Introduction to Spin and Promela

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What is this all about?

- Spin
  - On-the-fly verifier developed at Bell-labs by Gerard Holzmann and others
- Promela
  - Modeling language for SPIN
  - Targeted at asynchronous systems
    - Switching protocols

Roadmap

- Historical perspective
- Overview of Spin
- Overview of Promela
- Simulation with Spin
- Overview of LTL
- Verification with Spin

Part I
Historical Perspective

History

- Work leading to Spin started in 1980
  - First bug found on Nov 21, 1980 by Pan
  - One-pass verifier for safety properties
- Succeeded by Pandora (82), Trace (83), SuperTrace (84), SdlValid (88), Spin (89)
- Spin covered omega-regular properties

Meanwhile …

- Temporal logic model checking
  - Clarke et. al. CMU 1981
  - Sifakis et. al. Grenoble 1982
- Symbolic model checking
  - McMillan 1991
  - SMV

Currently ..

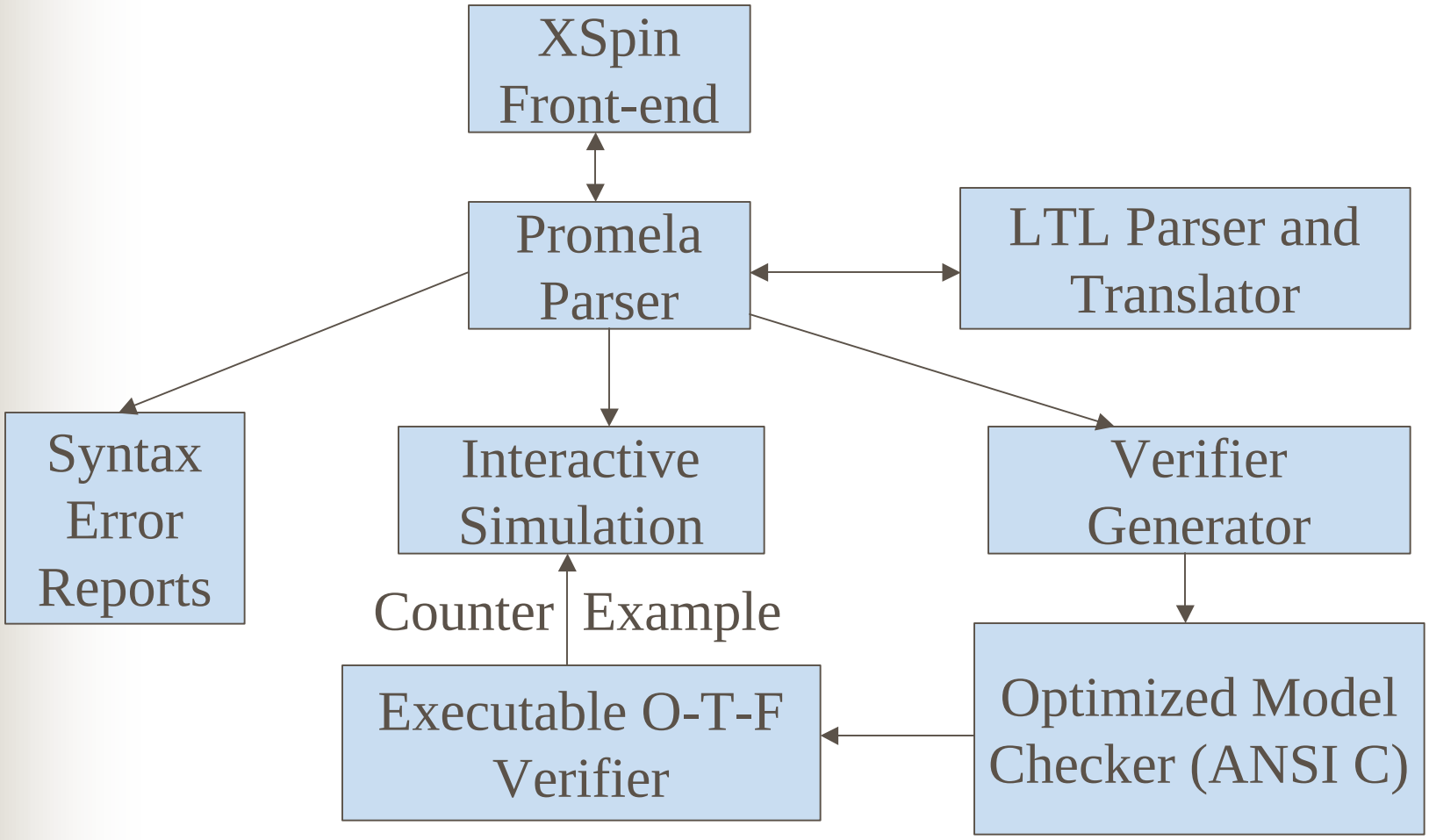
- Theory of symbolic and on-the-fly model checking well-understood
- Algorithms for different logics suited for different implementations
  - CTL properties – symbolic
  - LTL properties – on-the-fly

