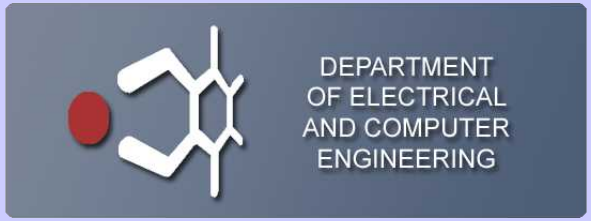


Parallel Task for parallelising OO desktop applications

Nasser Giacaman and Oliver Sinnen

PDSEC, IPDPS-10, Atlanta, USA,
April 2010

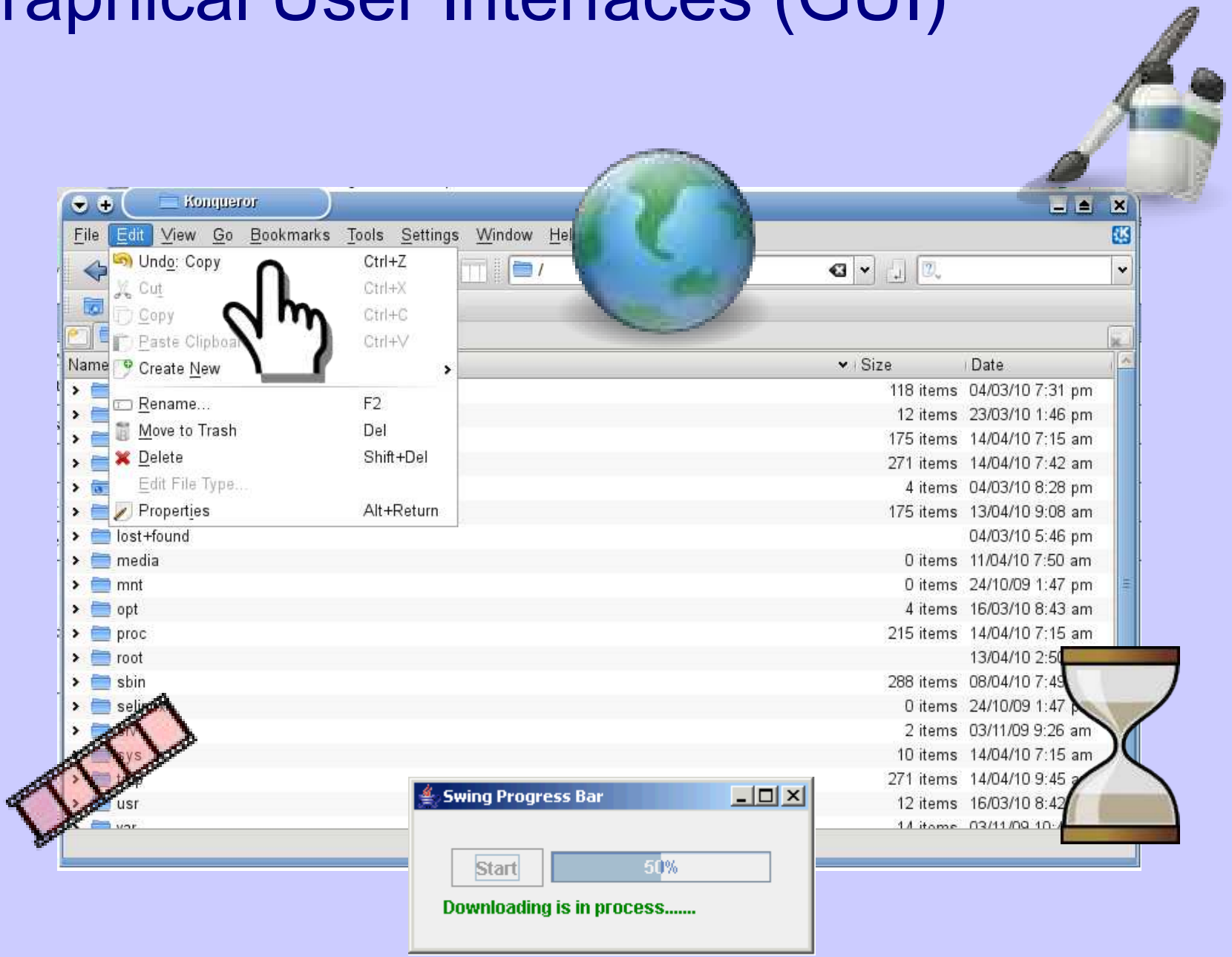
Overview

- Motivation
- Structure of desktop applications
- Parallel Task (ParaTask)
- Implementation
- Performance
- Conclusions

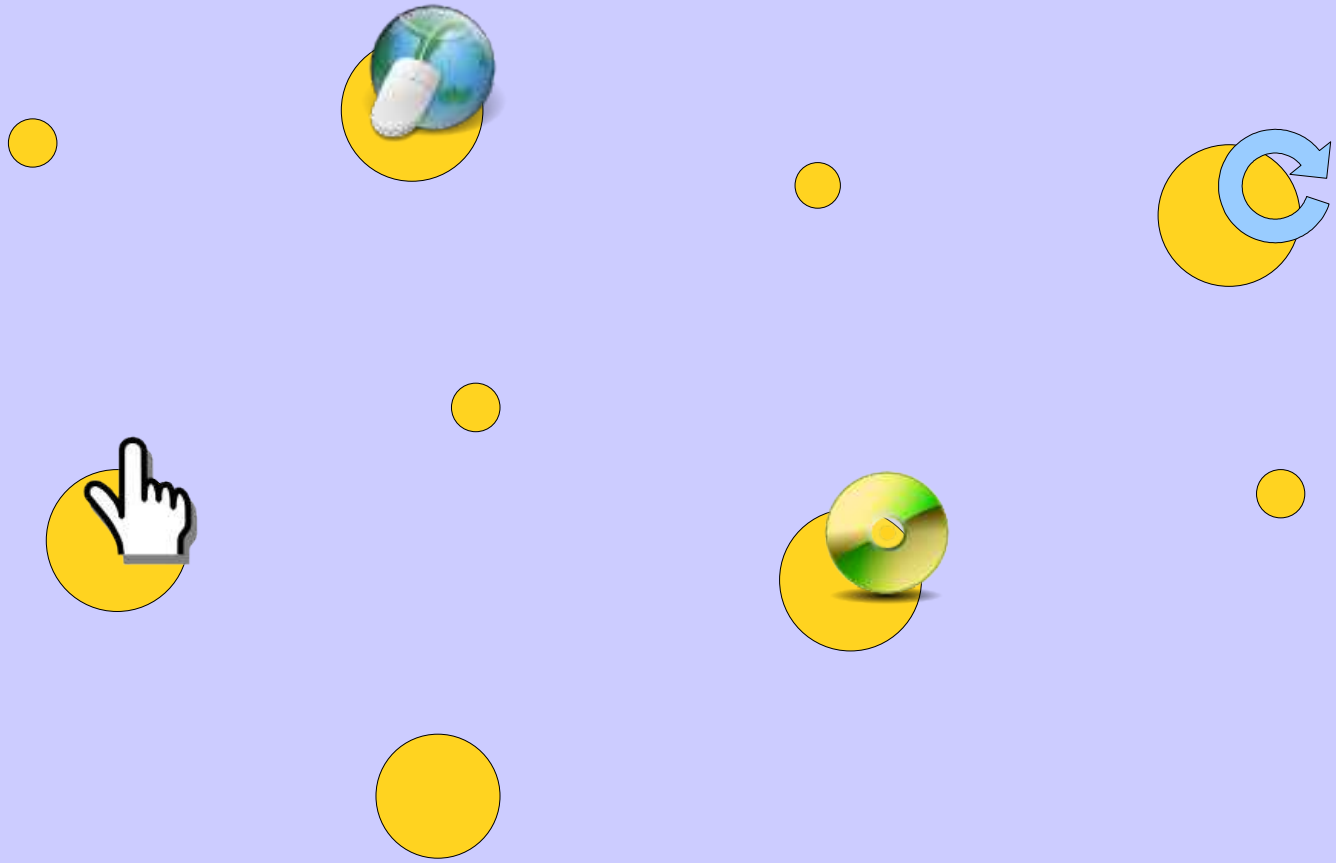
The need for desktop parallelisation

- Desktop systems becoming parallel
- Desktop software MUST be parallel
- Not as easy as “embarrassingly parallel” problems
- Desktop applications: OO & GUI

Graphical User Interfaces (GUI)



Structure of desktop applications



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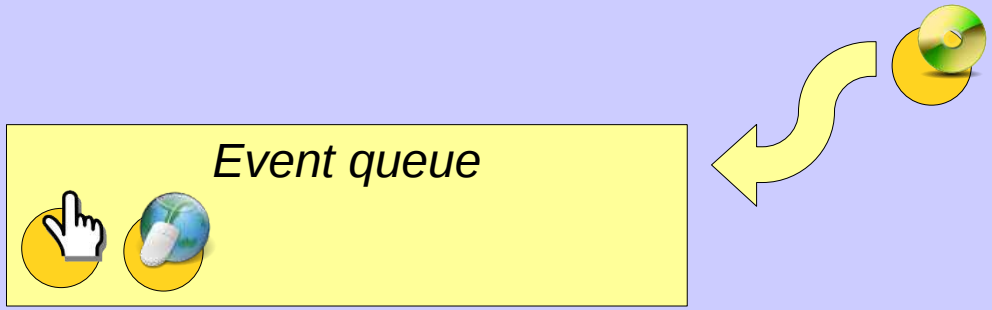

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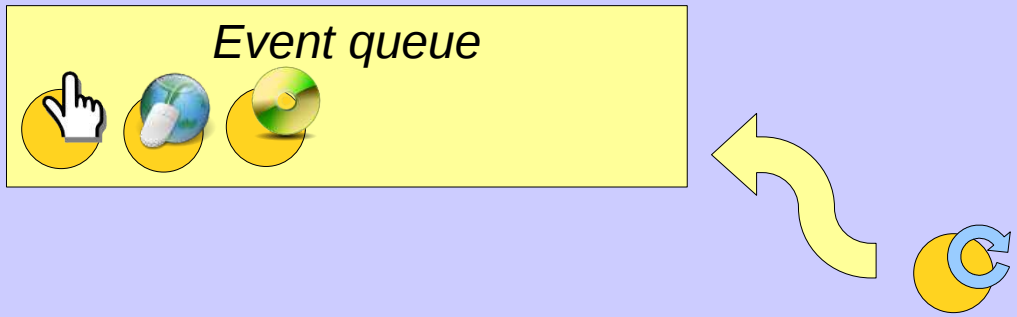

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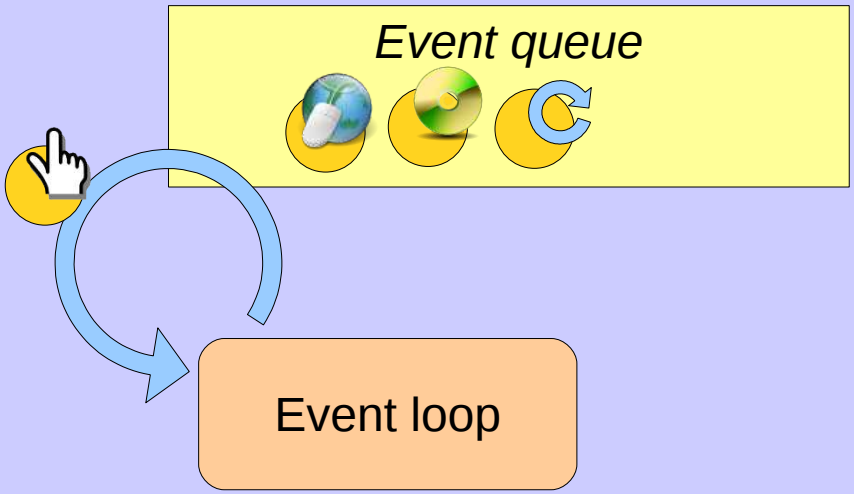

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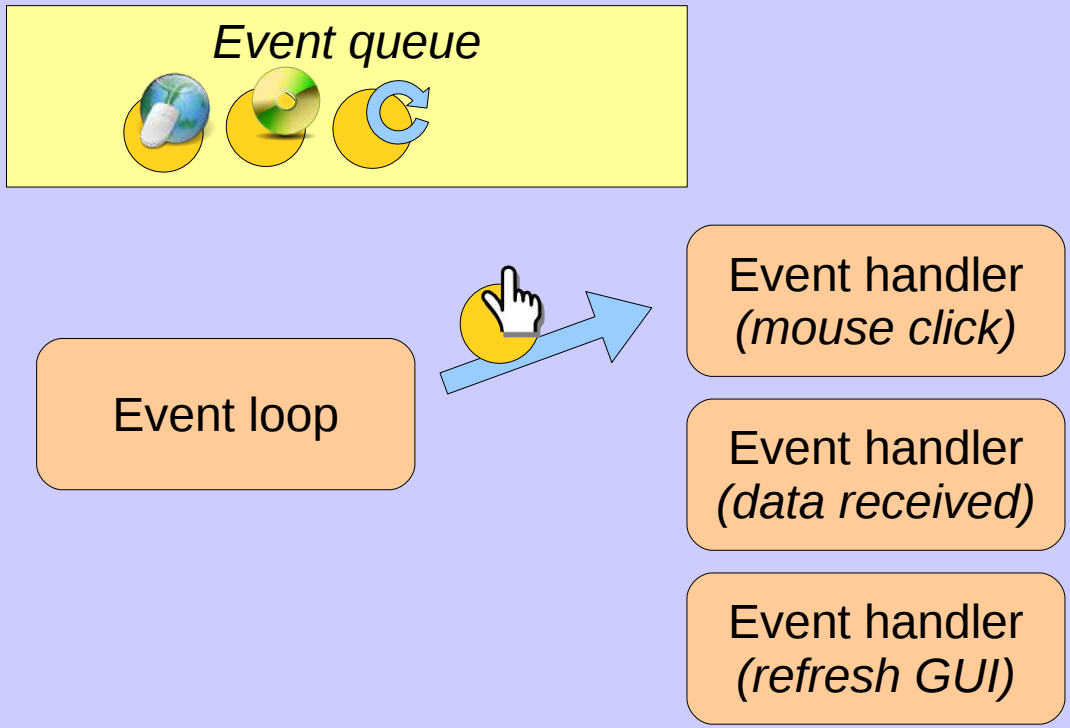

