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Lec. 4.2: Embedded System Software

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According to Peter Marwedel's Lectures

Increasing design complexity + Stringent time-to-market requirements ☞Reuse of components

Reuse requires knowledge from previous designs to be made available in the form of **intellectual property** (IP, for **SW & HW**).

- HW
- Operating systems
- Middleware (Communication, data bases, …)
- ….

Embedded operating systems
- Characteristics: Configurability -

Configurability

No overhead for unused functions tolerated,
no single OS fits all needs, ☞ configurability needed.

- Object-orientation could lead to a of derivation subclasses.
- Aspect-oriented programming
- Conditional compilation (using #if and #ifdef commands).
- Advanced compile-time evaluation useful.
- Linker-time optimization (removal of unused functions)

Dynamic data might be replaced by static data.

Embedded operating systems

- Characteristics: Disk and network handled by tasks -

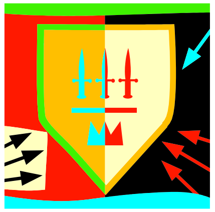
- **Effectively no device needs to be supported by all variants of the OS**, except maybe the system timer.
- Many ES without disk, a keyboard, a screen or a mouse.
- Disk & network handled by tasks instead of integrated drivers.

Embedded operating systems
- Characteristics: Protection is optional-

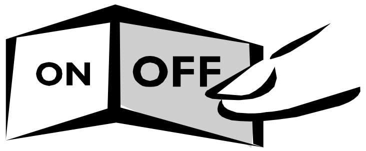
Protection mechanisms not always necessary:

ES typically designed for a single purpose,
untested programs rarely loaded, SW considered reliable.

Privileged I/O instructions not necessary and
tasks can do their own I/O.



However, protection mechanisms may be needed
for safety and security reasons.



Embedded operating systems
- Characteristics: Interrupts not restricted to OS -

Interrupts can be employed by any process

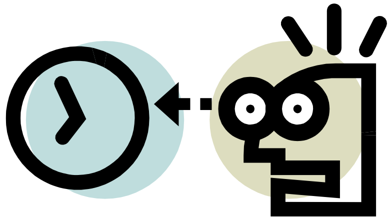
For standard OS: serious source of unreliability.

Since

- embedded programs can be considered to be tested,
- since protection is not always necessary and
- since efficient control over a variety of devices is required,
- it is possible to let interrupts directly start or stop SW (by storing the start address in the interrupt table).
- More efficient than going through OS services.
- Reduced composability: if SW is connected to an interrupt, it may be difficult to add more SW which also needs to be started by an event.

Embedded operating systems
- Characteristics: Real-time capability-

Many embedded systems are real-time (RT) systems and, hence, the OSs used in these systems must be **real-time operating systems (RTOSs).**



RT operating systems - Definition and requirement 1: predictability -

Def.: *(A) real-time operating system is an operating system that supports the construction of real-time systems.*

The following are the three key requirements

1. **The timing behavior of the OS must be predictable.**
   $\forall$ services of the OS: Upper bound on the execution time!
   RTOSs must be timing-predictable:
   - short times during which interrupts are disabled,
   - (for hard disks:) contiguous files to avoid unpredictable head movements.

[Takada, 2001]

Real-time operating systems requirement 2: Managing timing

2. **OS should manage the timing and scheduling**
   - OS possibly has to be aware of task deadlines; (unless scheduling is done off-line).
   - Frequently, the OS should provide precise time services with high resolution.

[Takada, 2001]

Real-time operating systems requirement 3: Speed

3. **The OS must be fast**

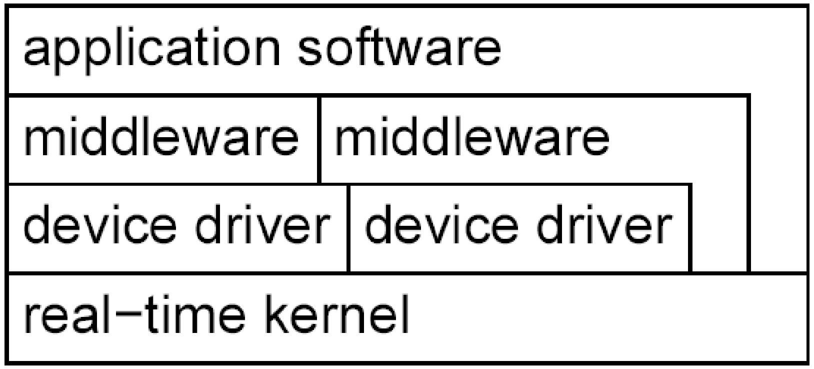
   Practically important.

