TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Informatik Institut für Systemarchitektur, Professur für Betriebssysteme

OPERATING-SYSTEM CONSTRUCTION

Material based on slides by
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Exercise 7: Interrupt-transp. Queue, SPIN, Task #7

https://tud.de/inf/os/studium/vorlesungen/betriebssystembau

HORST SCHIRMEIER

Agenda

- The Interrupt-Transparent Queue
- Correctness Proofs with SPIN
- OOStuBS: What's Missing for a Monolith?
- Lab Task #7

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- **The Interrupt-Transparent Queue**
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Tricky Pointers: Queue in Task #3

- Queue elements inherit from class Chain
  - Thereby, they inherit a pointer to the next element

```
class Chain {
public:
      Chain* next;
};
```

- A Queue object contains
  - a pointer to the first element
  - **a pointer to a pointer called 'tail'?!**

```
class Queue {
      Chain* head;
      Chain** tail;
public:
      Queue () { head = 0; tail = &head; }
      void enqueue (Chain* item);
      Chain* dequeue ();
      void remove (Chain*);
};
```

Tricky Pointers: Queue in Task #3

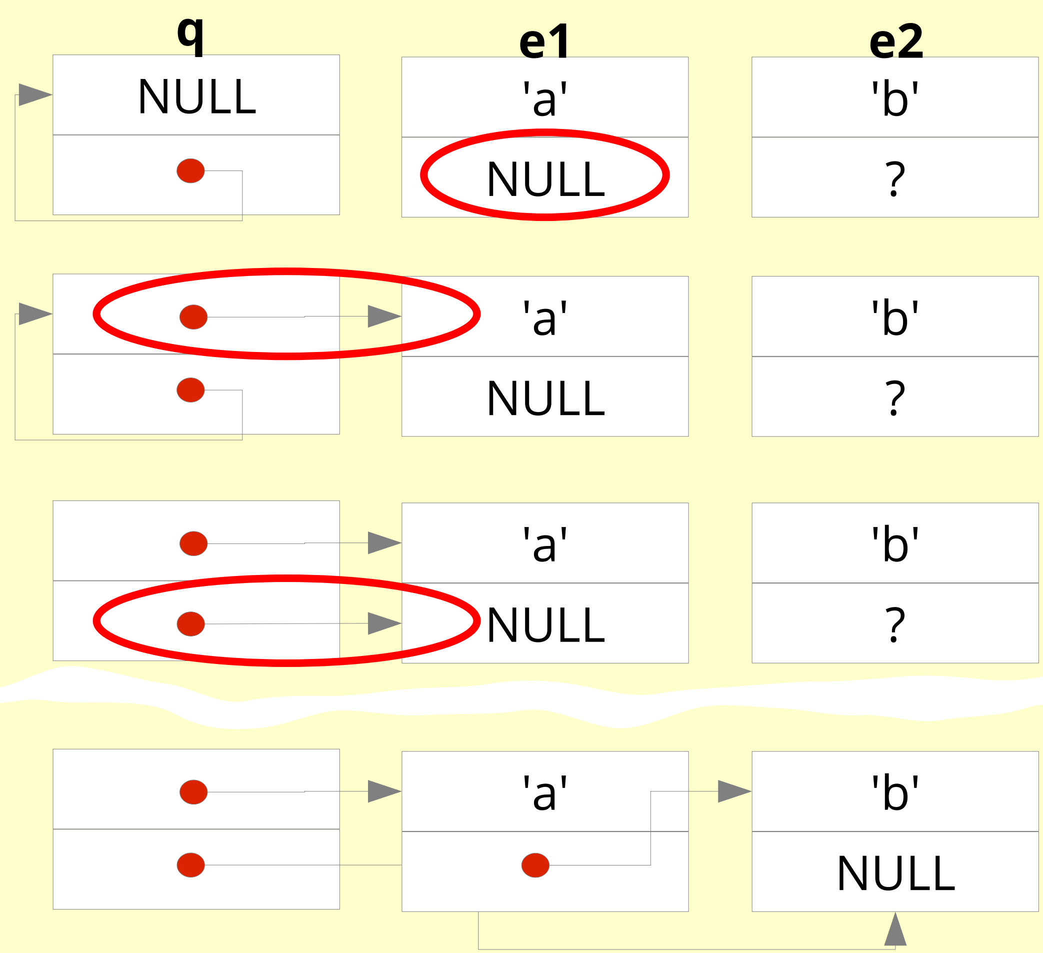
- 'tail' is a pointer to the 'next' pointer in the last element
  - This simplifies enqueueing!

q.enqueue(&e1)

```
item->next = NULL;
```

```
*tail = item;
```

```
tail = &item->next;
```



⋮

q.enqueue(&e2)

```
item->next  = NULL;
*tail = item;
tail  = &item->next;
```

Interrupt-Transparent Queue

On the whiteboard or in …

[1] F. Schön, W. Schröder-Preikschat, O. Spinczyk, and U. Spinczyk. ***On Interrupt-Transparent Synchronization in an Embedded Object-Oriented Operating System***. In The Third IEEE International Symposium on Object-Oriented Real-Time Distributed Computing (ISORC 2000), pages 270-277, Newport Beach, California, March 15-17, 2000. IEEE Computer Society. ISBN 0-7695-0607-0.
→ available online

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Model Checking (with *SPIN*)

- No deductive mathematical proof!
- Correctness proof by exhaustive analysis of the **state space**
  - State space must be **finite**
    - Fixed number of processes, value ranges, memory, …
  - Complexity limits for "large" systems / algorithms
    - Verification of a simplified model (→ ***Model Checking***)
- Basic principle
  - Model and negated correctness properties → Finite automatons
  - Search: Input string that both automatons accept (counterexample)

Model Checking with *SPIN*

- Modeling of the system/algorithm in **PROMELA**
  - Very simple/reduced language, similarities with C/Java
    - No pointers, references, functions, classes, generics, …
  - Reduction to the essential → Minimal state machines
  - But: Model ⇔ Implementation?