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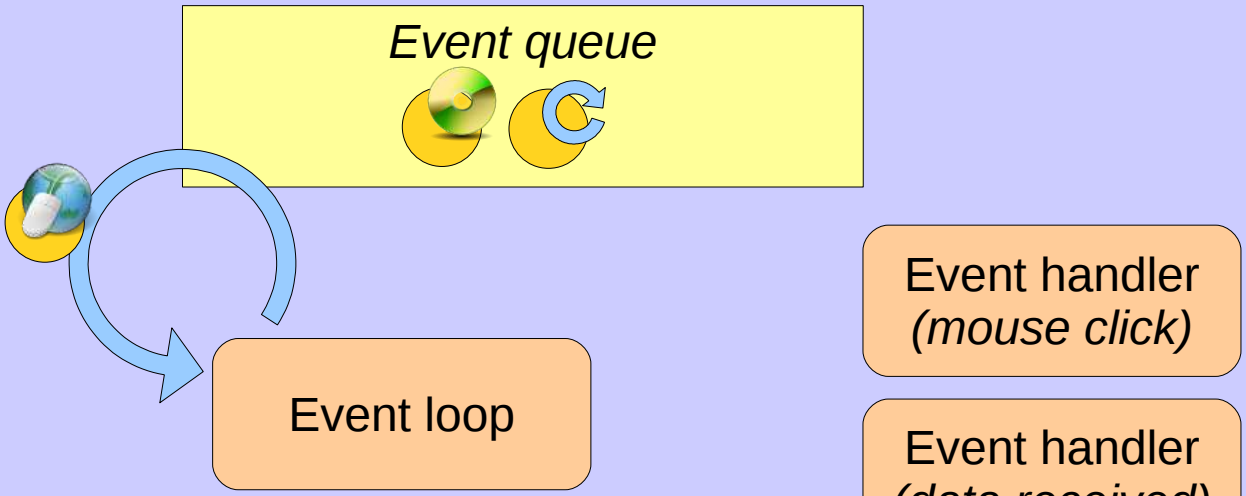
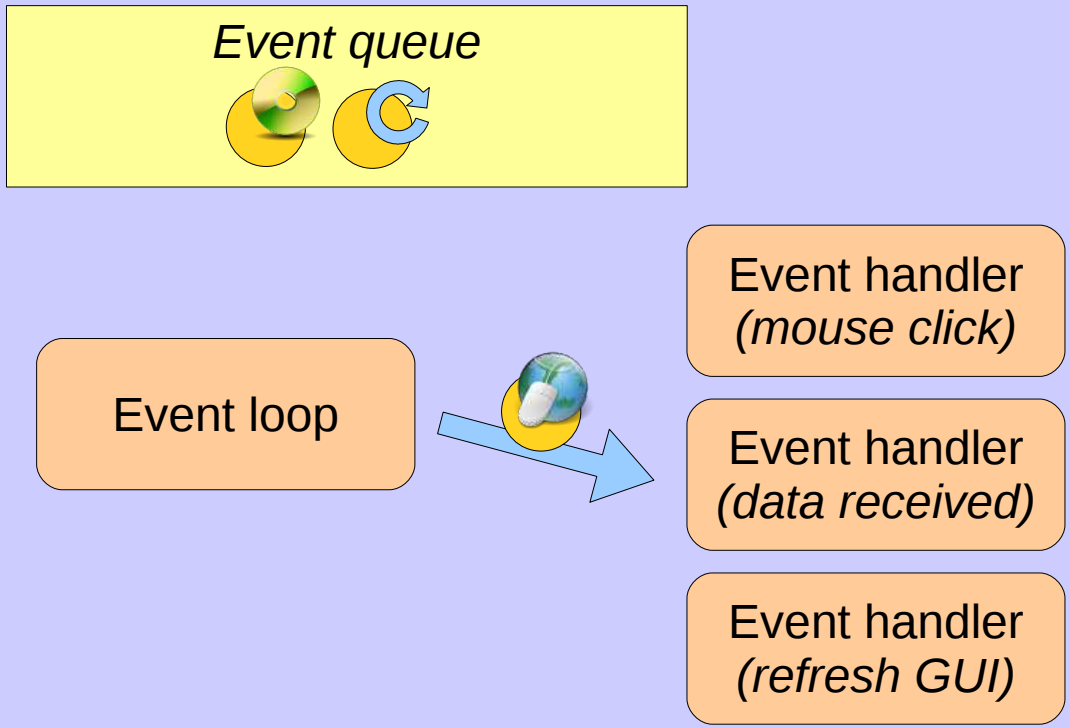


Event handler
(mouse click)

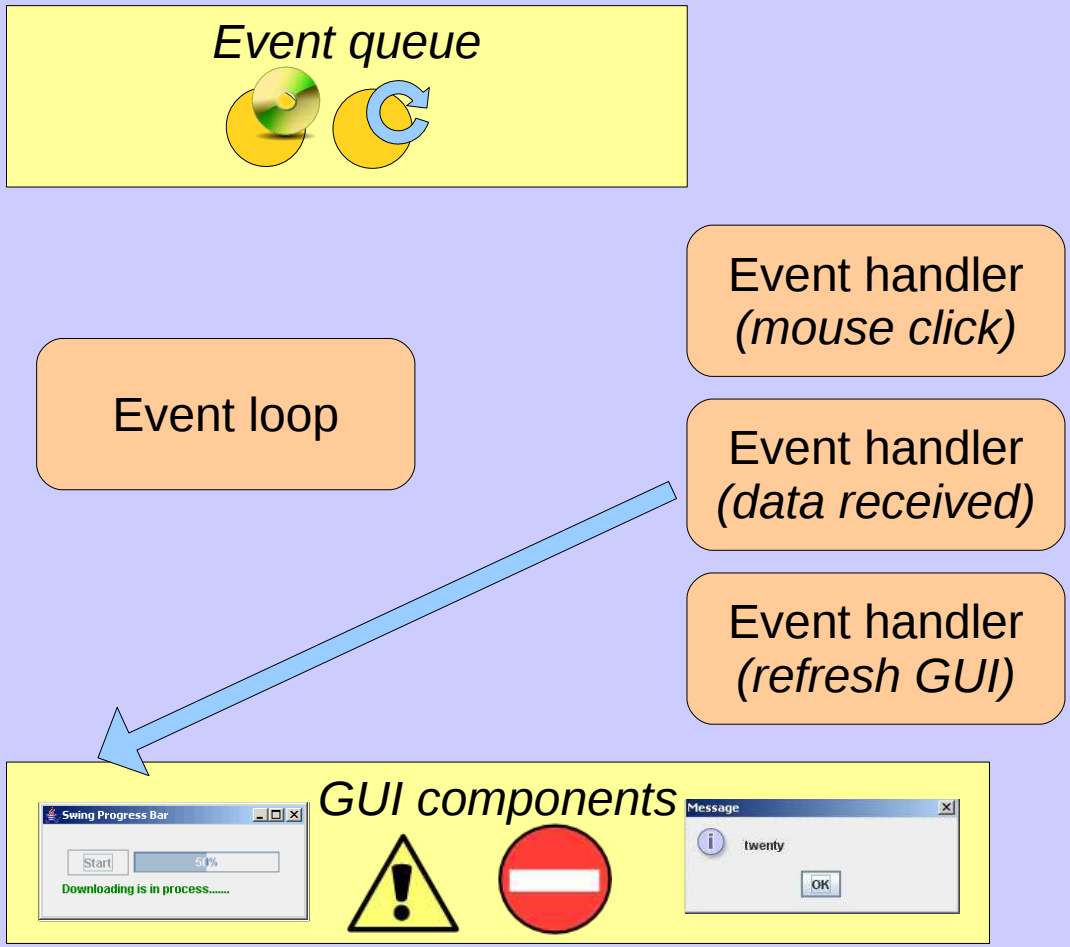
Event handler
(data received)

Event handler
(refresh GUI)

Structure of desktop applications

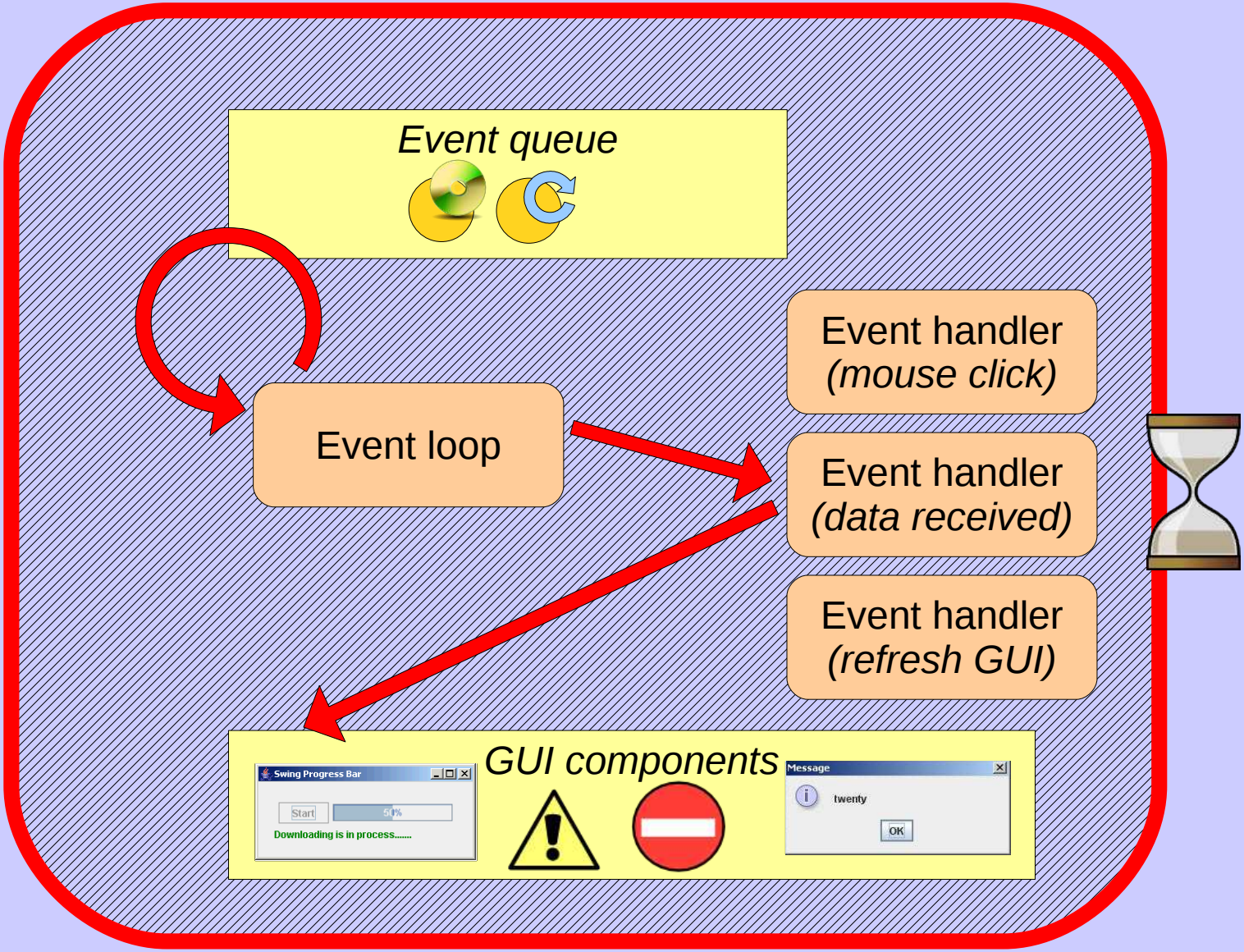


Structure of desktop applications



Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

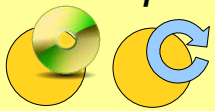


Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Helper Thread

Event queue



Event loop

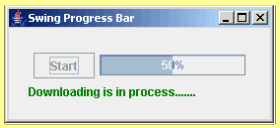
Event handler
(mouse click)

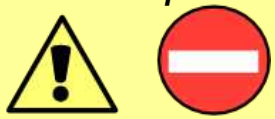
Event handler
(data received)

Event handler
(refresh GUI)

Process long task

GUI components

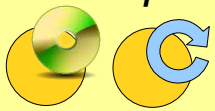




Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Event queue



Event loop

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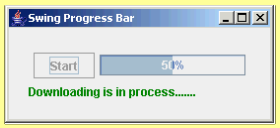
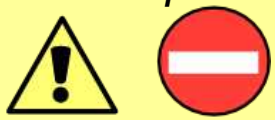
(data received)

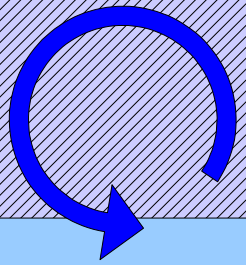
Event handler
(refresh GUI)

