discuss the importance and advantages of the following architectural styles with reference to an appropriate application area	June 11	8
9	List out the design considerations for mobile robotics case study. With the help of the design considerations, evaluate the pros and cons of the layered architecture and implicit invocation architecture for mobile robots	June 11	12
10	Discuss the invariants, advantages and disadvantages of pipes and filters architectural style	Dec 11	9
11	What are the basic requirements for a mobile robot's architecture? How the implicit invocation model handles them?	Dec 11	8
12	Write a note on heterogeneous architectures	Dec 11	3
13	Explain the process control paradigm with various process control definitions	June 12	6
14	List the basic requirements for mobile robot architecture	June 12	4
15	Explain the process control view of cruise control architectural style and obtain the complete cruise control system	June 12	10