CENG 523
Advanced Topics of Real-Time Systems

Lecture 1

Introduction to Real-TimeSystems

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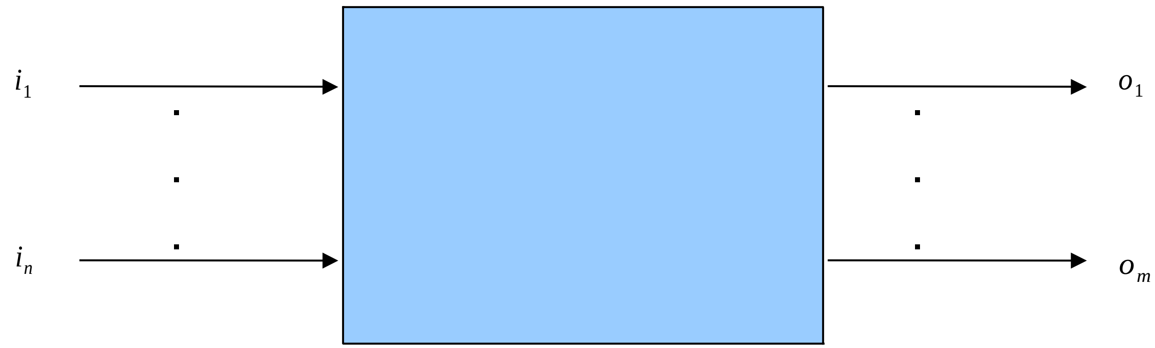
System

A system has a set of one or more inputs entering a black box and a set of one or more outputs exiting the black box.



System with *n* inputs and *m* outputs.

More formally:

$$Let\ i_1 \in I_1 \ldots i_n \in I_n, o_1 \in O_1 \ldots o_m \in O_{m.}$$

Then the system is a cross product of $I_{1.}..I_n \wedge O_{1.}..O_n$

$$S \subseteq I_1 \times \ldots \times I_n \times O_1 \times \ldots \times O_n$$

$$I_1 \times \ldots \times I_n\ are\ called\ input\ space. O_1 \times \ldots \times O_n\ are\ called\ output\ space.$$

Deterministic System

Definition.

A system is said to be deterministic if for each possible state, and each set of inputs, a unique set of outputs, response times and next state of the system can be determined.

Event determinism.

Next states and outputs of the system are known for each set of inputs which trigger events.

Temporal determinism.

The response time of each set of outputs is known.

Real-Time (1)

The Oxford dictionary of Computing offers this definition for real-time systems:

Any system in which the time at which the output is produced is significant. This is usually because the input corresponds to some movement in the physical world, and the output has to relate to that same movement. The lag from input time to output time must be sufficiently small for acceptable timeliness.

Real-Time system is defined as a system where the correctness of the system depends not only the result of computations but also on the time at which it is produced. Therefore the *time* is the most important item to be managed.

Definition in Laplante's book:

A real-time system is a system that must satisfy explicit (bounded) response-time constraints or risk severe consequences, including failure.

Real-Time (2)

It can be argued that
all practical systems are real-time!

Hard Real-Time

Systems where failure to meet system response time constraints leads to a system failure are called hard real-time systems.

Soft Real-Time:

Systems where performance is degraded but not destroyed by failure to meet system response time constraints.