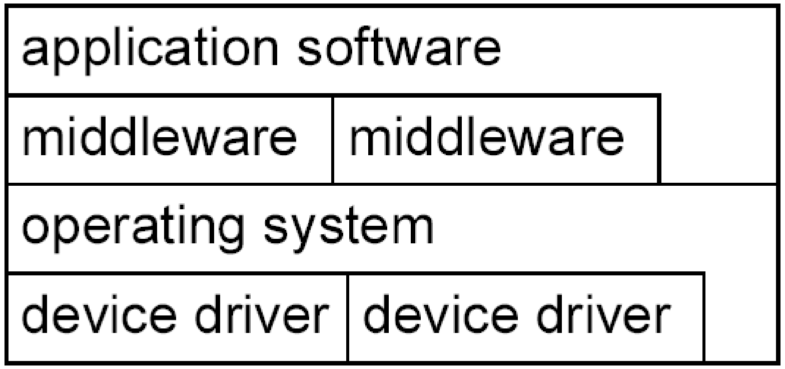
[Takada, 2001]

RTOS-Kernels

Distinction between

- real-time kernels and modified kernels of standard OSes.





Distinction between

- general RTOSs and RTOSs for specific domains,
- standard APIs (e.g. POSIX RT-Extension of Unix, ITRON, OSEK) or proprietary APIs.

Source: R. Gupta, UCSD

Functionality of RTOS-Kernels

Includes

- processor management,
- memory management,
- and timer management;

$\left.\begin{array}{l}\text{processor management,}\\ \text{memory management,}\\ \text{and timer management;}\end{array}\right\}$ resource management

- task management (resume, wait etc),
- inter-task communication and synchronization.

Classes of RTOSes:
1. Fast proprietary kernels

For complex systems, these kernels are inadequate, because they are designed to be fast, rather than to be predictable in every respect

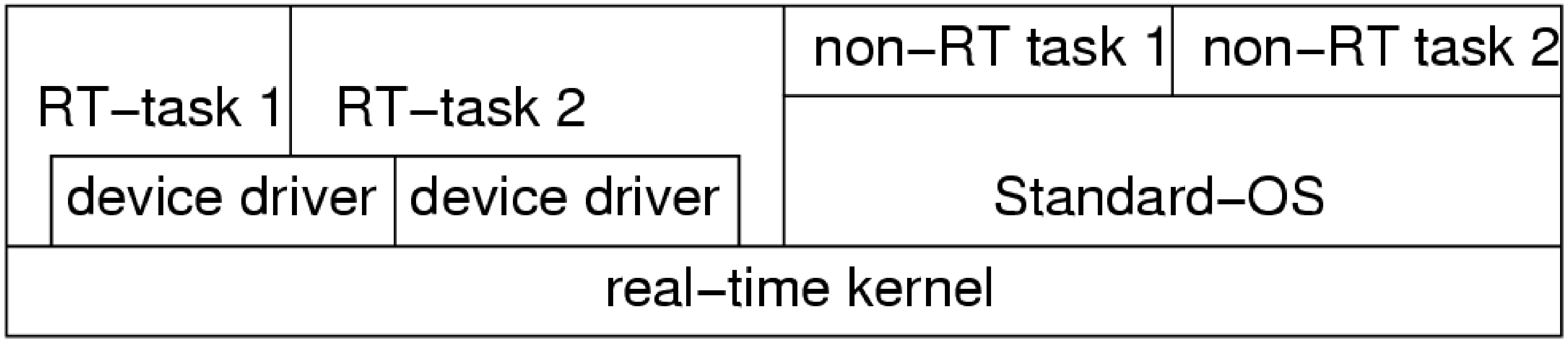
[R. Gupta, UCI/UCSD]

Examples include

QNX, PDOS, VCOS, VTRX32, VxWORKS.

Classes of RTOSs: 2. RT extensions to standard OSs

Attempt to exploit comfortable main stream OS.
RT-kernel running all RT-tasks.
Standard-OS executed as one task.



+ Crash of standard-OS does not affect RT-tasks;
- RT-tasks cannot use Standard-OS services; less comfortable than expected

Evaluation

According to Gupta, trying to use a version of a standard OS:

not the correct approach because too many basic and inappropriate underlying assumptions still exist such as optimizing for the average case (rather than the worst case), ... ignoring most if not all semantic information, and independent CPU scheduling and resource allocation.

Dependences between tasks not frequent for most applications of std. OSs & therefore frequently ignored.

Situation different for ES since dependences between tasks are quite common.

Classes of RTOSs:
3. Research trying to avoid limitations

Research systems trying to avoid limitations.
Include MARS, Spring, MARUTI, Arts, Hartos, DARK, and Melody

Research issues [Takada, 2001]:

- low overhead memory protection,
- temporal protection of computing resources
- RTOSes for on-chip multiprocessors
- support for continuous media
- quality of service (QoS) control.

Summary

- General requirements for embedded operating systems
  - Configurability
  - Disk and network handled by tasks.
  - Protection is optional.
  - Interrupts not restricted to OS
  - Real-time Capability
- General properties of real-time operating systems
  - Predictability
  - Managing time
  - Speed