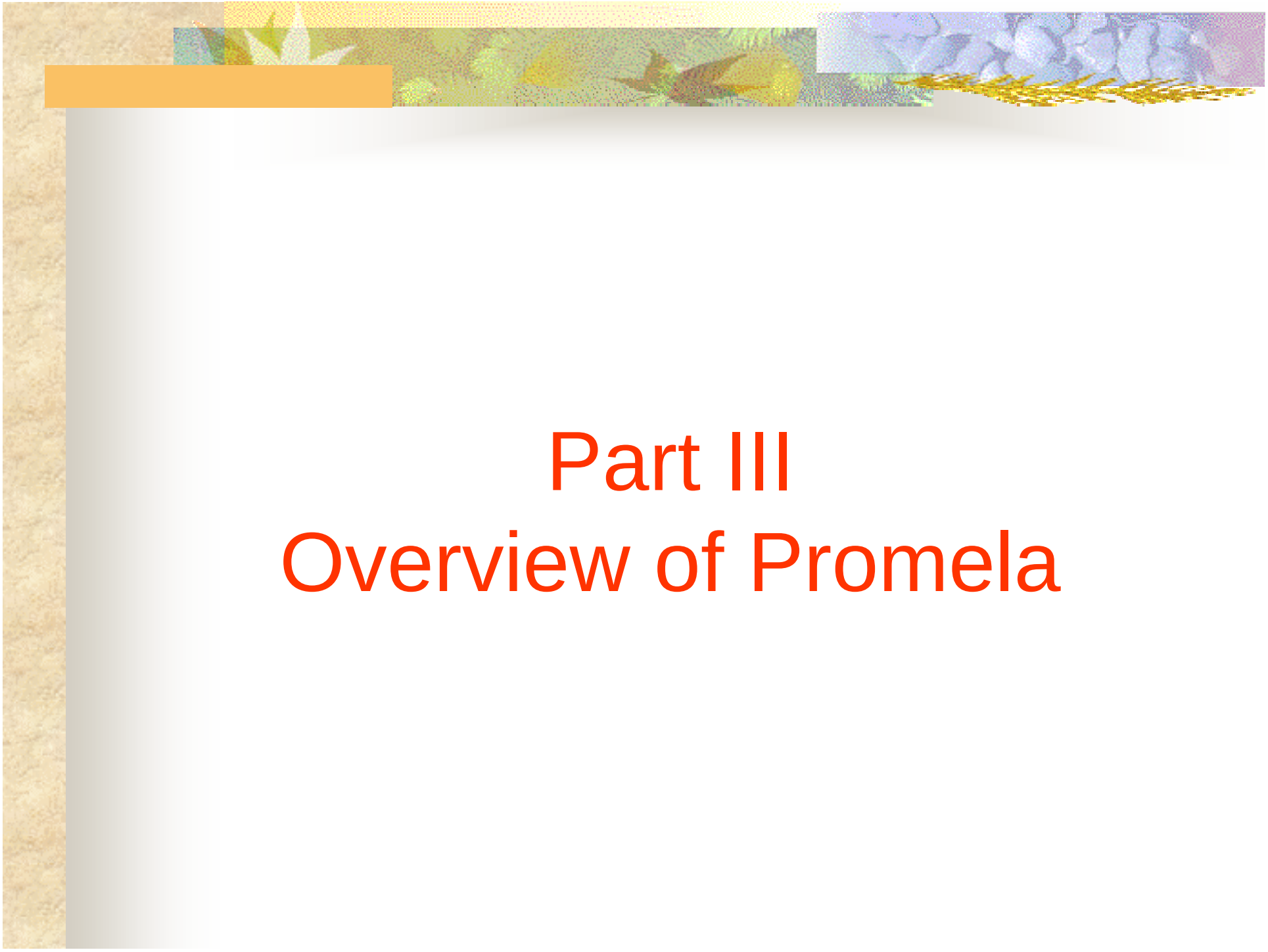
Part II
Overview of Spin

Spin capabilities

- Interactive simulation
  - For a particular path
  - For a random path
- Exhaustive verification
  - Generate C code for verifier
  - Compile the verifier and execute
  - Returns counter-example
- Lots of options for fine-tuning

Spin overall structure





Part III
Overview of Promela

Promela

- Language for asynchronous programs
  - Dynamic process creation
  - Processes execute asynchronously
  - Communicate via shared variables and message channels
    - Races must be explicitly avoided
    - Channels can be queued or rendezvous
  - Very C like

Executability

- No difference between conditions and statements
  - Execution of every statement is conditional on its executability
  - Executability is the basic means of synchronization

Executbility

- Declarations and assignments are always executable
- Conditionals are executable when they hold
- The following are the same
  - while (a != b) skip
  - (a == b)

Delimitors

- Semi-colon is used a statement separator not a statement terminator
  - Last statement does not need semi-colon
  - Often replaced by -> to indicate causality between two successive statements
  - (a == b); c = c + 1
  - (a == b) -> c = c + 1

Data Types

- Basic : bit/bool, byte, short, int, chan
- Arrays: fixed size
  - byte state[20];