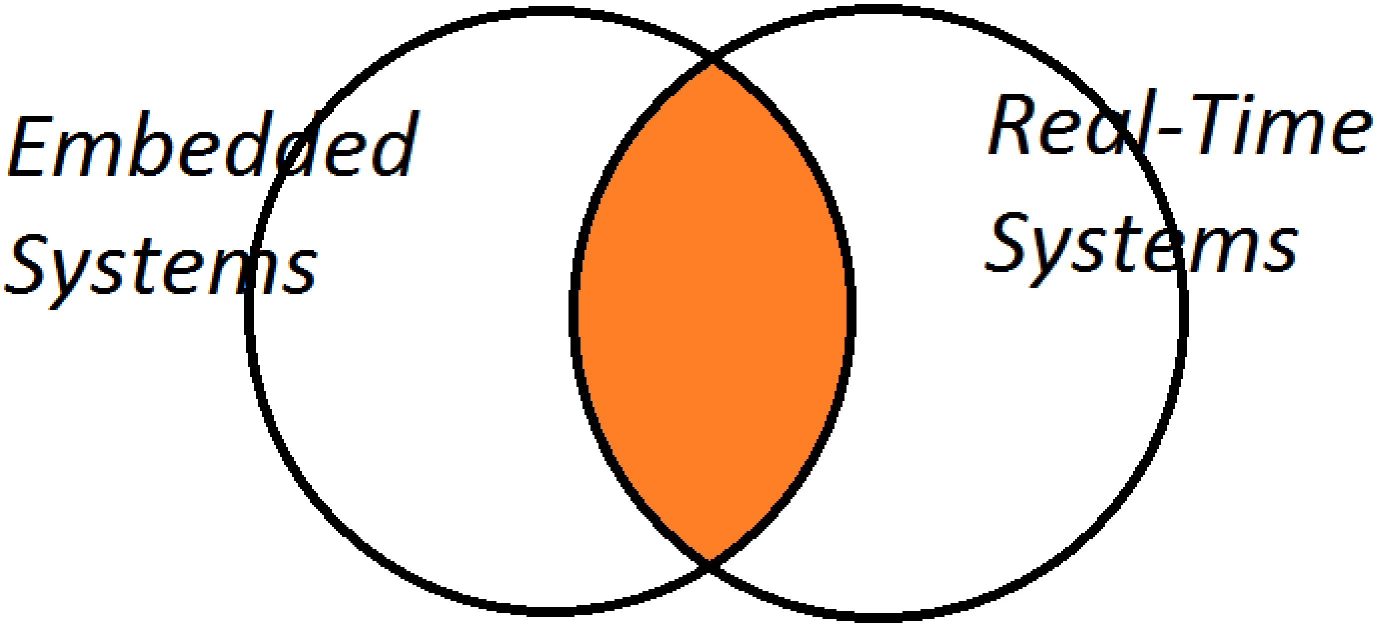
Firm Real-Time:

Systems with hard deadlines where some low probability of missing deadline can be tolerated.

A Sample of Hard, Soft and Firm RT Systems

	Real-Time Classification	Explanation
Automated teller machine	Soft	Missing even many deadlines will not lead to catastrophic failure, only degraded performance.
Embedded navigation controller for autonomous robot weed killer	Firm	Missing critical navigation deadlines causes the robot to veer hopelessly out of control and damage crops.
Avionics weapons delivery system in which pressing a button launches an air-to-air missile	Hard	Missing the deadline to launch the missile within a specified time after pressing the button can cause the target to be missed, which will result in catastrophe.

Real-Time System Embedded System



Main Characteristics of Real-Time Systems

- ***Determinism*** *in terms of time*
- ***Reliability***
- ***Dependability***

Common Terms

- *Dependability*: the property of a computing system which allows reliance to be placed on the service it delivers;
- *System failure*: occurs when the delivered service deviates from service stated by the specification;
- An *error* is that part of the system state which is liable to lead to failure;
- A *fault* is an adjudged cause of an error;
- An error is thus the manifestation of a fault in the system and a failure is the effect of an error on the service.

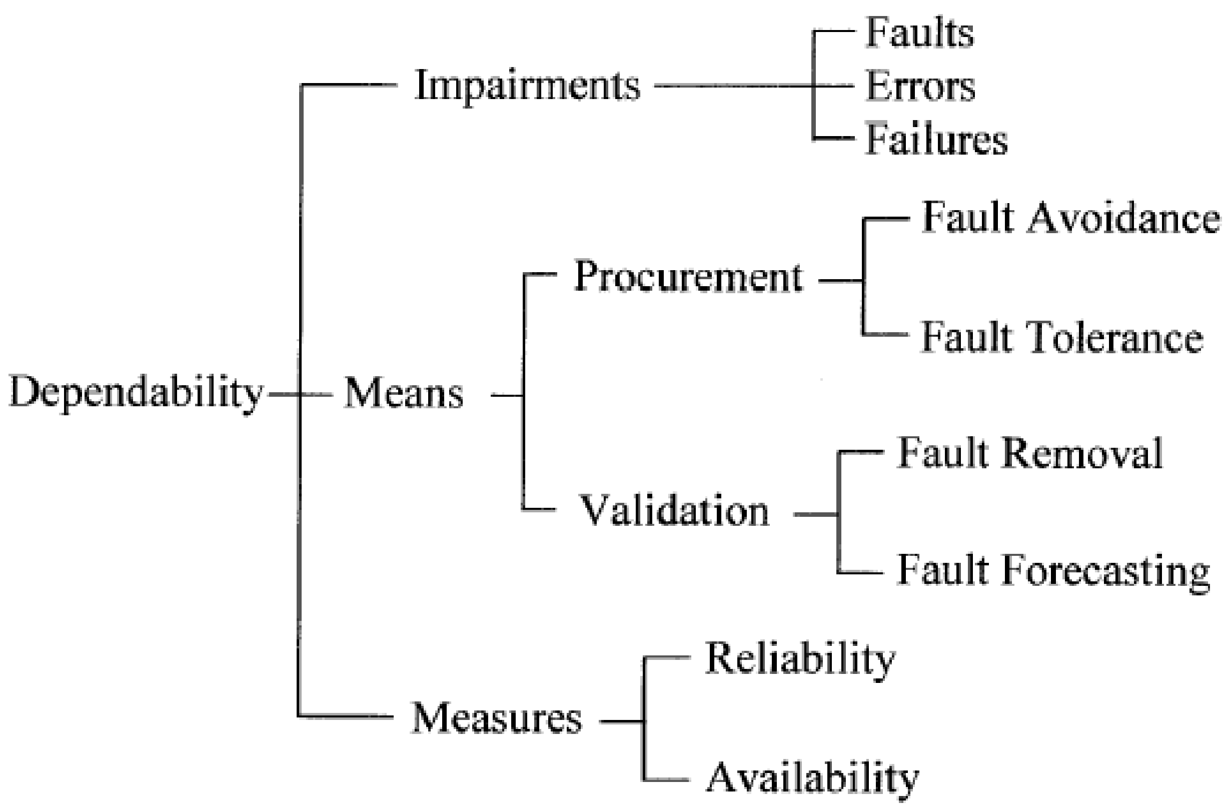
Fault Chain:
FAULT -> ERROR -> FAILURE -> FAULT -> ...