- Specifying correctness properties
  - `assert(...)` statements (local)
  - Linear temporal logic (global)

Example: Mutual Exclusion in C

```
// Peterson's solution to the mutual exclusion problem (1981)
volatile bool flag[2] = {false, false};
volatile int turn;

void P0() {
    flag[0] = true;
    turn = 1;
    while (flag[1] && turn == 1) { /* busy wait */ }
    // critical section
    ...
    // end of critical section
    flag[0] = false;
}
void P1() {
    flag[1] = true;
    turn = 0;
    while (flag[0] && turn == 0) { /* busy wait */ }
    // critical section
    ...
    // end of critical section
    flag[1] = false;
}
```

Example: Implementation in PROMELA

```
// Peterson's solution to the mutual exclusion problem (1981)
bool turn, flag[2];            // the shared variables, booleans
byte ncrit;                    // nr of procs in critical section

active [2] proctype user() {   // two processes
  assert(_pid == 0 || _pid == 1);
  again:
  flag[_pid] = 1;
  turn = _pid;
  (flag[1 - _pid] == 0 || turn == 1 - _pid);

  ncrit++;
  assert(ncrit == 1);          // critical section
  ncrit--;

  flag[_pid] = 0;
  goto again
}
// analysis:
// $ spin -a peterson.pml
// $ gcc -o pan pan.c
// $ ./pan
```

Boolean expressions (without `if`) **block** until the condition holds

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- The Interrupt-Transparent Queue
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- **OOStuBS: What's Missing for a Monolith?**
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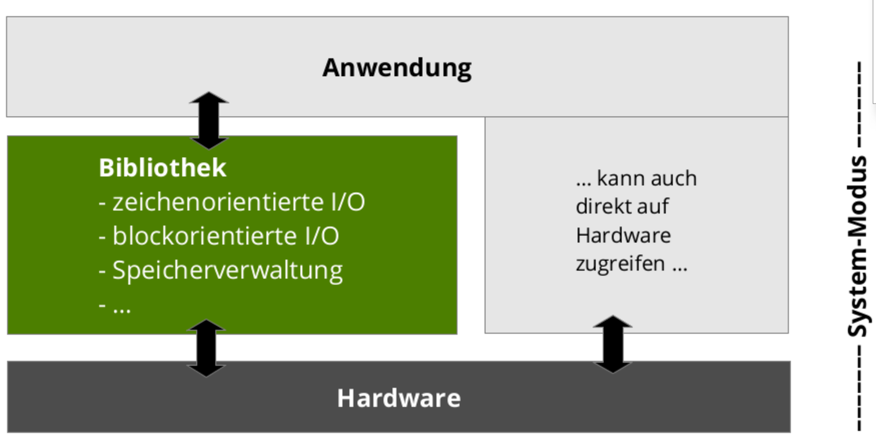
OOStuBS: What’s Missing for a Monolith?

- Currently, OOStuBS is a “library OS”:

Bibliotheks-Betriebssysteme

- Zusammenfassung von **häufig benutzten Funktionen zur Ansteuerung von Geräten** in Software-Bibliotheken (*Libraries*), die von allen Programmen genutzt werden konnten
  - Aufruf von Systemfunktionen als normale Funktionsaufrufe
- Bibliothek konnte im Speicher des Rechners bleiben
  - verringerte Programmladezeiten, „**Residenter Monitor**“
- Fu
- Fe

Bibliotheks-Betriebssysteme



Bibliotheks-BS: Bewertung

- **Isolation**
  - Ideal – ***Single Tasking***-System - aber hohe „Task-Wechselzeiten“
- **Interaktionsmechanismen**
  - Direkt (Funktionsaufrufe)
- **Interruptbehandlungs-Mechanismen**
  - Teilweise keinerlei Interrupts → ***Polling***
- **Anpassbarkeit**
  - Eigene Bibliotheken für jede Hardware-Architektur, keine Standards
- **Erweiterbarkeit**
  - Abhängig von Bibliotheks-Struktur: Globale Strukturen, „**Spaghetti-Code**“
- **Robustheit**
  - Direkte Kontrolle über die gesamte Hardware: Fehler → Systemstillstand
- **Leistung**
  - Hoch, durch direktes Operieren auf der Hardware ohne Privilegierungsmechanismen

see „Betriebssysteme und Sicherheit“, lecture 24 „Betriebssystemarchitekturen“

OOStuBS: What's Missing for a Monolith?

- Primarily, **isolation** is missing
  - of applications from each other,
  - and especially of the kernel, and of hardware from the applications.
- Usual implementation:
  - Kernel in **supervisor mode** (ring 0), applications in **user mode** (ring 3)
    - Necessitates modifying the system-call mechanism, separated stacks
  - **Address-space separation:** use the MMU
    - Switch page-table hierarchy (base address in CR3) at context switch, only map pages of the respective process and of the kernel
    - Make kernel pages only accessible from ring 0
- optional: dynamic program loader; virtual addresses (static or dynamic linking), file system, storage drivers

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