GUI components



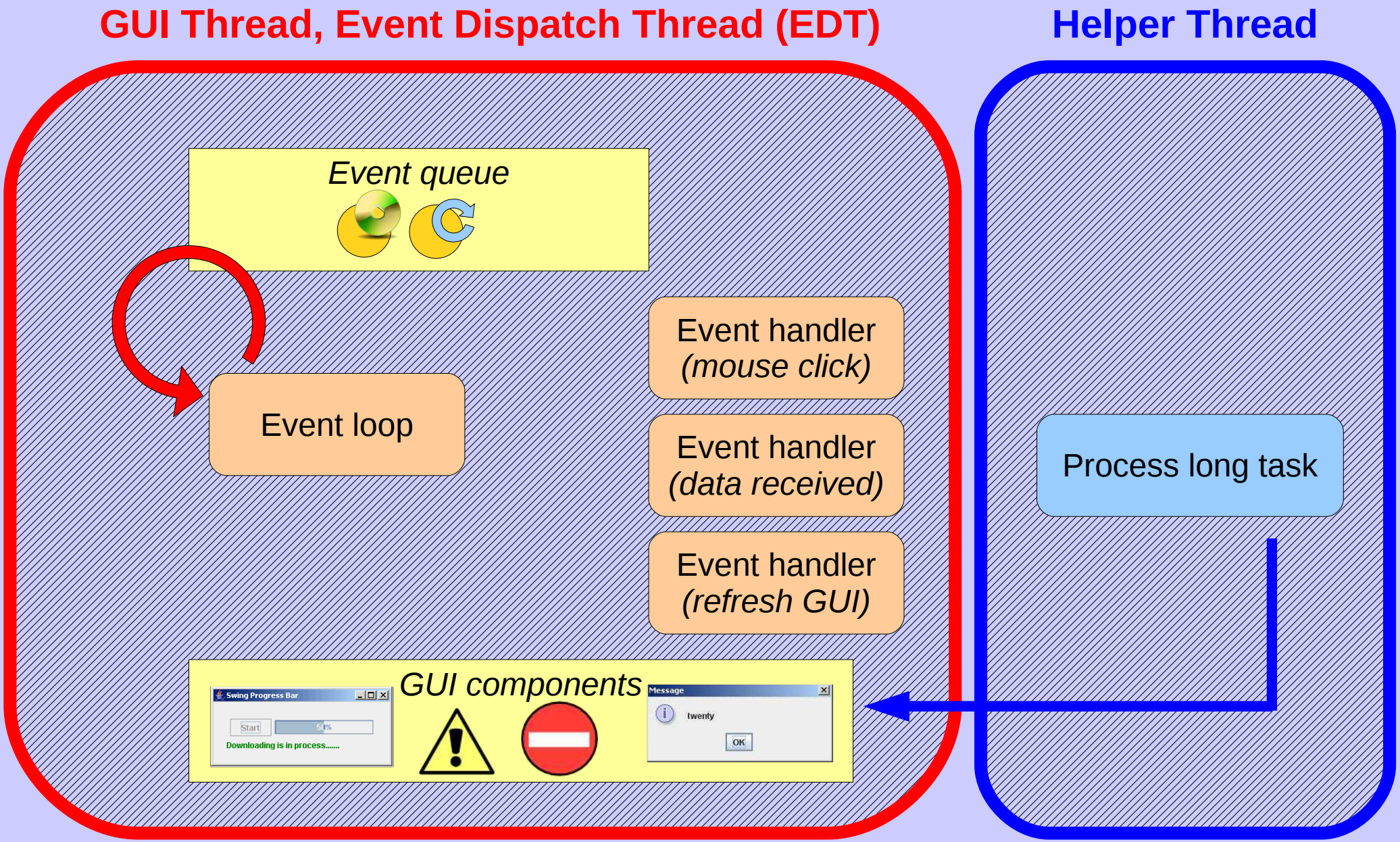


Helper Thread

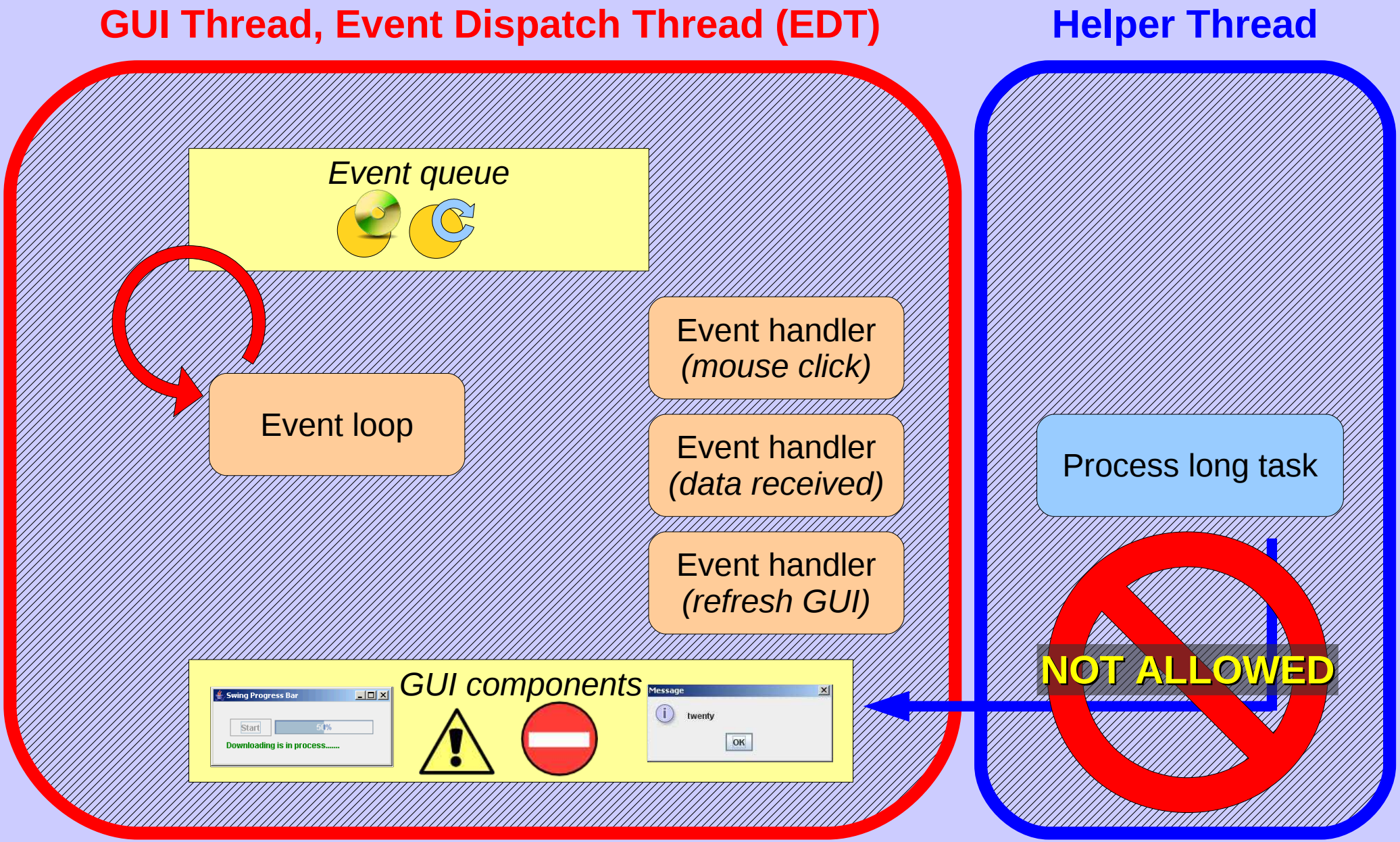


Process long task

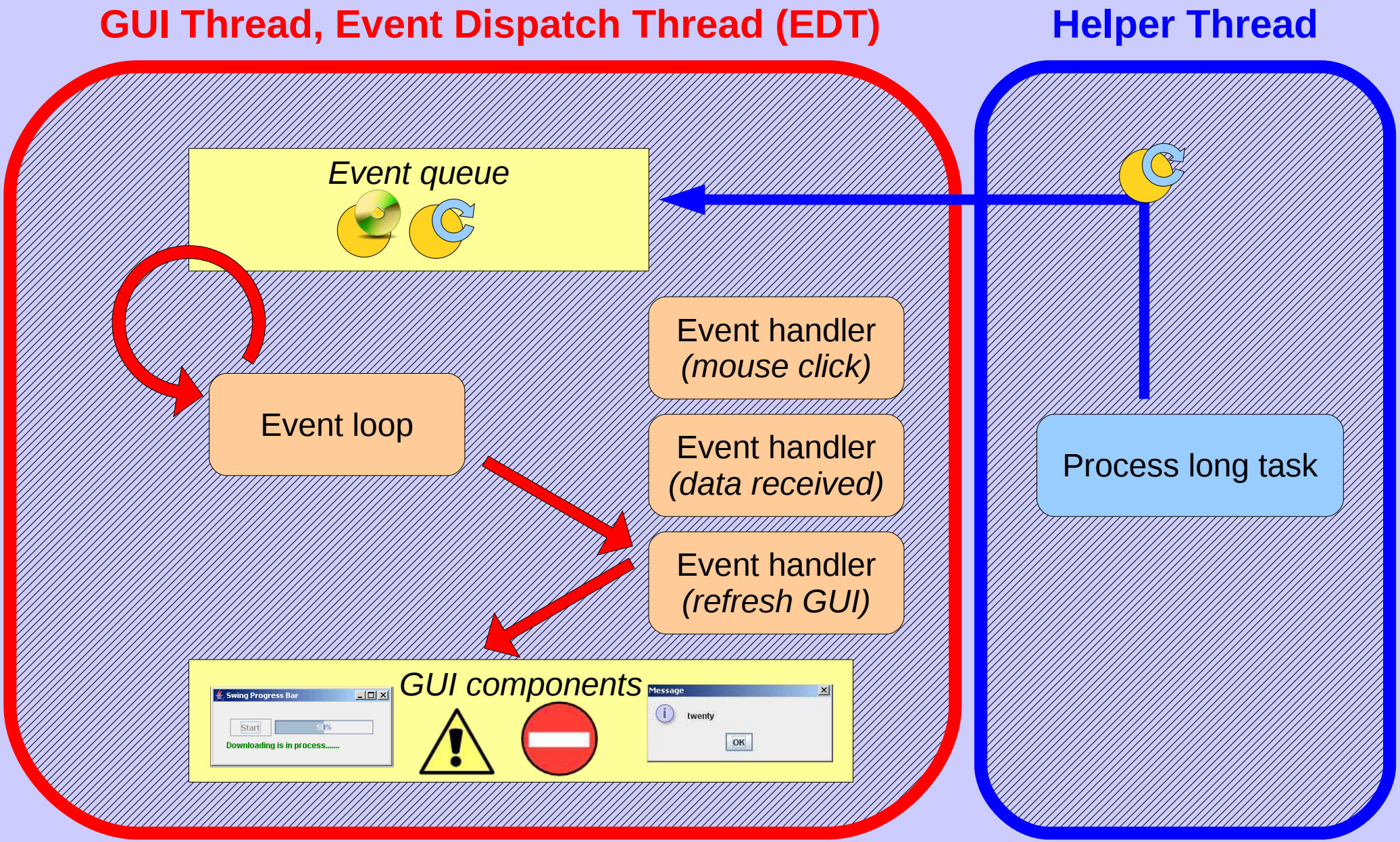
Structure of desktop applications



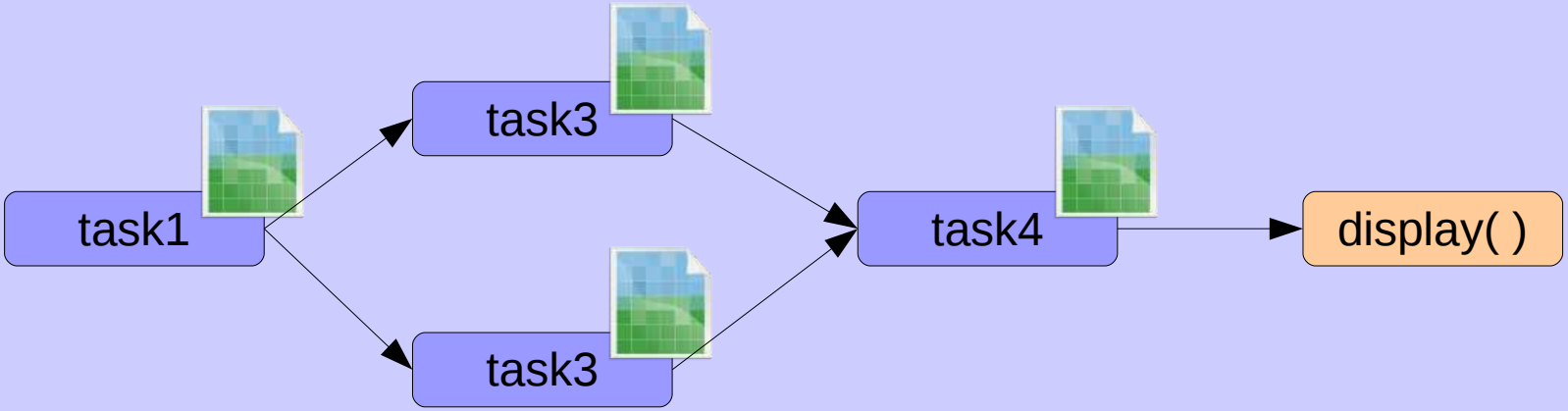
Structure of desktop applications



Structure of desktop applications

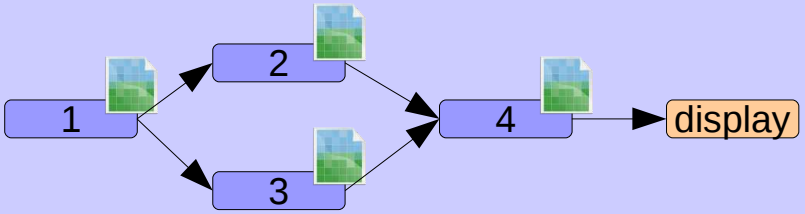


Background: *Task parallelism*




```
class ImageApp {
   ...
    void task1(String f) { ... }
    void task2(String f) { ... }
    void task3(String f) { ... }
    void task4(String f1, f2) { ... }
    void display(String f) { ... }
}
```

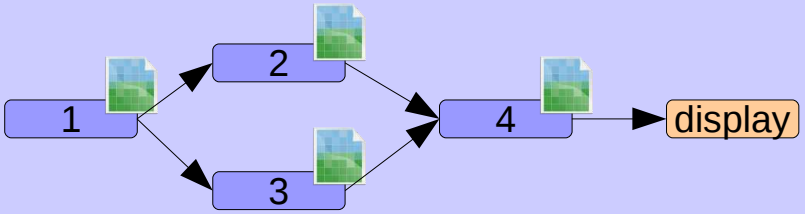
Using threading library




```
class Task1 : Thread {

    ThreadTask1(String file) {...}
    ...
    void run() {
        // do task1
    }
}
```

```
class ImageApp {
  ...
    void task1(String f) { ... }
    void task2(String f) { ... }
    void task3(String f) { ... }
    void task4(String f1, f2) { ... }
    void display(String f) { ... }
}
```

Using threading library



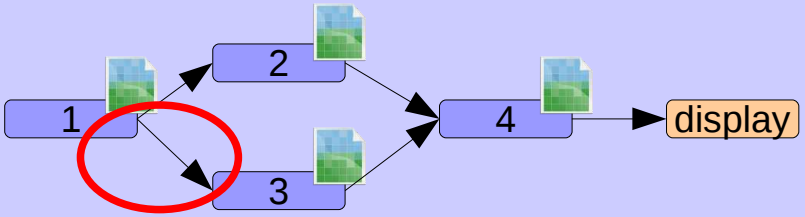

```
class Task4 : Thread {

    ThreadTask4(String file) {...}
```

```
class Task3 : Thread {

    ThreadTask3(String file) {...}
```

```
class Task2 : Thread {

    ThreadTask2(String file) {...}
```

```
class Task1 : Thread {

    ThreadTask1(String file) {...}

    void run() {
        // do task1
    }
}
```