Common Terms

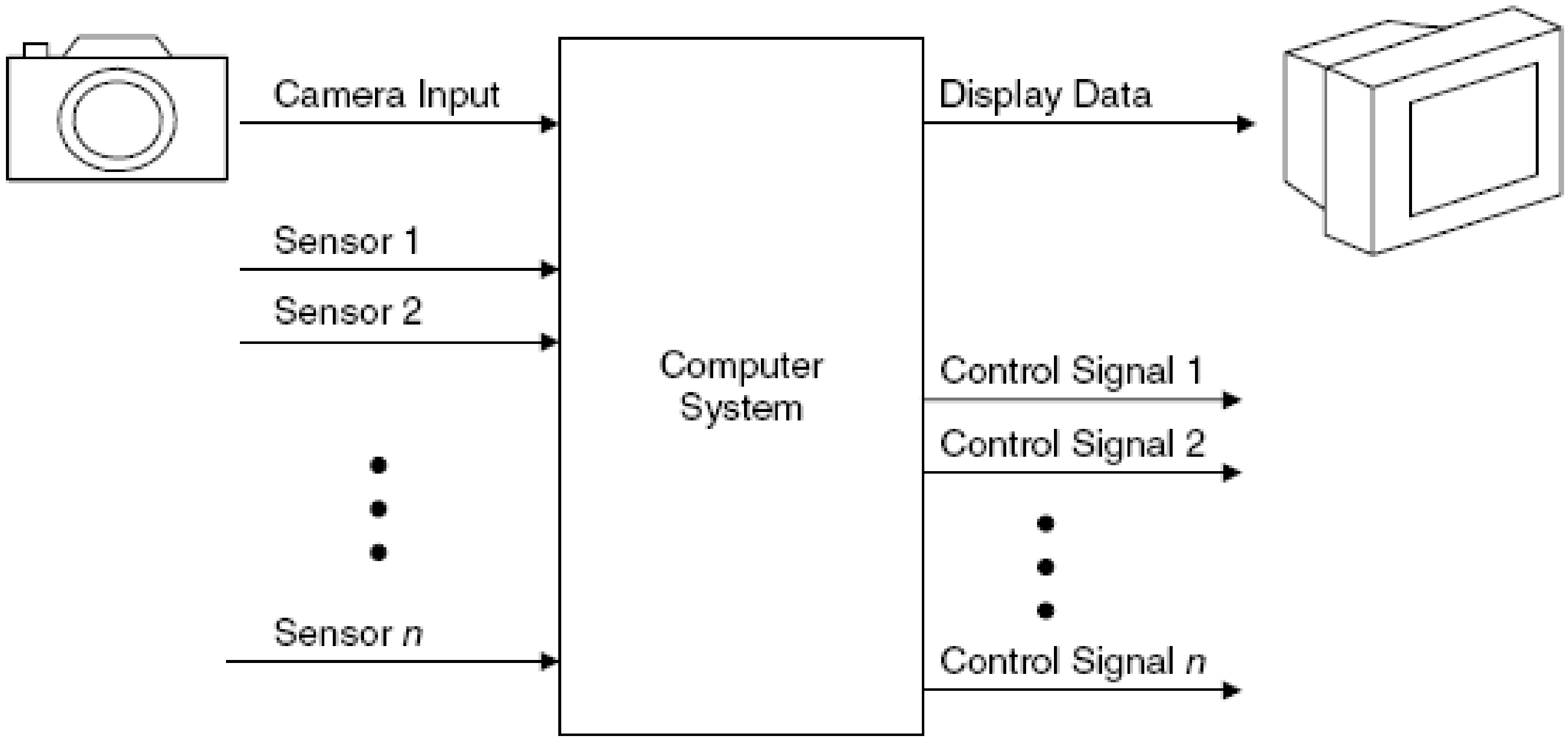
In order to achieve a dependable computing system, a number of diverse techniques can be used at various stages of the system design Probably the most successful method of achieving reliable systems is to use a combination of one or more of the following:

- ***Fault Avoidance***: how to prevent, by construction, fault occurrence or introduction;
- ***Fault Tolerance***: how to provide, by redundancy, a service complyingwith the specification in spite of faults;
- ***Fault Removal***: how to minimize, by verification, the presence of faults;
- ***Fault Forecasting***: how to estimate, by evaluation, the presence, the creation and the consequences of faults.

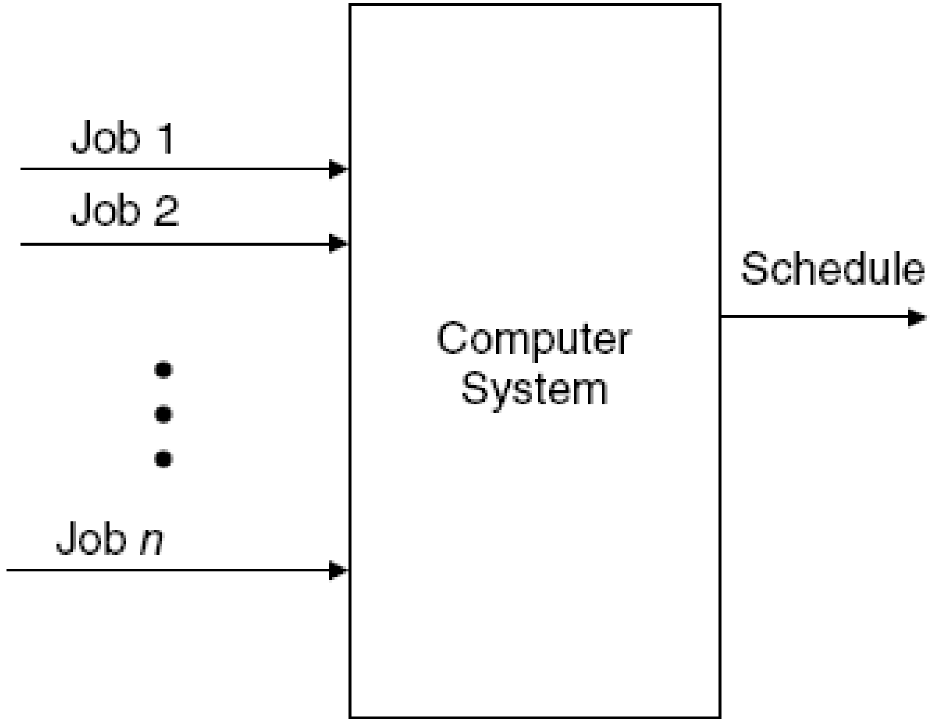
Relationship between Dependability and its Impairments, Means and Measures