  - state[0] = state[3 * i] + 5 * state[7/j];
- Symbolic constants
  - Usually used for message types
  - mtype = {SEND, RECV};

Process types

byte state = 2;

proctype A() { (state == 1) -> state = 3 }

proctype B() { state = state – 1 }

Process instantiation

```
byte state = 2;
proctype A() { (state == 1) -> state = 3 }
proctype B() { state = state – 1 }
init { run A(); run B() }
```

- *run* can be used anywhere

Parameter passing

```
proctype A(byte x; short foo) {
    (state == 1) -> state = foo
}
init { run A(1,3); }
```

- Data arrays or processes cannot be passed

Variable scoping

- Similar to C
  - globals, locals, parameters

```
byte foo, bar, baz;
proctype A(byte foo) {
    byte bar;
    baz = foo + bar;
}
```

Races and deadlock

```
byte state = 1;
proctype A() {
    (state == 1) -> state = state + 1
}
proctype B() {
    (state == 1) -> state = state – 1
}
init { run A(); run B() }
```

Atomic sequences

```
byte state = 1;
proctype A() { atomic {
    (state == 1) -> state = state + 1
}   }
proctype B() { atomic {
    (state == 1) -> state = state – 1
}   }
init() { run A(); run B() }
```

Message passing

- Channel declaration
  - chan qname = [16] of {short}
  - chan qname = [5] of {byte,int,chan,short}
- Sending messages
  - qname!expr
  - qname!expr1,expr2,expr3
- Receiving messages
  - qname?var
  - qname?var1,var2,var3