Using threading library



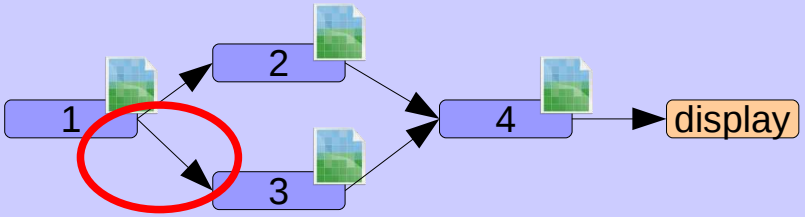

```
class Task4 : Thread {
    Condition waitFor2, waitFor3;
    ThreadTask4(String file) {...}
```

```
class Task3 : Thread {
    Condition waitFor1, notify4;
    ThreadTask3(String file) {...}
```

```
class Task2 : Thread {
    Condition waitFor1, notify4;
    ThreadTask2(String file) {...}
```

```
class Task1 : Thread {
    Condition notify2, notify3;
    ThreadTask1(String file) {...}

    void run() {
        // do task1
    }
}
```

Using threading library




```
class Task4 : Thread {
    Condition waitFor2, waitFor3;
    ThreadTask4(String file) {...}
```

```
class Task3 : Thread {
    Condition waitFor1, notify4;
    ThreadTask3(String file) {...}
```

```
class Task2 : Thread {
    Condition waitFor1, notify4;
                        ) {...}
```

```
class Task1 : Thread {
    Condition notify2, notify3;
    ThreadTask1(String file) {...}

    void run() {
        // do task1
        notify2.signal();
        notify3.signal();
    }
}
```

Problems with using threading library

- Code restructuring
- Thread management
- Manage dependences
- Coupling between tasks
- Task completion
- Performance hit

ParaTask: Task declaration

```
public class ImageApp
{
   ...
   TASK public void task1(String f)
   {
      // user code
   }
}
```

ParaTask: Task invocation

```
List images = ...;
for (int i = 0; i < images.size(); i++)
{
   TaskID id = task1(images.at(i));
   ...
}
```

Additional features

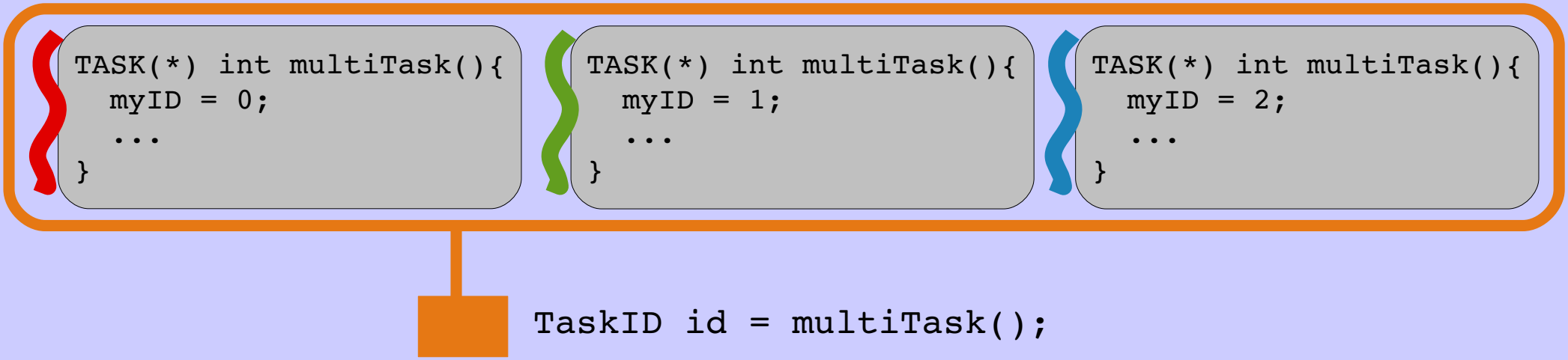
1) Different task types
2) Task dependences
3) Task completion & return values
   - Blocking (i.e. “Futures”)
   - Non-blocking
4) Exception handling

Different task types

- One-off tasks
  - ➡ Task parallelism
- Multi-tasks
  - ➡ Data parallelism
- Interactive
  - ➡ Latency hiding

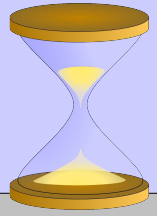
Multi-tasks

```
TASK(*) public int multiTask() {
    ...
}
```



Interactive tasks

Task queue:



```
TASK void A(){
   ...
}
```

```
TASK(*) int B(){
   ...
}
```

```
INT_TASK int input(){
   // block
   ...
}
```

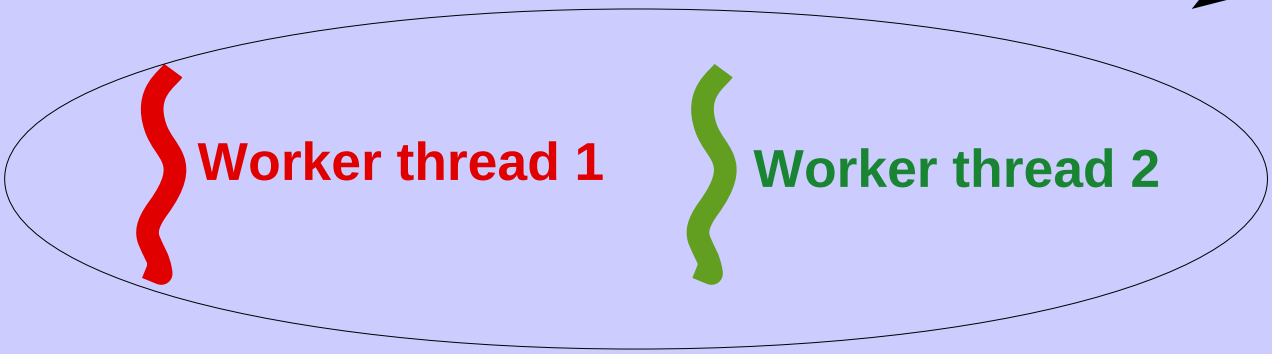
```
TASK void C(){
   ...
}
```

(quick)

(quick)

- user-interactive
- web access
- blocking

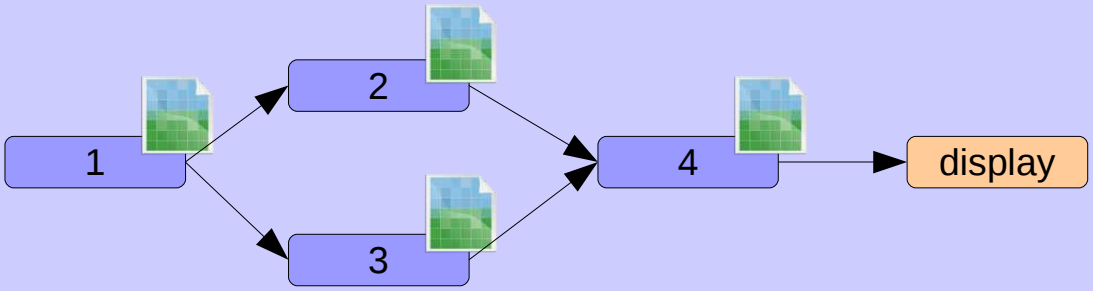
(quick)



Additional features

1) Different task types: `TASK(*), INTERACTIVE_TASK`
2) Task dependences
3) Task completion & return values
   - Blocking (i.e. “Futures”)
   - Non-blocking
4) Exception handling

Task dependences

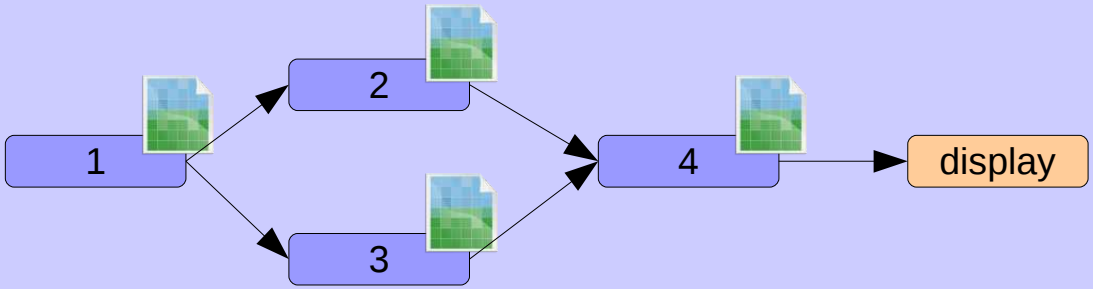



```
List images = ...;
for (int i = 0; i < images.size(); i++)
{
  TaskID id1 = task1(images.at(i));
  TaskID id2 = task2(images.at(i)) dependsOn(id1);
  TaskID id3 = task3(images.at(i)) dependsOn(id1);
  TaskID id4 = task4(images.at(i)) dependsOn(id2,id3);
  ...
}
```

Additional features

1) Different task types: `TASK(*), INTERACTIVE_TASK`
2) Task dependences: `dependsOn`
3) Task completion & return values
   - Blocking (i.e. “Futures”)
   - Non-blocking
4) Exception handling

Task completion & return values



1st approach: Blocking (typical “Future” concept)

```
...
TaskID id4 = task4(“image.jpg”);
File result = id4.getResult(); // blocking
display(result);
```

Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Helper Thread

Event queue

Event loop

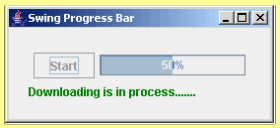
Event handler
(mouse click)
...

```
id = task4();
id.getResult();
```

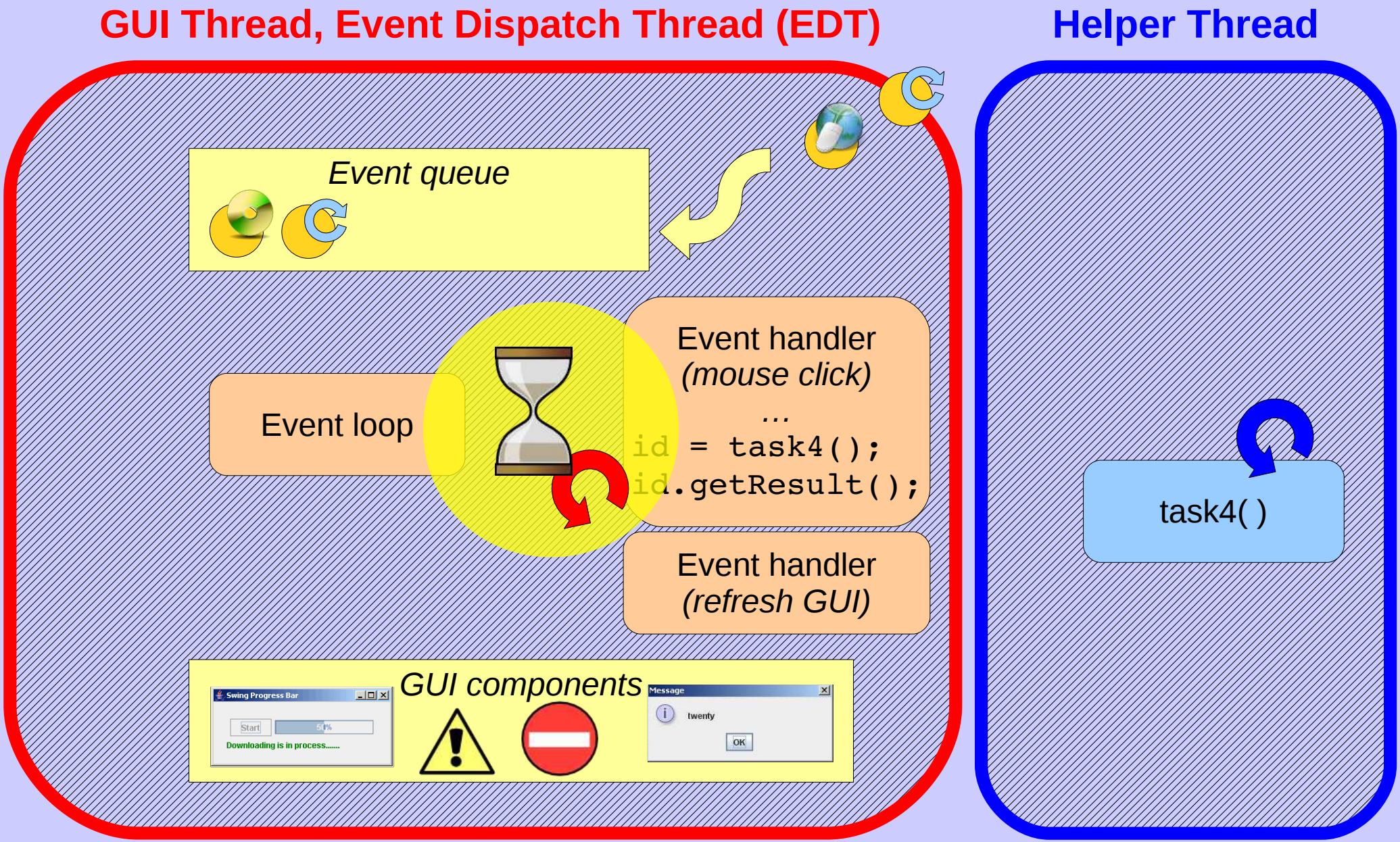
Event handler
(refresh GUI)

task4( )

GUI components



Structure of desktop applications



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Event handler
(mouse click)
...

```
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id.getResult();
```
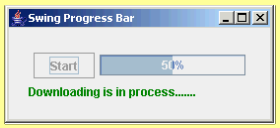

Event handler
(refresh GUI)

task4( )

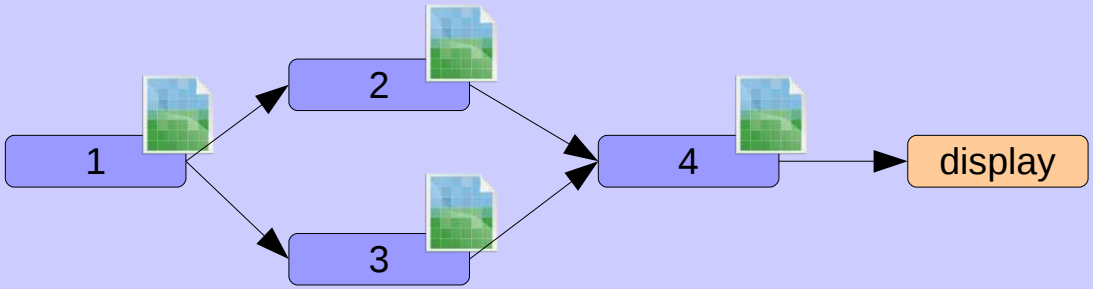
GUI components



Additional features

1) Different task types: `TASK(*), INTERACTIVE_TASK`
2) Task dependences: `dependsOn`
3) Task completion & return values
   - Blocking (i.e. “Futures”): `getResult()`
   - Non-blocking
4) Exception handling

Task completion & return values



2nd approach: Non-blocking

```
...
TaskID id4 = task4() notify(display(TaskID));
/* ... no blocking, return to Event Loop ... */
```

Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Helper Thread

Event queue

Event loop

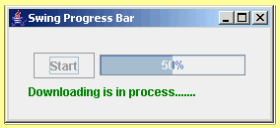
Event handler
(mouse click)
...

```
id = task4()
notify(display());
```

Event handler
(display())

task4( )

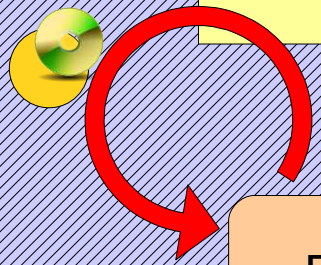
GUI components



Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Event queue



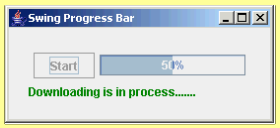
Event loop

Event handler
(mouse click)
...