Typical Real-Time Control System

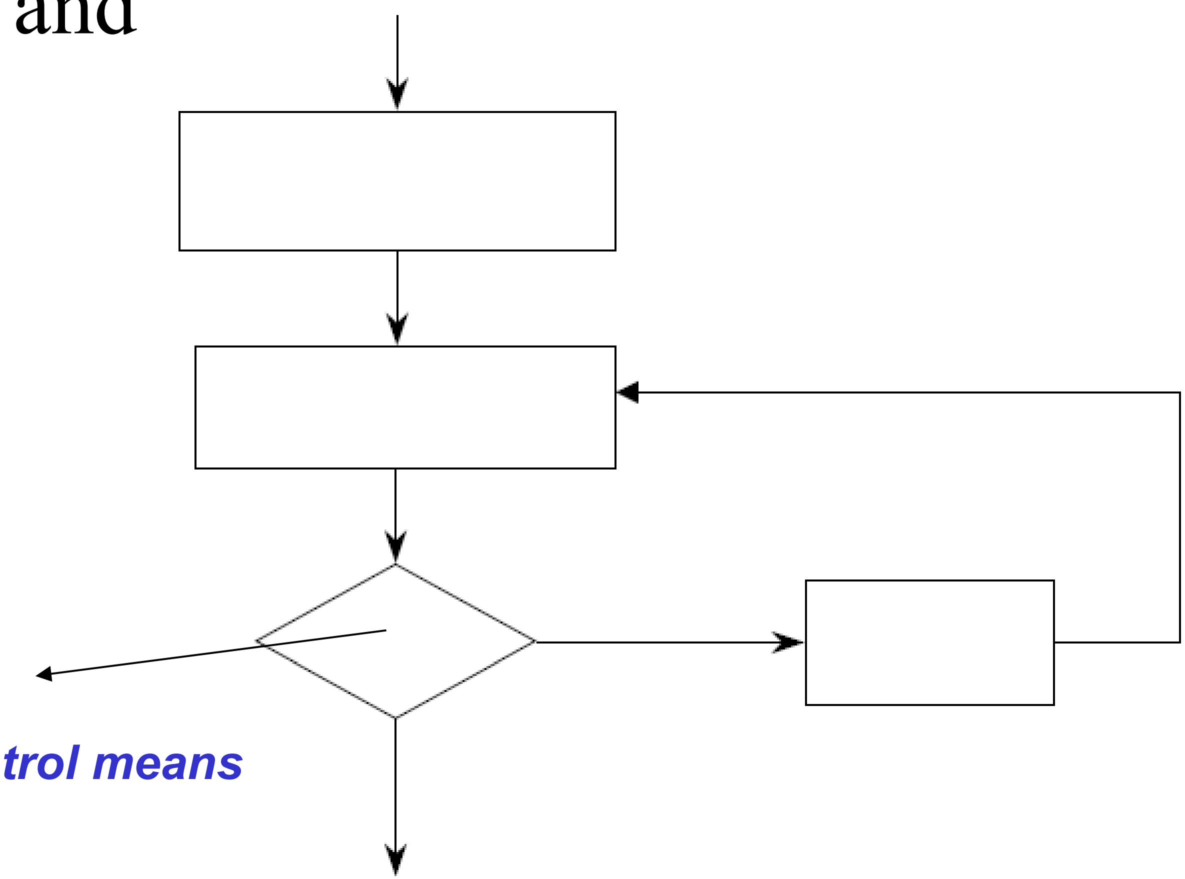


Representation of RT Systems



Events

Any occurrence that causes the program counter to change nonsequentially is considered a change of flow-of-control, and



Change in flow-of-control means EVENT!

Synchronous vs. Asynchronous Events

	Periodic	Aperiodic	Sporadic
Synchronous	Cyclic code	Typical branch instruction	Branch instruction, e.g., error recovery
	Processes scheduled by internal clock	Garbage collection	Traps
Asynchronous	Clock-generated interrupt	Regular, but not fixed-period interrupt	Externally generated exception
			"Random events"

