The Producer-Consumer Problem

The producer-consumer problem (also known as the bounded-buffer problem) is a classical concurrency problem.

The problem is to synchronize two threads, the producer and the consumer, who share a common, fixed-size buffer. The producer repeatedly generates a data item and puts it into the buffer. At the same time, the consumer removes data items from the buffer, one item at a time.

The problem is to make sure that the producer will not try to add data items to a full buffer and that the consumer will not try to remove data items from an empty buffer.

The Producer-Consumer Problem

We assume that the items are integers. We represent the buffer by means of an array of integers. The array has a fixed size.

```
int N = 10; // capacity of buffer
```

The producer and consumer share the following variables.

```
int[] buffer; // array representing buffer
int next = 0; // index of cell for next item
int size = 0; // number of items stored in buffer
```

The Producer-Consumer Problem

Producer:

```
while (true)
  int value = produce an item;
  buffer[next] = value;
  size++;
  next = (next + 1) mod N;
```

Consumer:

```
while (true)
  int value = buffer[(next - size) mod N];
  size--;
```

The Producer-Consumer Problem

Question

How can we make sure that the producer will not try to add data items to a full buffer?

Answer

Introduce a semaphore that keeps track of the number of available slots in the buffer.

The Producer-Consumer Problem

Question

How can we make sure that the consumer will not try to remove data items from an empty buffer?

Answer

Introduce a semaphore that keeps track of the number of filled slots in the buffer.

The Producer-Consumer Problem

Question

Are we done?

Answer

No, particular blocks of code need to be executed atomically.

The readers and writers problem, due to Courtois, Heymans and Parnas, is another classical concurrency problem. It models access to a database. There are many competing threads wishing to read from and write to the database. It is acceptable to have multiple threads reading at the same time, but if one thread is writing then no other thread may either read or write. The problem is how do you program the reader and writer threads?

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- Canadian early pioneer of software engineering
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- Won numerous awards including ACM SIGSOFT's "Outstanding Research" award

David Parnas

source: Hubert Baumeister

Pierre-Jacques Courtois

- Professor emeritus at the Catholic University of Leuven

Pierre-Jacques Courtois

source: www.info.ucl.ac.be/~courtois

The Readers-Writers Problem

Reader:

```
...
read;
...
```

Writer:

```
...
write;
...
```

Problem

Given a number of reader and writer threads, add communication (in the form of shared variables) and synchronization (in the form of semaphores).

The Readers-Writers Problem

The readers and writers share the following variable.

```
semaphore mutex = 1;
```

Reader:

```
P(mutex);
read;
V(mutex);
```

Writer:

```
P(mutex);
write;
V(mutex);
```

The Readers-Writers Problem

Question

Does it solve the readers-writers problem?

Answer

Yes!

Question

Is it a satisfactory solution?

Answer

No!

Question

Why not?

Answer

It does not allow multiple readers to read at the same time.

The Readers-Writers Problem

Options

While a writer is writing, readers and writers arrive. Once the writer is done, can the readers start reading?

Options

While readers are reading, readers and writers arrive. Can the readers start reading?

No reader is kept waiting unless a writer is writing.

The Readers-Writers Problem

Options

While a writer is writing, readers and writers arrive. Once the writer is done, can the readers start reading?

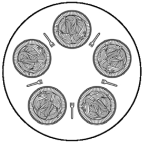
Options

While readers are reading, readers and writers arrive. Can the readers start reading?

If a writer wants to write, it writes as soon as possible.

The Dining Philosophers Problem

In the dining philosophers problem, due to Dijkstra, five philosophers are seated around a round table. Each philosopher has a plate of spaghetti. The spaghetti is so slippery that a philosopher needs two forks to eat it. The layout of the table is as follows.



The life of a philosopher consists of alternative periods of eating and thinking. When philosophers get hungry, they try to pick up their left and right fork, one at a time, in either order. If successful in picking up both forks, the philosopher eats for a while, then puts down the forks and continues to think.

The Dining Philosophers Problem

```
int N = 5;

philosopher(i):
while (true)
  think;
  takeForks(i);
  eat;
  putForks(i);

takeForks(i):
  ...
putForks(i):
  ...
```

The Dining Philosophers Problem

```
int N = 5;
semaphore mutex = 1;

philosopher(i):
while (true)
  think;
  takeForks(i);
  eat;
  putForks(i);

takeForks(i):
P(mutex);

putForks(i):
V(mutex);
```

The Dining Philosophers Problem

Question

Is this solution correct?

Answer

Yes!

Question

Does this solution allow two philosophers to eat at the same time?

Answer

No!

The Cigarette Smokers Problem

In the Cigarette Smokers Problem, due to Patil, there are an agent and three smokers. The smokers loop forever, first waiting for ingredients, then making and smoking cigarettes. The ingredients are tobacco, paper, and matches. We assume that the agent has an infinite supply of all three ingredients, and each smoker has an infinite supply of one of the ingredients; that is, one smoker has matches, another has paper, and the third has tobacco.

The agent repeatedly chooses two different ingredients at random and makes them available to the smokers. Depending on which ingredients are chosen, the smoker with the complementary ingredient should pick up both resources and proceed. For example, if the agent puts out tobacco and paper, the smoker with the matches should pick up both ingredients, make a cigarette, and then signal the agent.

The Cigarette Smokers Problem

Question

Can we implement the random choices made by the agent using concurrency?

Answer

Yes, we can introduce a thread for each choice and run them concurrently.

Question

How can we ensure that at most one of those threads executes at any time?

Answer

Introduce a binary semaphore.

The Cigarette Smokers Problem

Problem

Use semaphores `paper` and `tabacco` for the agent who puts out tobacco and paper, signal the smoker with the matches.

The Cigarette Smokers Problem

Shared variables

```
semaphore agent = 1
semaphore match = 0
semaphore paper = 0
semaphore tabacco = 0
```

Agent (paper and tabacco):

```
P(agent); V(tabacco); V(paper)
```

Agent (paper and matches):

```
P(agent); V(paper); V(match)
```

Agent (tabacco and matches):

```
P(agent); V(tabacco); V(match)
```

The Cigarette Smokers Problem

Smoker (paper):

```
P(tabacco); P(match); V(agent)
```

Smoker (matches):

```
P(tabacco); P(paper); V(agent)
```

Smoker (tabacco):

```
P(paper); P(match); V(agent)
```

The Cigarette Smokers Problem

Question

Is this solution correct?

Answer

No, because it can deadlock.

Paper

Make sure that you study the final version of the paper, and not a preliminary version of the paper posted on the web, as such a version may contain mistakes.