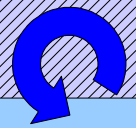
```
id = task4()
notify(display());
```

Event handler
(display())

GUI components

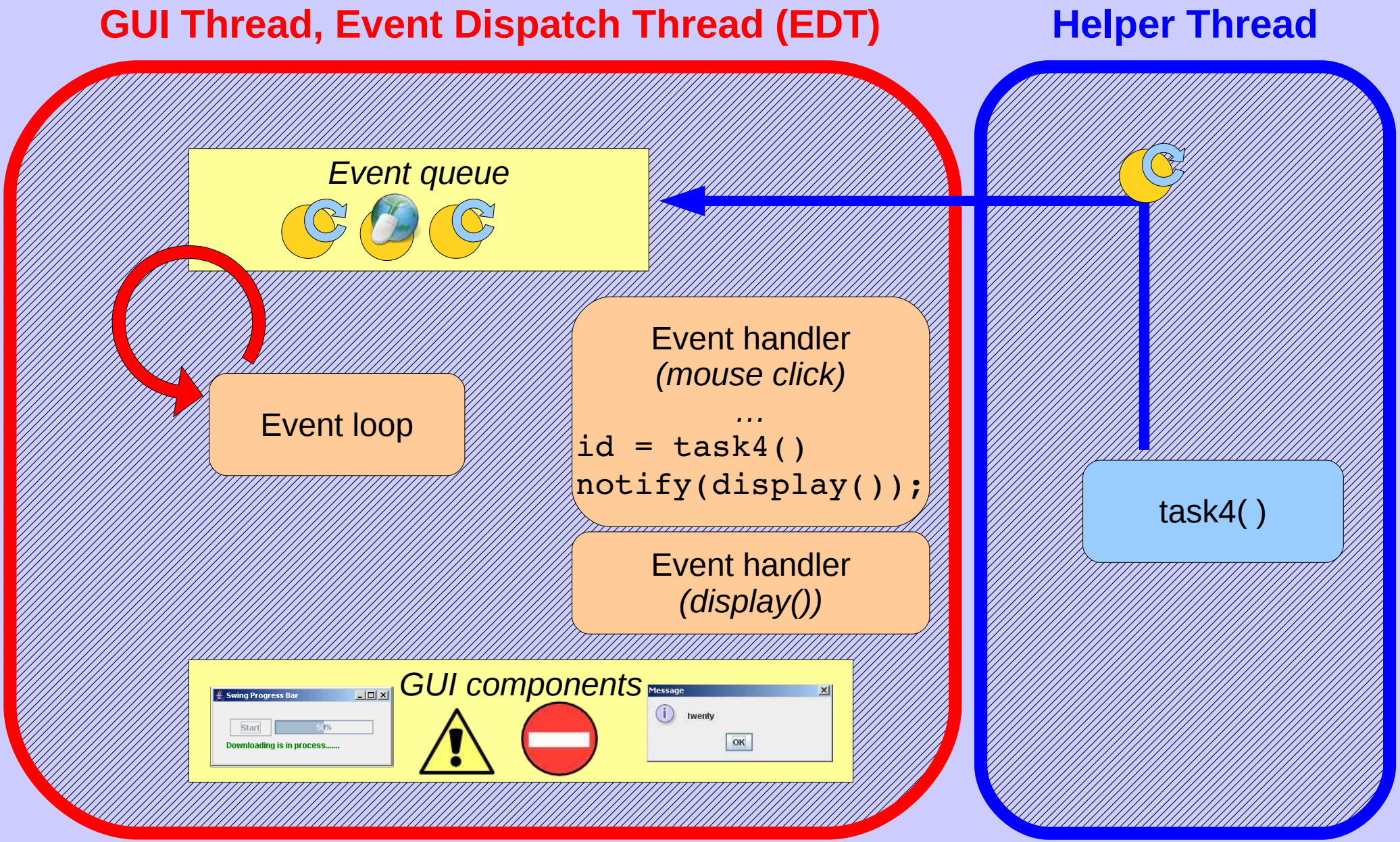


Helper Thread



task4( )

Structure of desktop applications

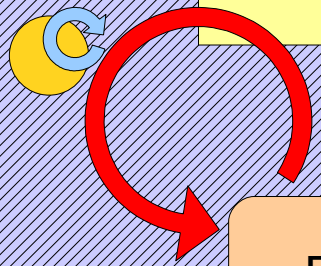


Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Helper Thread

Event queue



Event loop

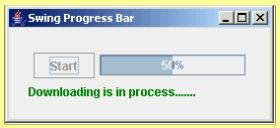
Event handler
(mouse click)
...

```
id = task4()
notify(display());
```

Event handler
(display())

task4( )

GUI components



Structure of desktop applications

GUI Thread, Event Dispatch Thread (EDT)

Helper Thread

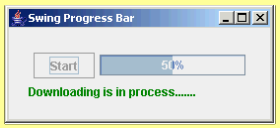
Event queue

Event loop

Event handler
(mouse click)
...
```
id = task4()
notify(display());
```

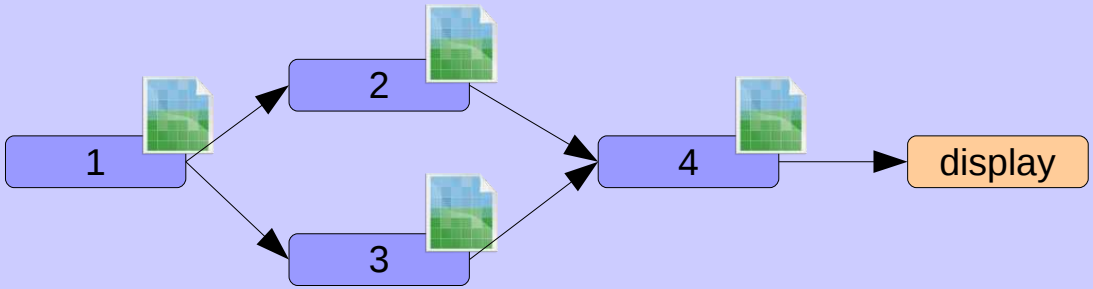
Event handler
(display())

GUI components



task4( )

Putting it all together...




```
TaskID id1 = task1(images.at(i));
TaskID id2 = task2(images.at(i)) dependsOn(id1);
TaskID id3 = task3(images.at(i)) dependsOn(id1);
TaskID id4 = task4(images.at(i)) dependsOn(id2,id3)
             notify(display(TaskID));
```

Additional features

1) Different task types: `TASK(*), INTERACTIVE_TASK`
2) Task dependences: `dependsOn`
3) Task completion & return values
   - Blocking (i.e. “Futures”): `getResult()`
   - Non-blocking: `notify`
4) Exception handling

Exception handling

```
TASK int myTask() throws IOException {
   ...
}
```

```
void myMethod() {
   ...
   TaskID id = myTask();
   ...
}
```

Exception handling

```
TASK int myTask() throws IOException {
   ...
}
```

```
void myMethod() {
   ...
   TaskID id = myTask();
   ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
       error Unhandled exception type IOException
}
```

Exception handling

```
TASK int myTask() throws IOException {
   ...
}
```

```
void myMethod() {
   ...
   TaskID id = myTask()
       trycatch(IOException handler());
}
```

Additional features

1) Different task types: `TASK(*), INTERACTIVE_TASK`
2) Task dependences: `dependsOn`
3) Task completion & return values
   - Blocking (i.e. “Futures”): `getResult()`
   - Non-blocking: `notify`
4) Exception handling: `trycatch`

Related work

- Tasks as ***objects***
  - Active objects
  - ThreadWeaver, Intel TBB, SwingWorker
- Tasks as ***functions***
  - Cilk++ / JCilk, CC++
  - Visual Studio 2010 TPL, X10, QtConcurrent
  - OpenMP tasks

Over 100 concurrent OO languages surveyed by [Philippsen 2000]

Implementation overview

```
void method() {
   ...
   myTask(“Hello”);
   ...
}
```

Main thread

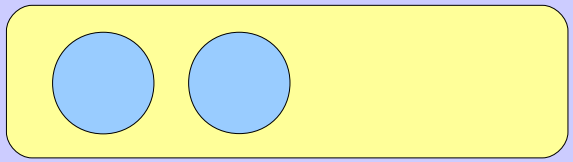
Implementation overview

```
void method() {
  ...
  myTask(“Hello”);
  ...
}
```

```
TaskID enqueue() {
  // analyse dependencies,
  // save arguments,
  // enqueue task,
  // ..., return ID
}
```

Main thread

Taskpool



Implementation overview

```
void method() {
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  myTask(“Hello”);
  ...
}
```

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TaskID enqueue() {
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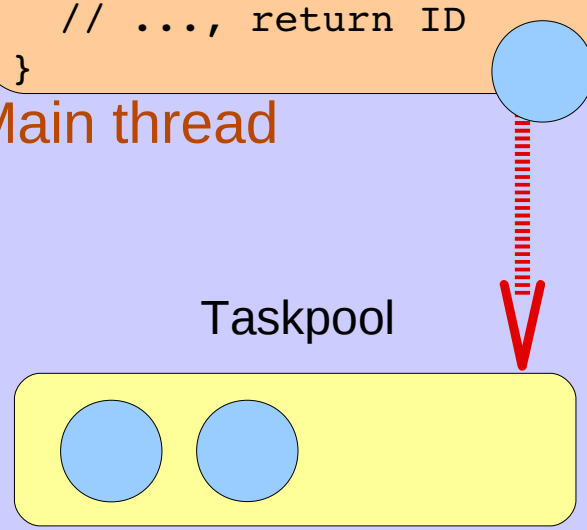
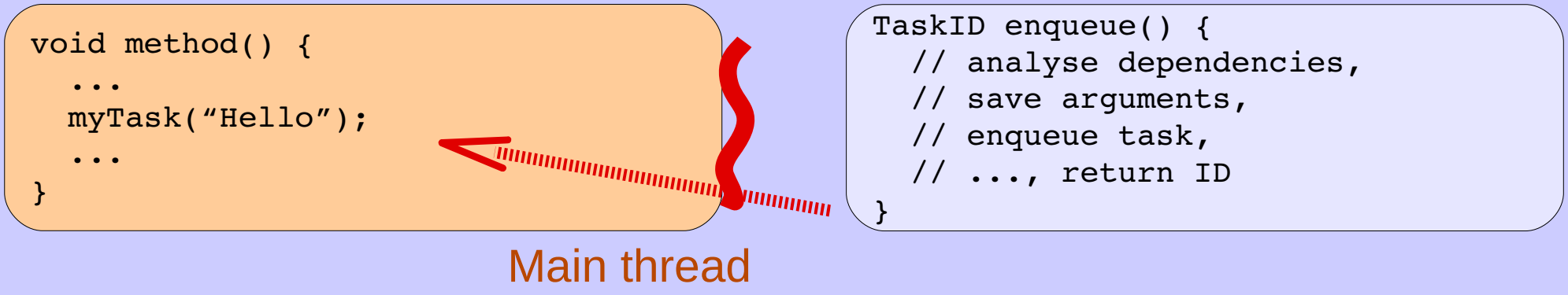
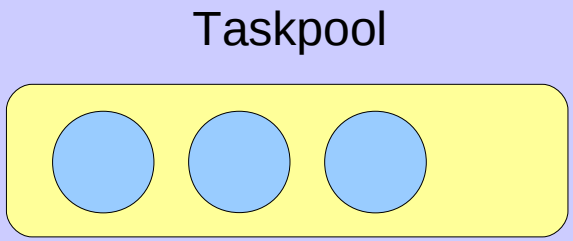
Main thread

Taskpool



Implementation overview



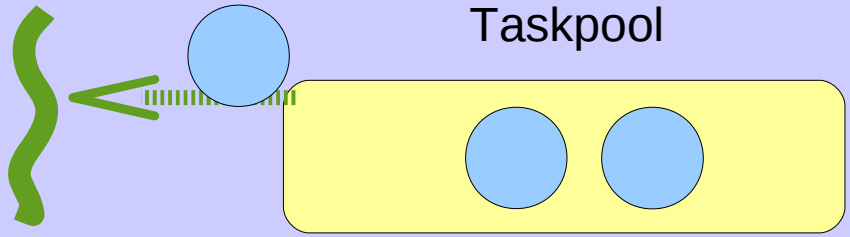


Implementation overview

```
void method() {
  ...
  myTask("Hello");
  ...
}
```

```
TaskID enqueue() {
  // analyse dependencies,
  // save arguments,
  // enqueue task,
  // ..., return ID
}
```

Main thread



Worker thread

Implementation overview

```
void method() {
  ...
  myTask("Hello");
  ...
}
```

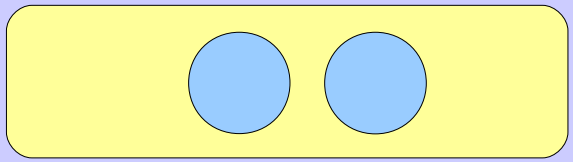
Main thread

```
TaskID enqueue() {
  // analyse dependencies,
  // save arguments,
  // enqueue task,
  // ..., return ID
}
```

```
TASK int myTask(String str) {
  // user code
}
```