Measuring System Performance

- ***CPU Utilization:***

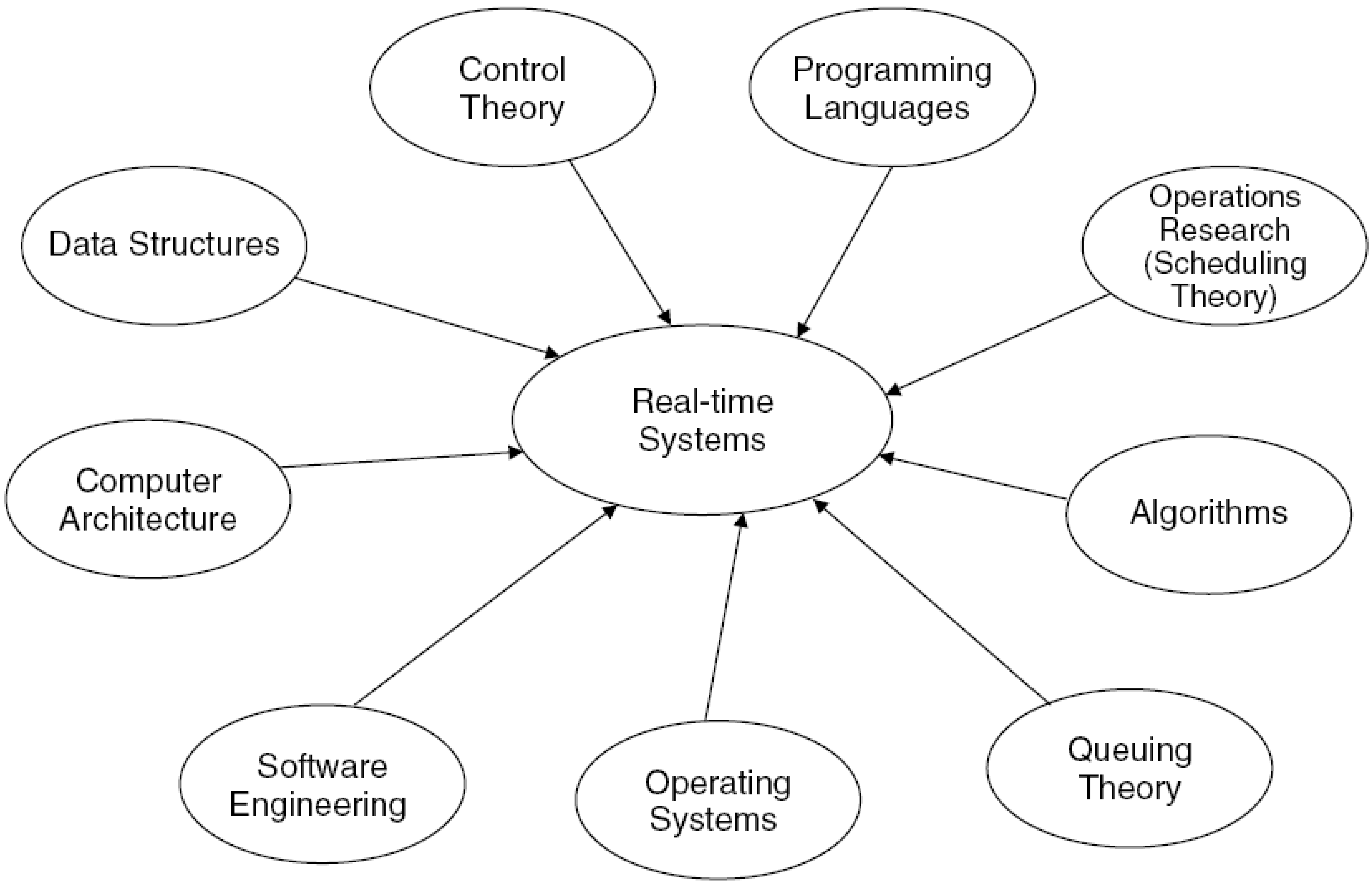
$$U = \sum_{i=1}^{n} \frac{C_i}{T_i}$$

where C is execution time and T is the period of a task.

CPU Utilization Zones

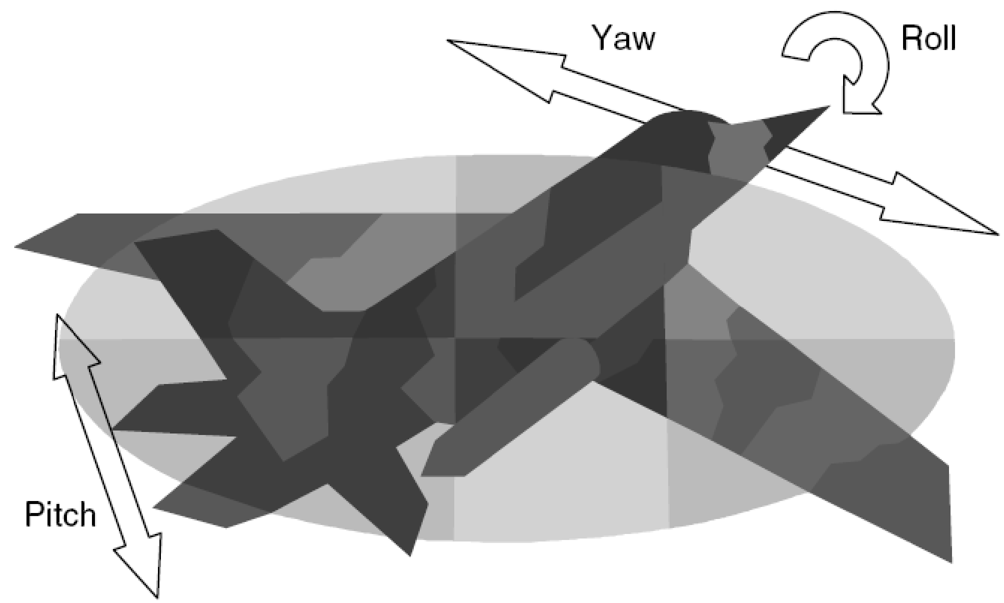
Utilization (%)	Zone Type	Typical Application
0–25	Significant excess processing power – CPU may be more powerful than necessary	Various
26–50	Very safe	Various
51–68	Safe	Various
69	Theoretical limit	Embedded systems
70–82	Questionable	Embedded systems
83–99	Dangerous	Embedded systems
100+	Overload	Stressed systems

Disciplines that have impact on RT Systems



Domains and Applications of RT Systems

Domain	Applications
Avionics	Navigation Displays
Multimedia	Games Simulators
Medicine	Robot surgery Remote surgery Medical imaging
Industrial Systems	Robotic assembly lines Automated inspection
Civilian	Elevator control Automotive systems