Message passing

- More parameters sent
  - Extra parameters dropped
- More parameters received
  - Extra parameters undefined
- Fewer parameters sent
  - Extra parameters undefined
- Fewer parameters received
  - Extra parameters dropped

Message passing

```
chan x = [1] of {bool};
chan y = [1] of {bool,bool};

proctype A(bool p, bool q) { x!p,q ; y?p }

proctype B(bool p, bool q) { x?p,q ; y!q }

init { run A(1,2); run B(3,4) }
```

Message passing

- Convention: first message field often specifies message type (constant)
  - Alternatively send message type followed by list of message fields in braces
  - qname!expr1(expr2,expr3)
  - qname?var1(var2,var3)

Executability

- Send is executable only when the channel is not full
- Receive is executable only when the channel is not empty

Executability

- Optionally some arguments of receive can be constants
  - qname?RECV,var,10
  - Value of constant fields must match value of corresponding fields of message at the head of channel queue

Queue length

- *len(qname)* returns the number of messages currently stored in *qname*
- If used as a statement it will be unexecutable if the channel is empty

Composite conditions

- Invalid in Promela
  - (qname?var == 0)
  - (a > b && qname!123)
  - Either send/receive or pure expression
- Can *evaluate* receives
  - qname?[ack,var]

Subtle issues

- Consider the following
  - qname?[msgtype] -> qname?msgtype
  - (len(qname) < MAX) -> qname!msgtype
- Second statement not necessarily executable after the first
  - Race conditions

Time for example 1

Rendezvous

- Channel of size 0 defines a rendezvous port
  - Can be used by two processed for a synchronous handshake
  - No queueing
  - The first process blocks
  - Handshake occurs after the second process arrives

Example

```
#define msgtype 33
chan name = [0] of {byte,byte};

proctype A() {
    name!msgtype(99); name!msgtype(100)
}

proctype B() {byte state; name?msgtype(state)}

init { run A(); run B() }
```

Control flow

- We have already seen some
  - Concatenation of statements, parallel execution, atomic sequences
- There are a few more
  - Case selection, repetition, unconditional jumps

Case selection

```
If
:: (a < b) -> option1
:: (a > b) -> option2
:: else -> option3              /* optional */
fi
```

- Cases need not be exhaustive or mutually exclusive
  - Non-deterministic selection

Time for example 2

Repetition

```
byte count = 1;
proctype counter() {
    do
    :: count = count + 1
    :: count = count – 1
    :: (count == 0) -> break
    od
}
```