Worker thread

Taskpool



Implementation overview

```
void method() {
  ...
  myTask("Hello");
  ...
}
```

Main thread

```
TaskID enqueue() {
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  // save arguments,
  // enqueue task,
  // ..., return ID
}
```

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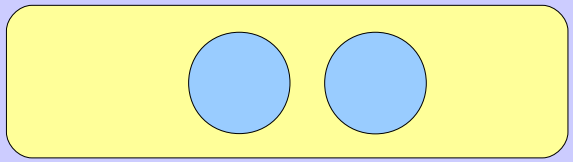
Worker thread

Taskpool



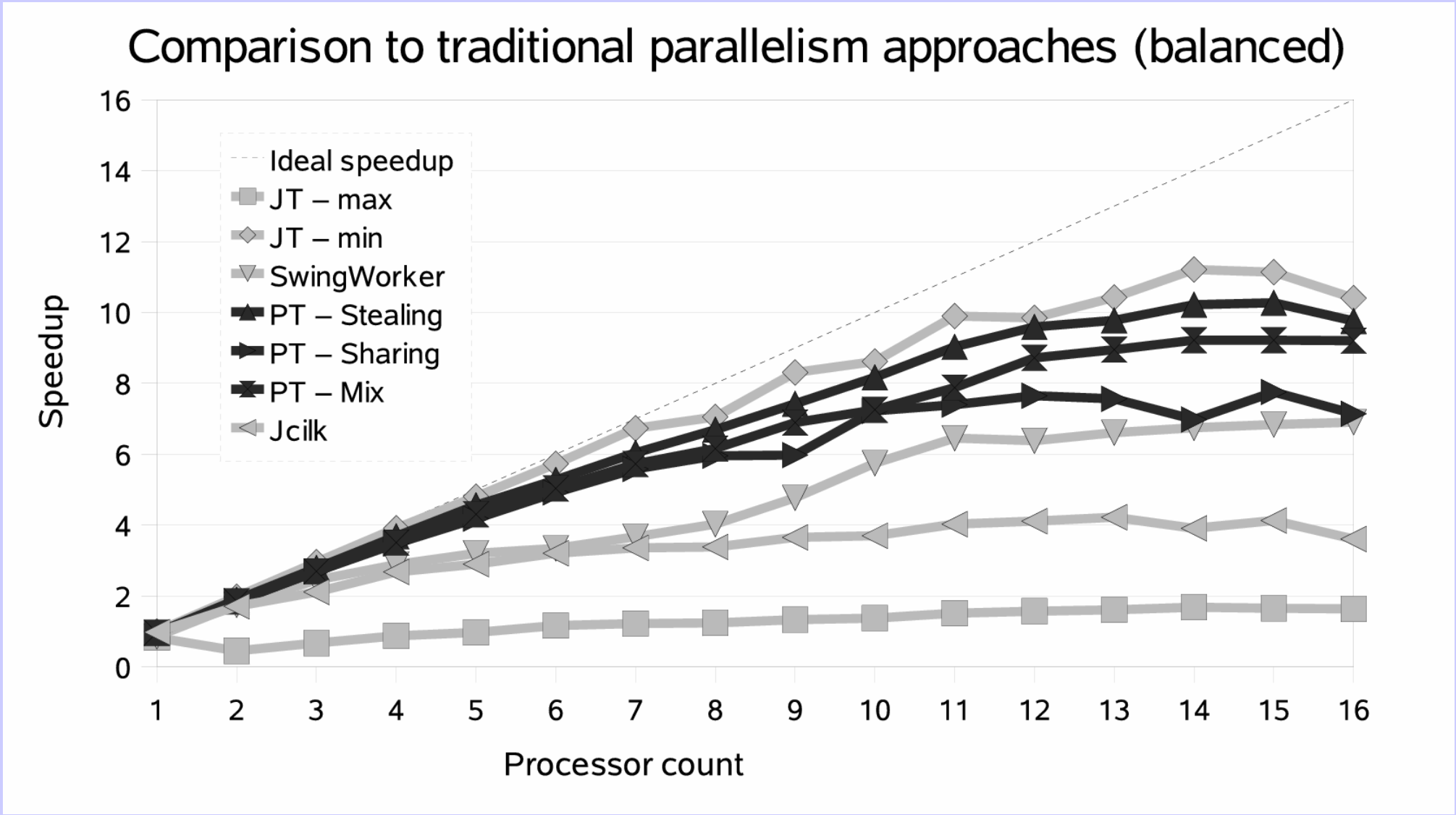
1) Source to source compiler

2) Runtime system

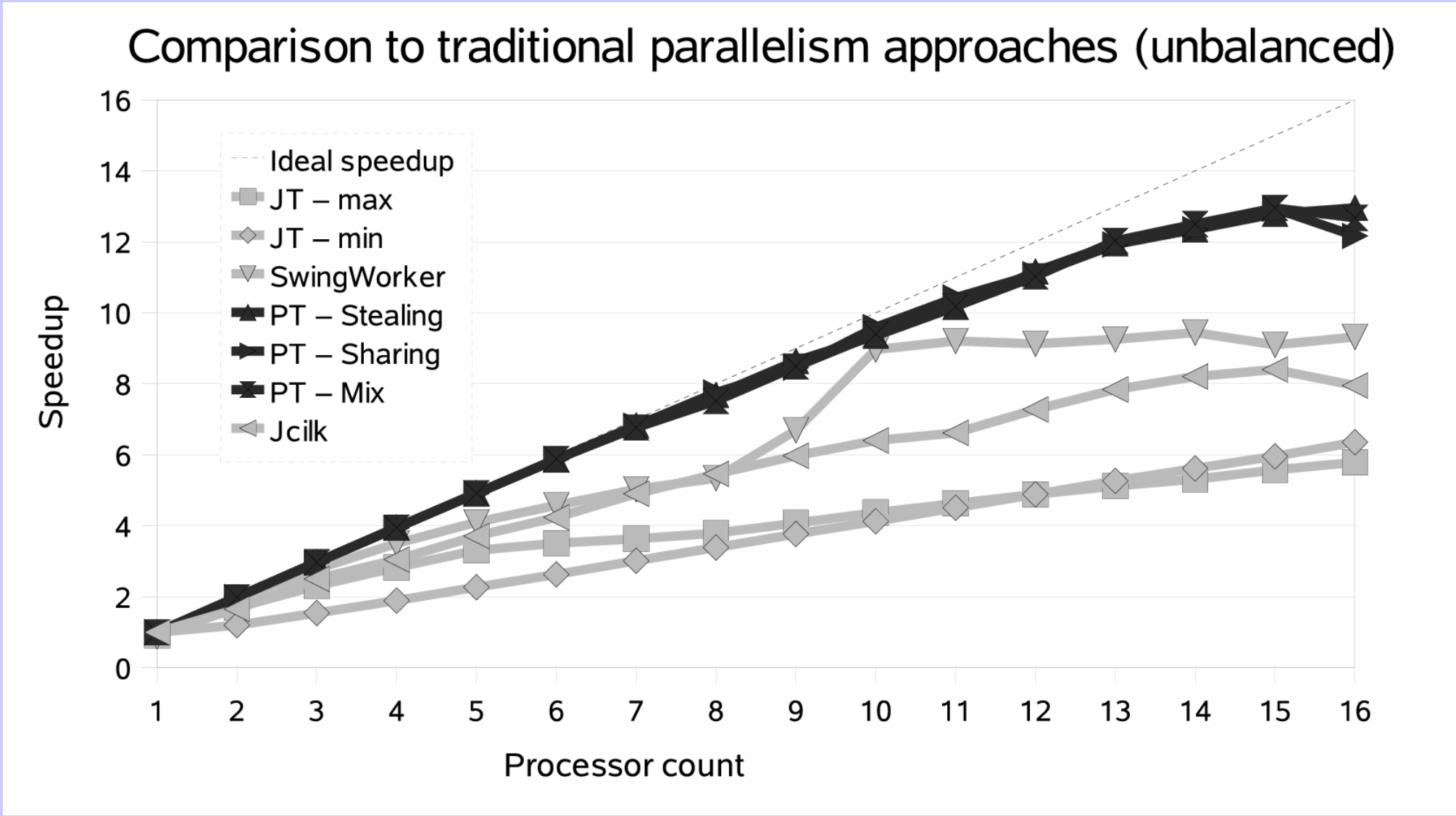
Performance

1) Compute-intensive applications
   - Balanced workload
   - Unbalanced workload
2) Disk-intensive applications
3) Recursive applications

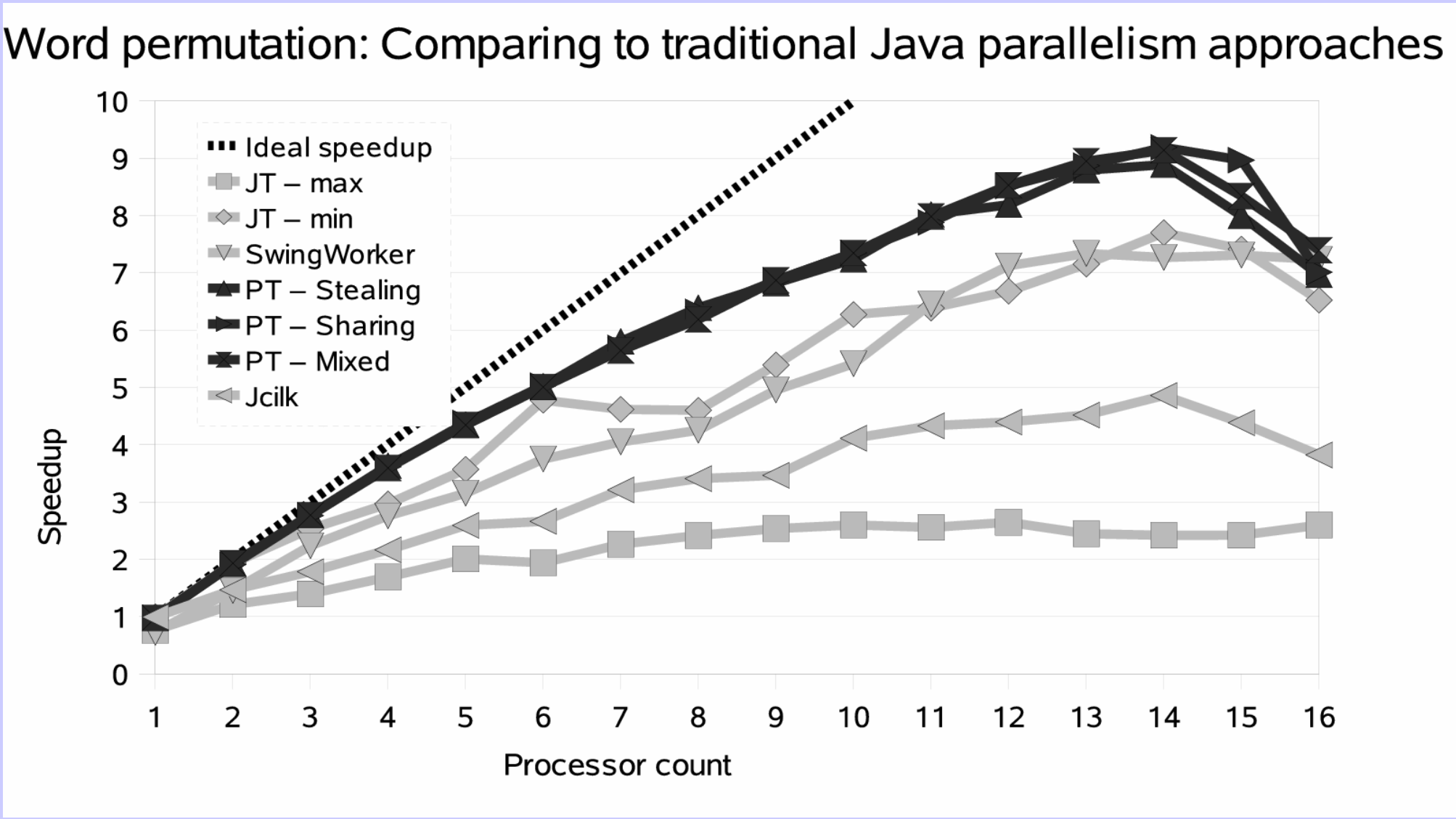
Compute-intensive & balanced workload



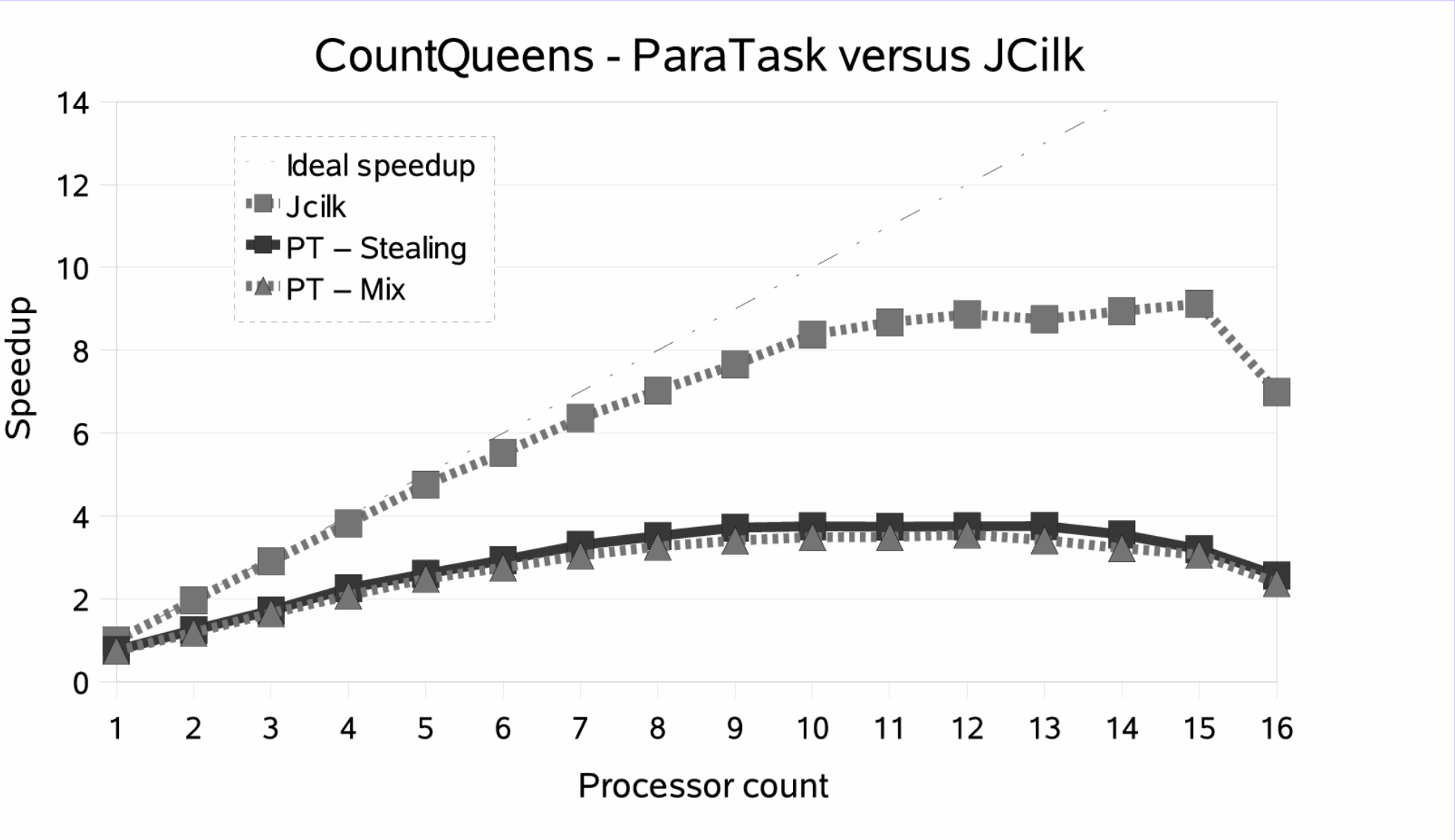
Compute-intensive & unbalanced workload



Disk-intensive workload



Recursive (fine grained)