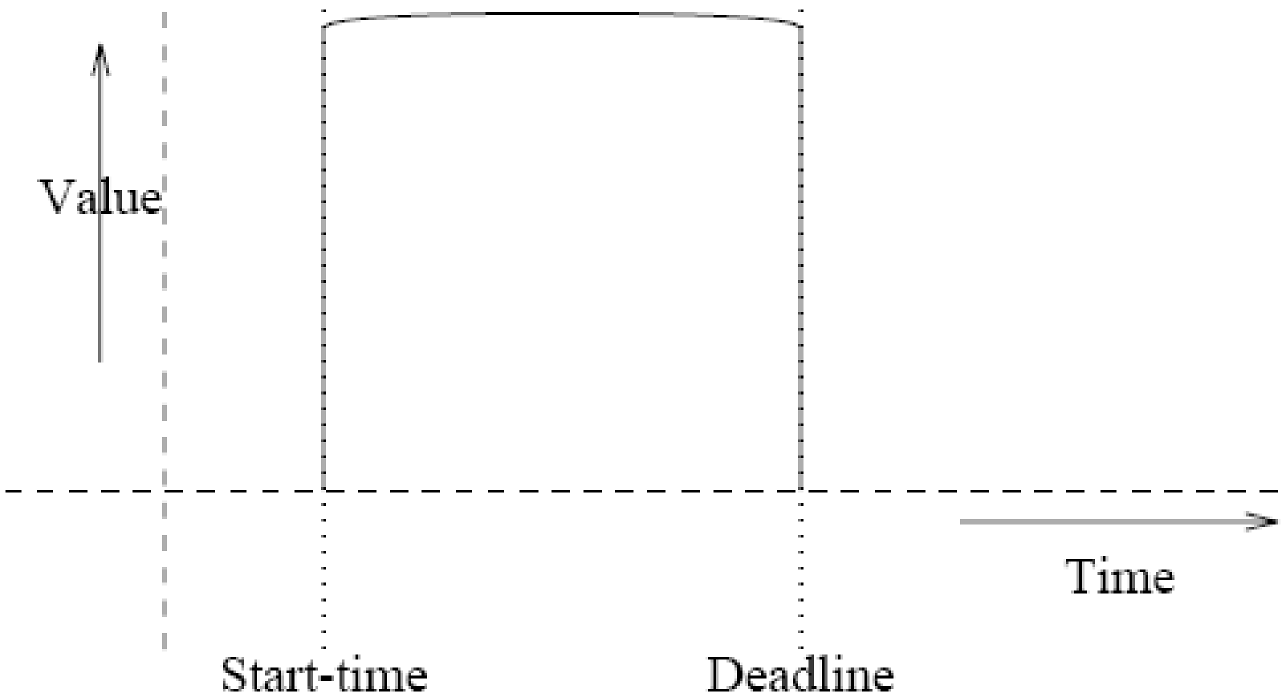


Task Characteristics

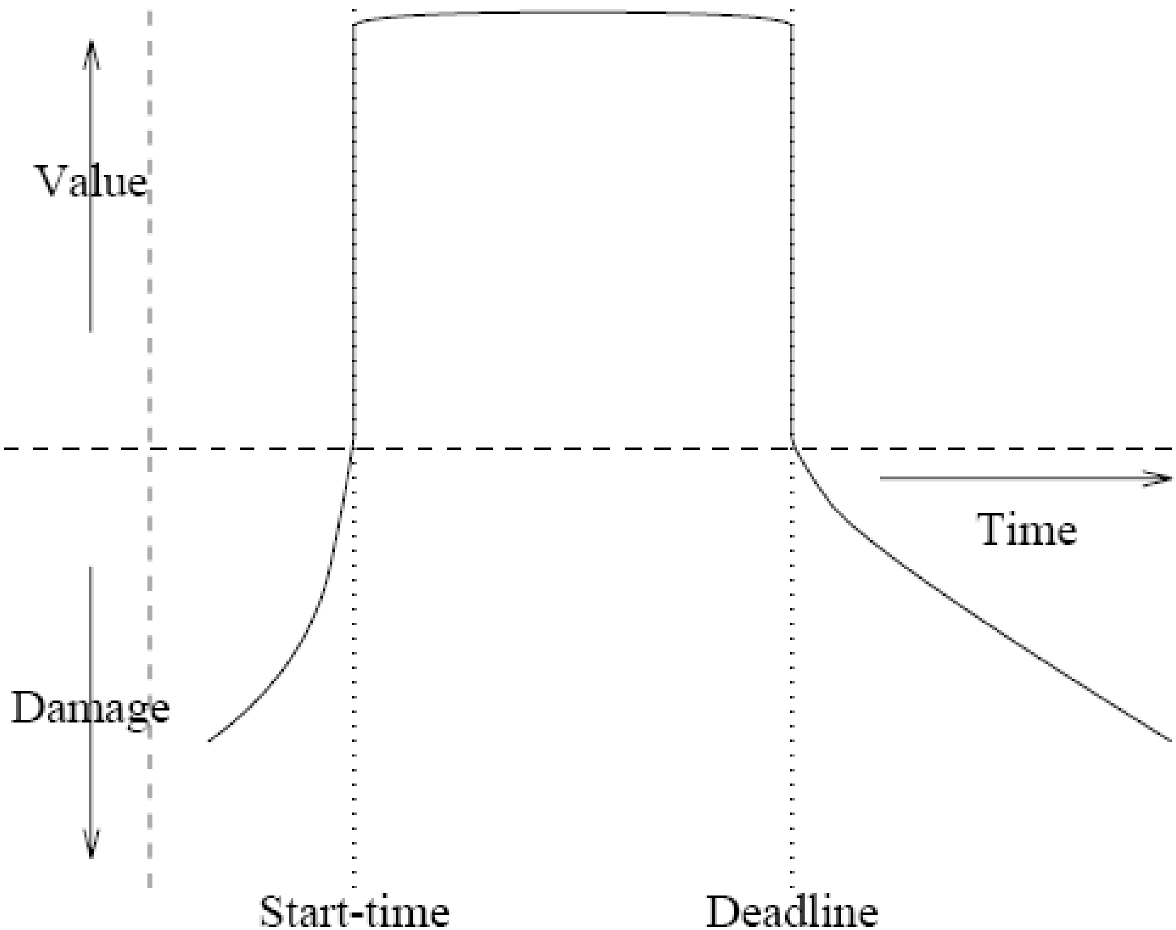
in terms of