Repetition

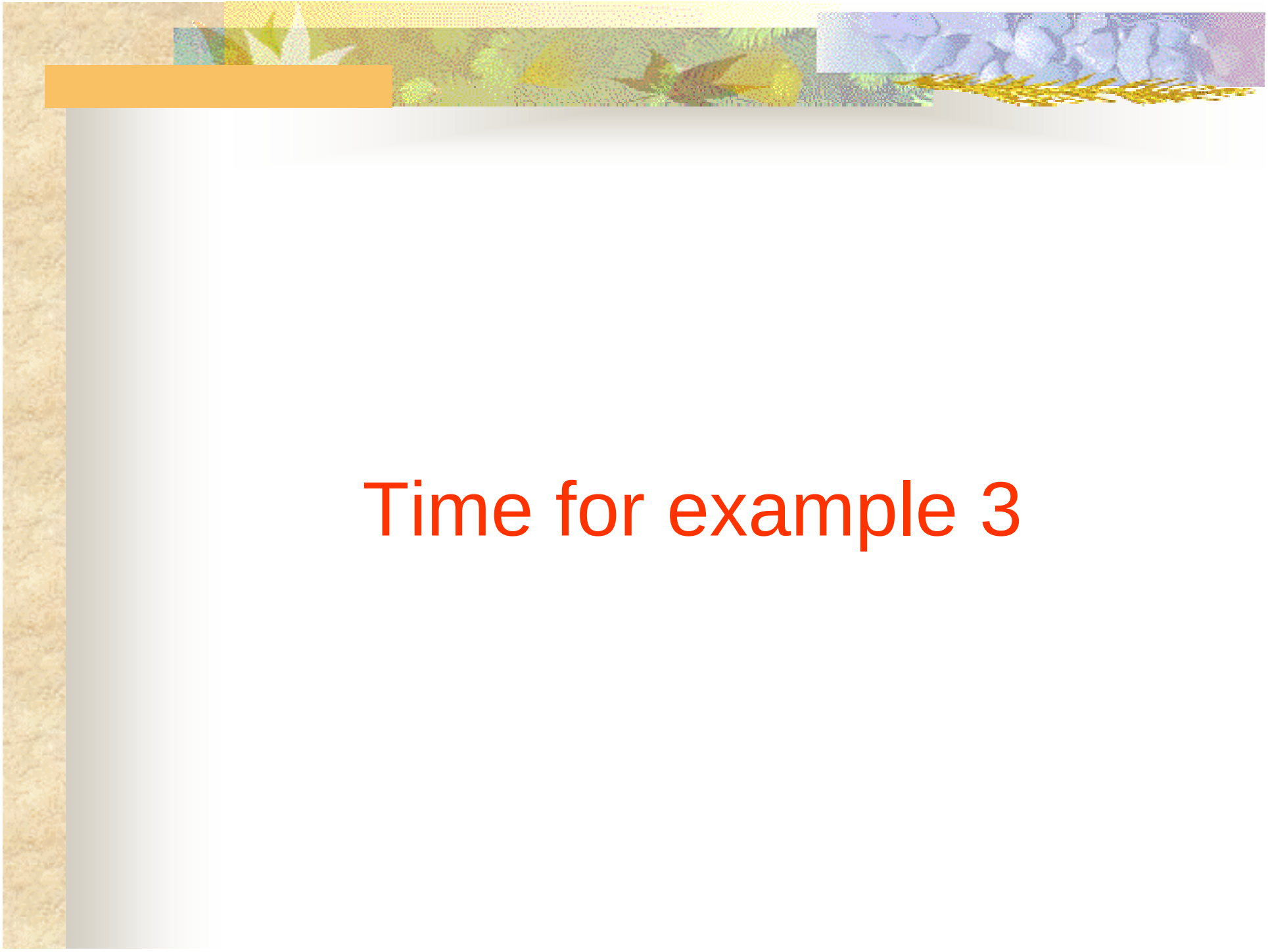
```
proctype counter()
{
        do
        :: (count != 0) ->
                if
                :: count = count + 1
                :: count = count – 1
                fi
        :: (count == 0) -> break
        od
}
```

Unconditional jumps

```
proctype Euclic (int x, y) {
    do
    :: (x > y) -> x = x – y
    :: (x < y) -> y = y – x
    :: (x == y) -> goto done
    od ;
done:  skip
}
```

Procedures and Recursion

- Procedures can be modeled as processes
  - Even recursive ones
  - Return values can be passed back to the calling process via a global variable or a message


Time for example 3

Timeouts

```
Proctype watchdog() {
    do
    :: timeout -> guard!reset
    od
}
```

- Get enabled when the entire system is deadlocked
- No absolute timing considerations

Assertions

- assert(any_boolean_condition)
  - pure expression
- If condition holds -> no effect
- If condition does not hold -> error report during verification with Spin

Time for example 4

References

- http://cm.bell-labs.com/cm/cs/what/spin/
- http://cm.bell-labs.com/cm/cs/what/spin/Man/Manual.html
- http://cm.bell-labs.com/cm/cs/what/spin/Man/Quick.html