Conclusions

- Multi-cores are here!
- Parallelisation of **desktop** applications
- OOP parallelism, familiar to developers
- Encapsulation of scheduling and parallelisation concerns
- ParaTask: different task types, dependences, non-blocking, exception handling

www.ece.auckland.ac.nz/~ngia003

Parsing task declarations

```
TASK int myTask(String str) {
   /* user code */
}
```

Parsing task declarations

```
TASK int myTask(String str) {
   /* user code */
}
```

```
TaskID myTask(String str, TaskInfo t) {
   return Taskpool.enqueue<int>(
      "__p_myTask(String)",
      t, ANY_THREAD, ARG(String, str));
}
int __p_myTask(String str) {
   /* user code */
}
```

Parsing task declarations

```
TASK int myTask(String str) {
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TaskID myTask(String str, TaskInfo t) {
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}
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   /* user code */
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```

Parsing task invocations

```
TaskID id2 = myTask(“Hello”) dependsOn(id1)
    notify(slot(), obj::slot2());
```

Parsing task invocations

```
TaskID id2 = myTask(“Hello”) dependsOn(id1)
    notify(slot(), obj::slot2());
```

```
TaskInfo __p_id2 = new TaskInfo();
__p_id2.addDependency(id1);
__p_id2.addNotify(this, “slot()”);
__p_id2.addNotify(obj, “slot2()”);
TaskID id2 = myTask(“Hello”, __p_id2);
```

Parsing task invocations

```
TaskID id2 = myTask(“Hello”) dependsOn(id1)
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```

```
TaskInfo __p_id2 = new TaskInfo();
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Parsing task invocations

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__p_id2.addNotify(obj, “slot2()”);
TaskID id2 = myTask(“Hello”, __p_id2);
```

Parsing task invocations

```
TaskID id = myTask("Hello") trycatch(
                    IOException handler());
```

```
TaskInfo __p_id = new TaskInfo();
Method _h = [Java reflection get "handler()"]
__p_id.addExcHandler(IOException.class, _h);
TaskID id = null;
try {
  id = myTask("Hello", __p_id);
} catch(IOException e){}
```

Parsing task invocations

```
TaskID id = myTask("Hello") trycatch(
                    IOException handler());
```

```
TaskInfo __p_id = new TaskInfo();
Method _h = [Java reflection get "handler()"]
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Parsing task invocations

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TaskID id = null;
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} catch(IOException e){}
```

Parsing task invocations

```
TaskID id = myTask("Hello") trycatch(
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TaskInfo __p_id = new TaskInfo();
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__p_id.addExcHandler(IOException.class, _h);
TaskID id = null;
try {
  id = myTask("Hello", __p_id);
} catch(IOException e){}
```
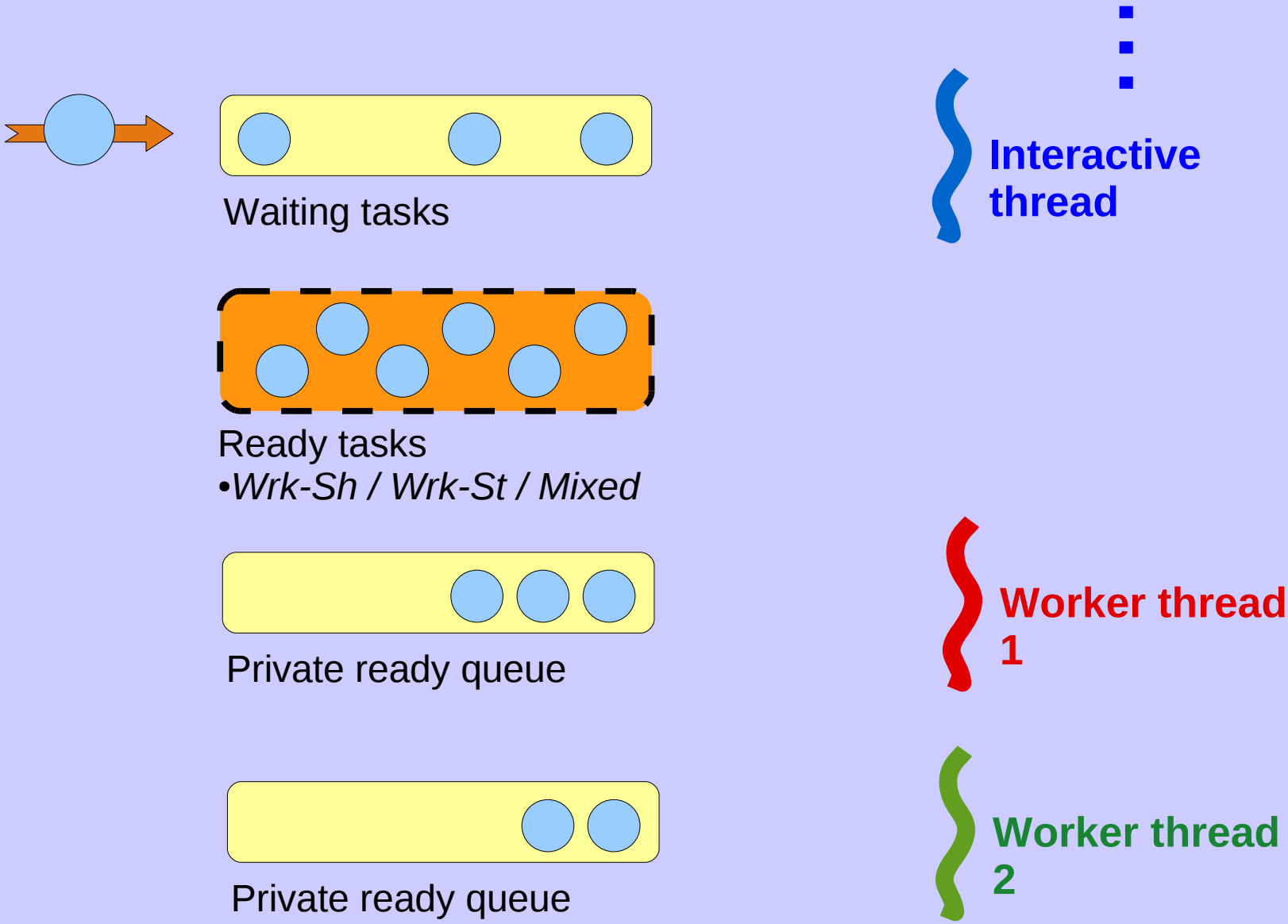
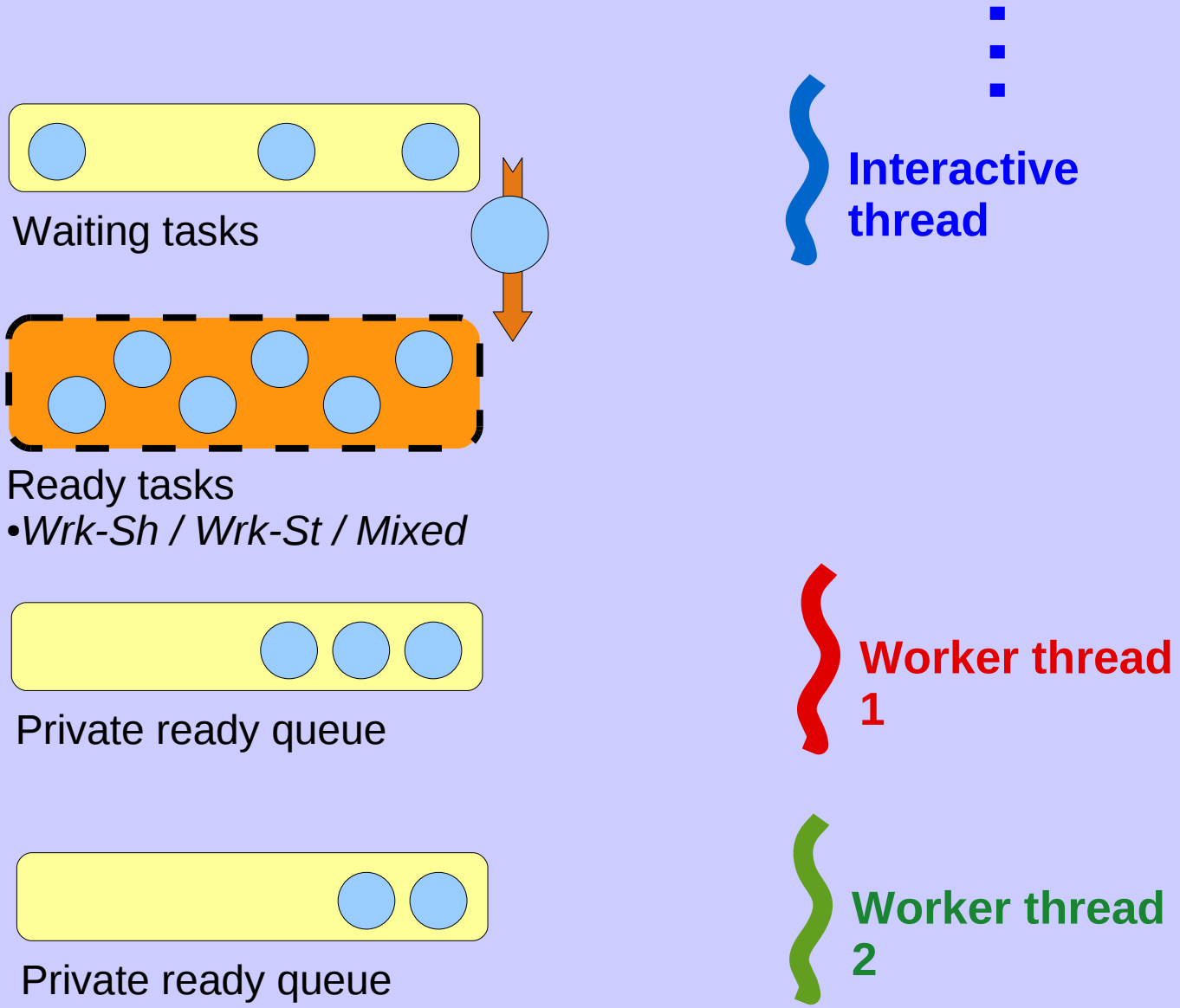
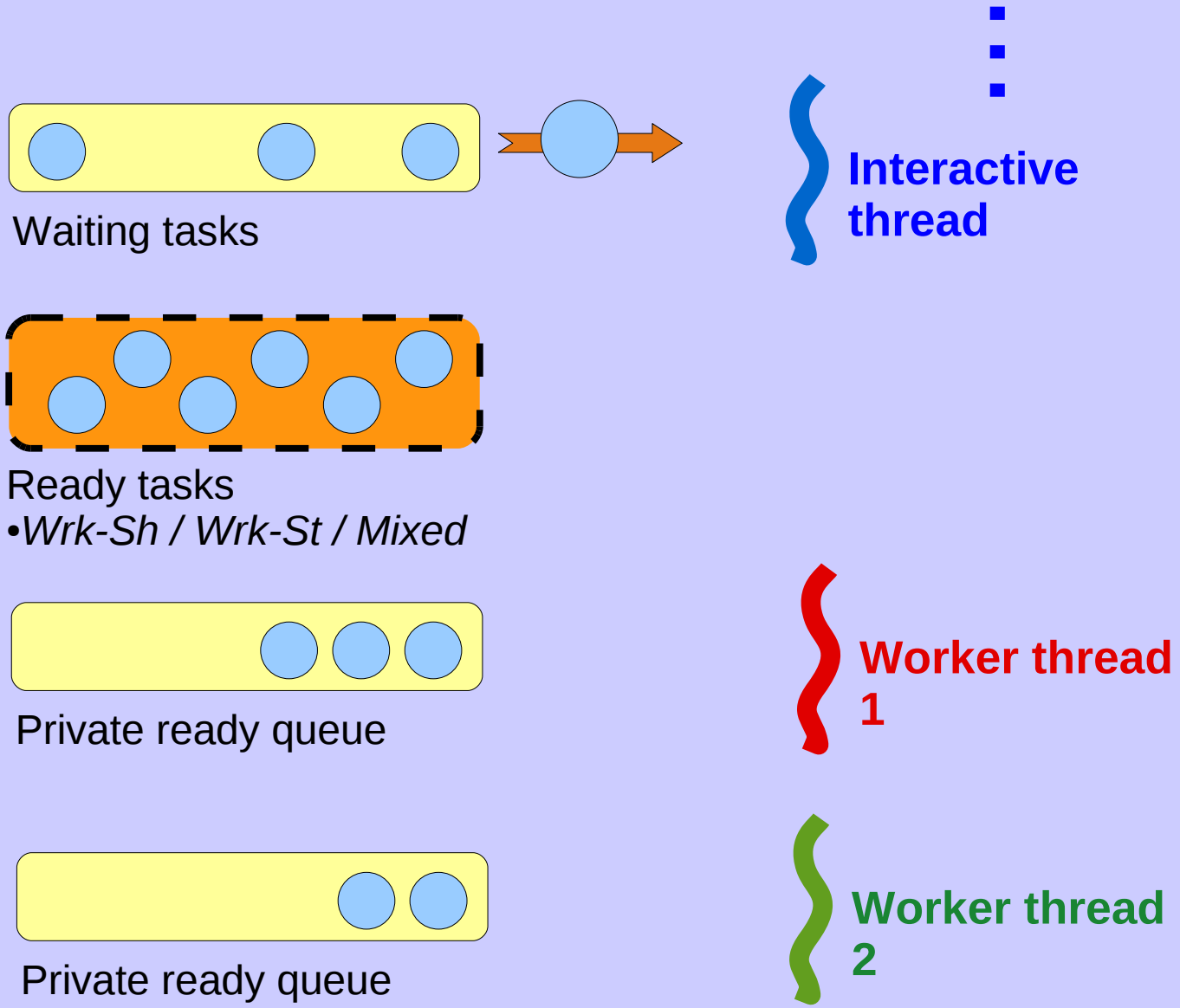