System Requirements

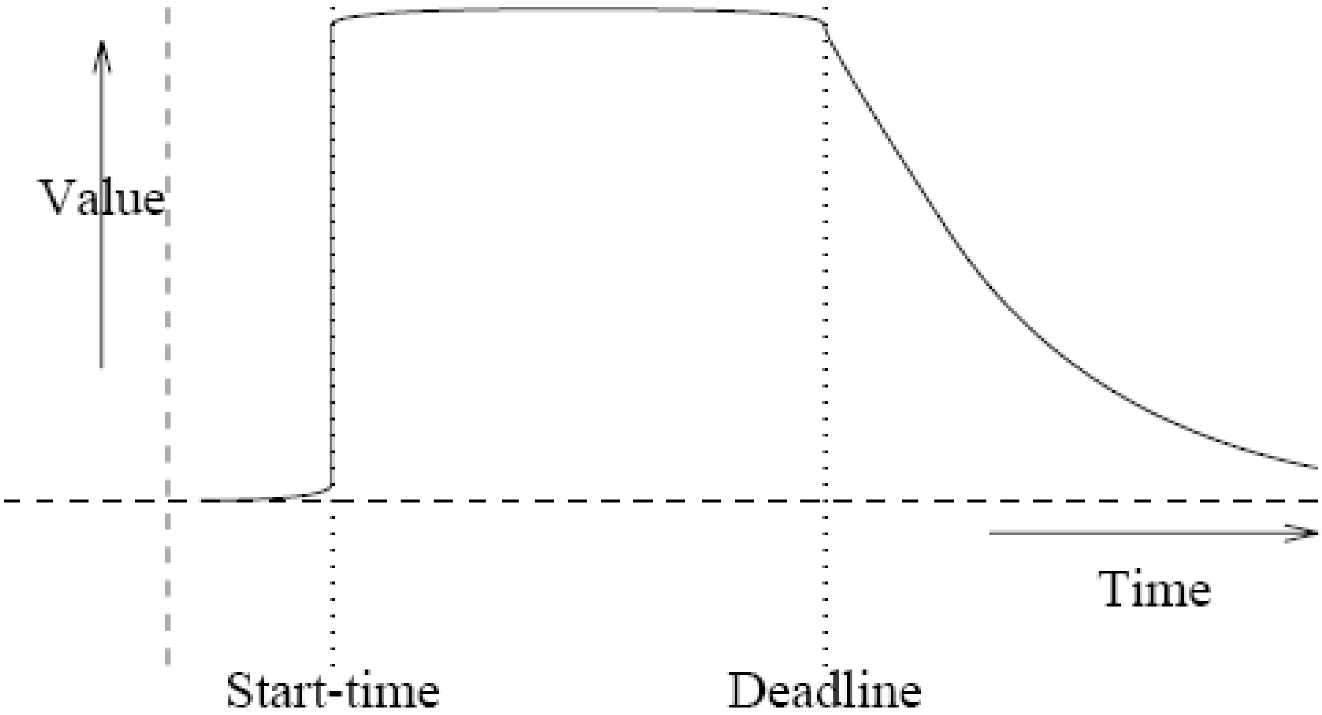
Hard Deadline



Safety Critical System



Soft Deadline



Hybrid System