Runtime system



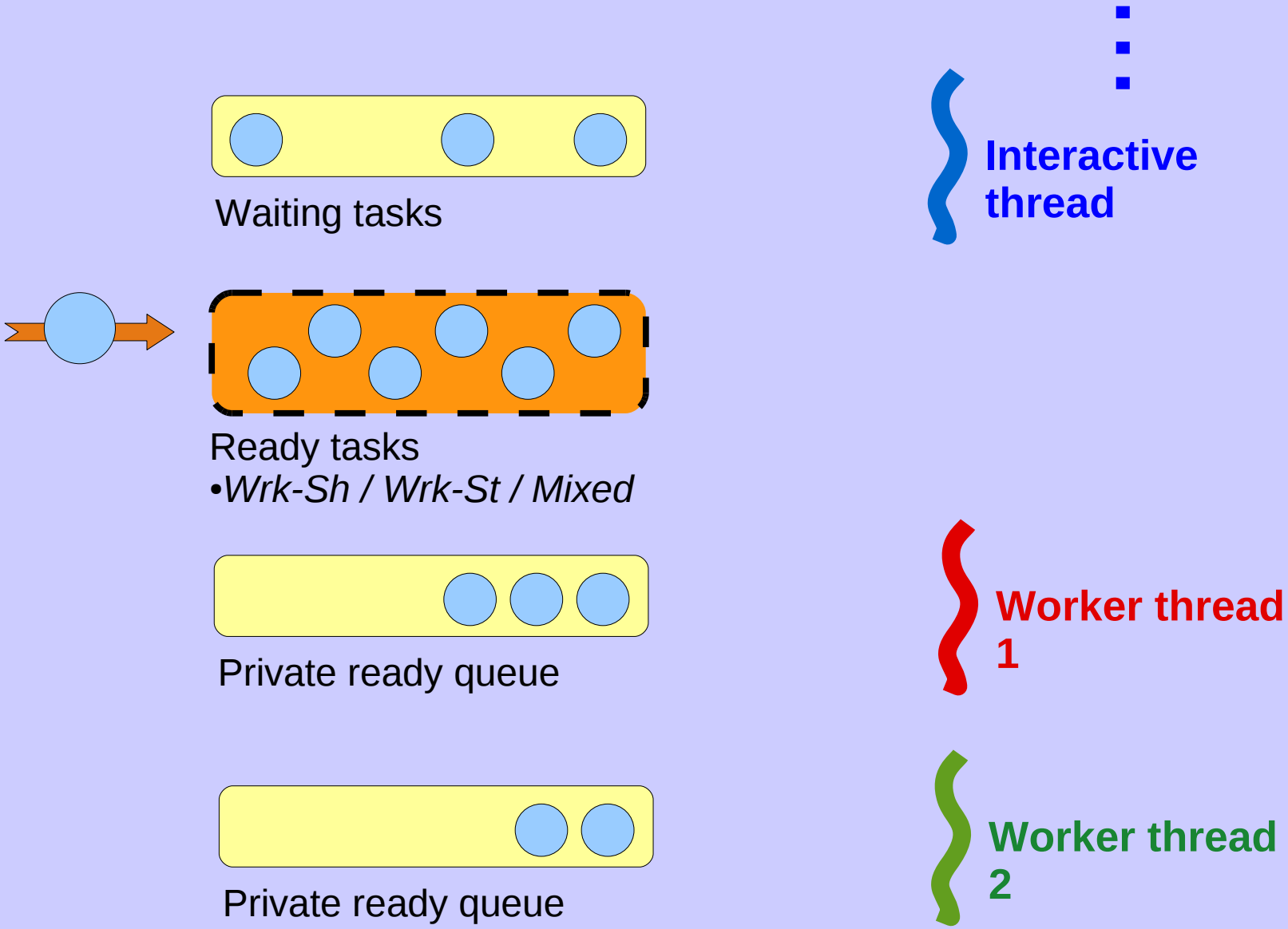
Runtime system



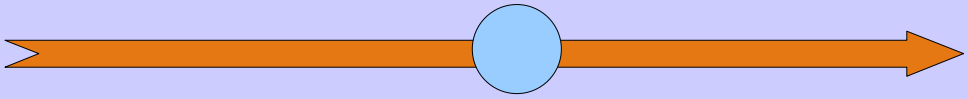
Runtime system

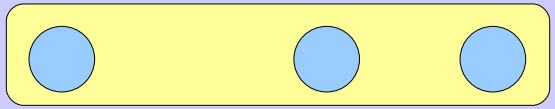


Runtime system

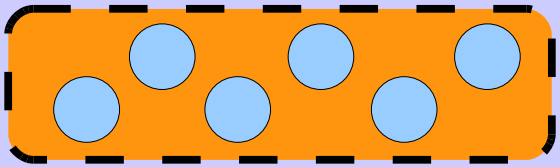


Runtime system

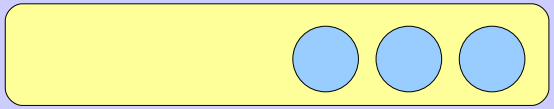




Waiting tasks

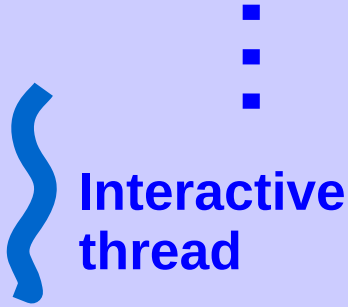


Ready tasks
•*Wrk-Sh / Wrk-St / Mixed*



Private ready queue

Private ready queue

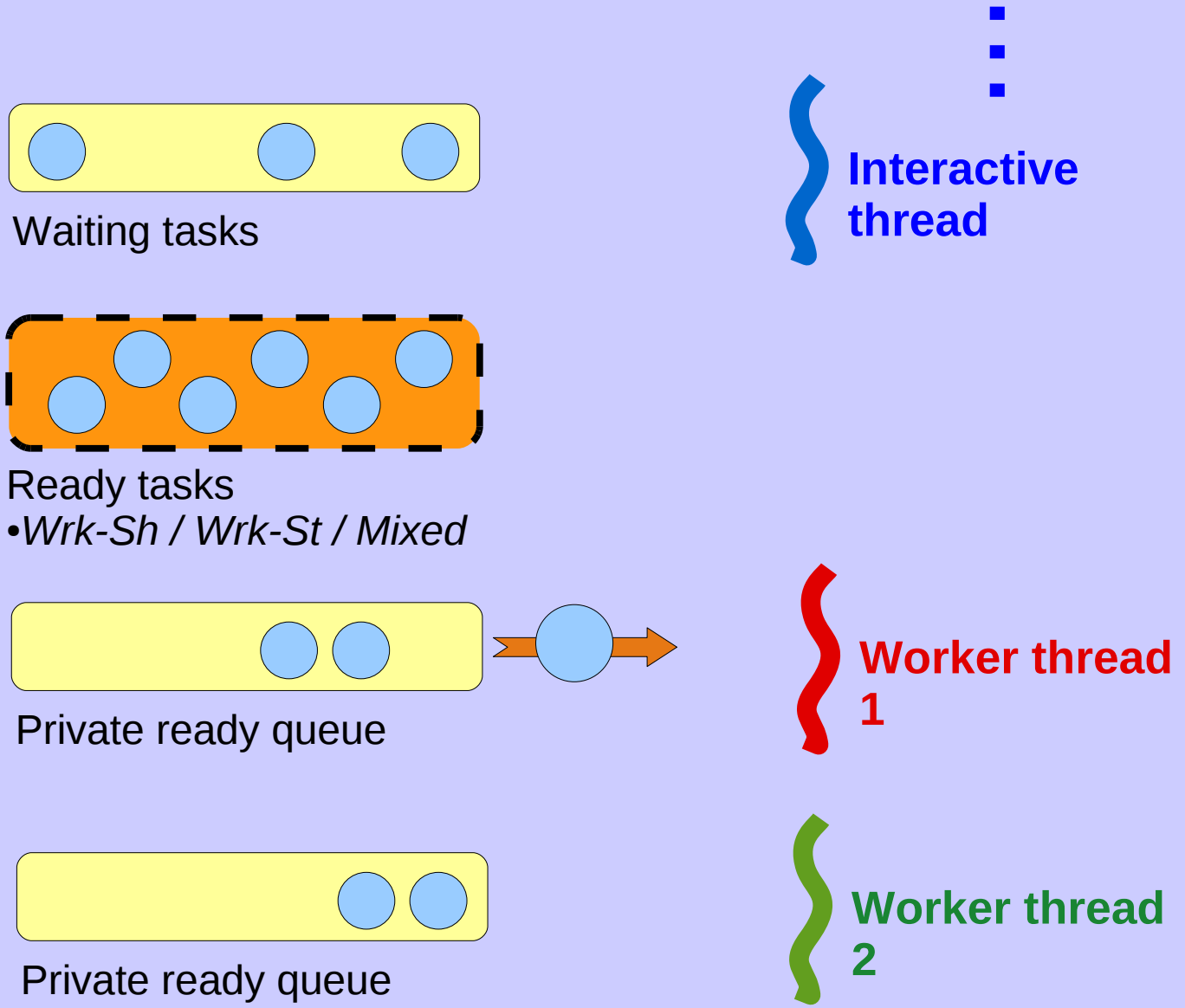


Interactive thread

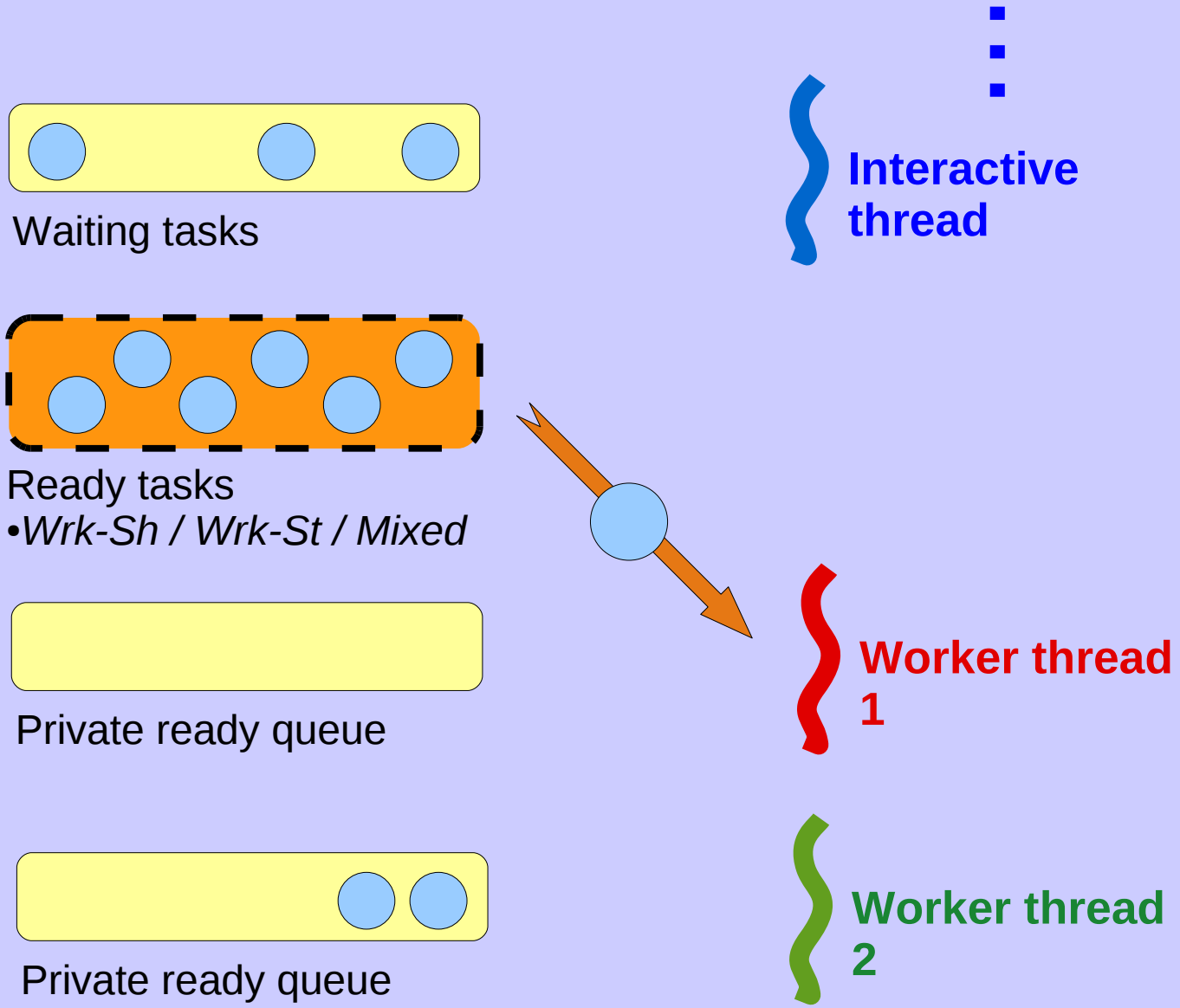
Worker thread 1

Worker thread 2

Runtime system



Runtime system



Runtime system