Deployment Components with Parametric Concurrency

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HATS
Highly Adaptable and Trustworthy Software using Formal Models

SEVENTH FRAMEWORK PROGRAMME

http://www.hats-project.eu

Outline

1. Motivation and aim
2. The Abs language
3. Time model
4. Deployment components
5. Resource reallocation
6. Conclusions and future work

Motivation

Software systems tend to be released for a range of different architectures

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Examples

- Software Product Lines
- Embedded Systems
- Sensors
- Web Services
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Need to model software which ranges over deployment scenarios

Abstraction levels in modeling

Specification level	Modeling formalisms
Design-oriented	Graphical notations
↕	↕
?	?
↕	↕
Implementation-oriented	Spec#, Java+JML

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Abstract behavioral modeling language for distributed active objects

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Syntactic categories.

C, I, m in Names
g in Guard
s in Stmt
x in Var
e in Expr
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Definitions.

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\begin{array}{rcl}
IF & ::= & \mathbf{interface}\ I\ \{\ [\overline{Sg}]\ \} \\
CL & ::= & \mathbf{class}\ C\ [(\overline{I\ x})]\ [\mathbf{implements}\ \overline{I}]\ \{\ [\overline{I\ x;}]\ \overline{M}\} \\
Sg & ::= & I\ m\ ([\overline{I\ x}]) \\
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s & ::= & s; s \mid x := rhs \mid \mathbf{release} \mid \mathbf{await}\ g \mid \mathbf{return}\ e \\
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- Every object has a set of processes to be executed
- At most one process per object is *active*, the others are *suspended*
- Scheduling is controlled by await statements
- Compositional proof theory, implemented in KeY

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Paper: **Lightweight Time Modeling in Timed Creol**

Proc. 1st Int. Workshop on Rewriting Techniques for Real-Time Systems (RTRTS 2010), ENTCS 36:67–81, 2010

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Apply performance analysis to OO models which range over deployment scenarios

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Processing resources are:

- Shared between the concurrent objects of a deployment component
- Updated for every *time interval*

Approach

- Propose an abstract model of *deployment components*
  - Concurrent object groups
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  - Time model
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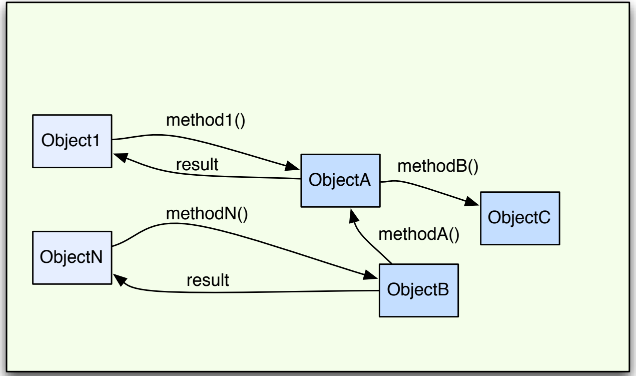
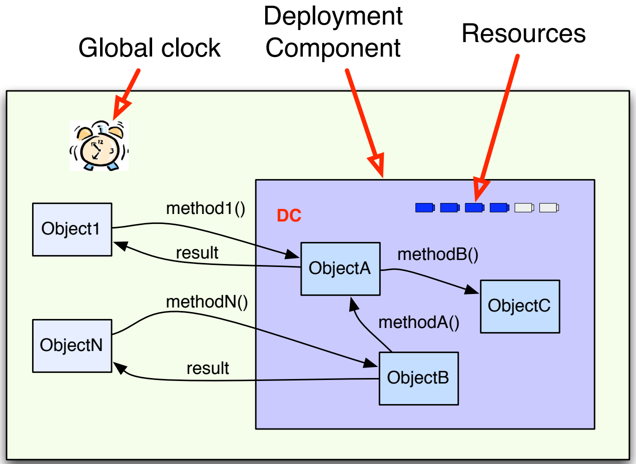
  - Resource reallocation
- Operational semantics in rewriting logic
  - Executable prototype using Maude
  - Language interpreter
  - Simulation of model behavior
  - Test suites

Model



Object1
method1()
result
ObjectA
methodB()
ObjectC
methodN()
methodA()
ObjectN
result
ObjectB

Model with DC



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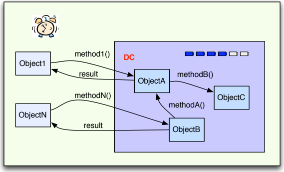
- Resources reflect the execution capacity of the deployment component in a time interval

Deployment Components (2)

Consider a deployment component D with r units of processing resources and G objects



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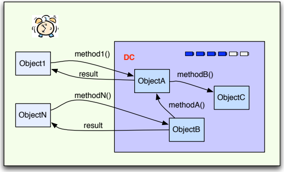

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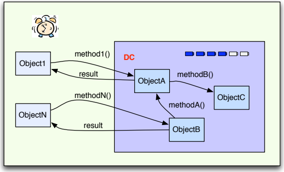

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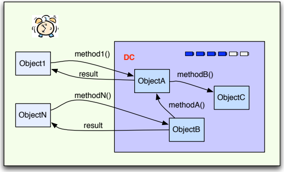

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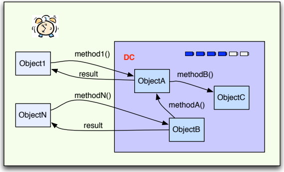

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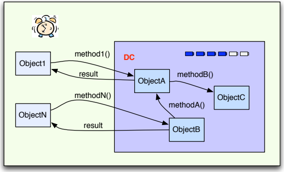

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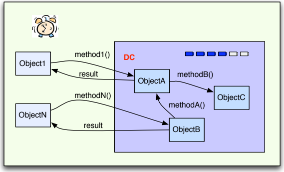
Execution inside the time interval stops when no units of resources are available or the objects are blocked

Abs Syntax Extension



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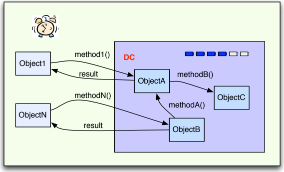

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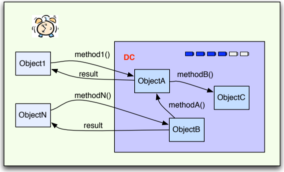

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  dc := **component** (r) ;

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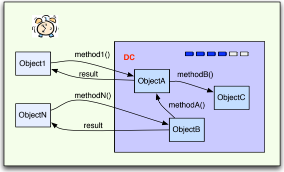

Extension of the Syntax of Abs:

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- An optional clause in the object creation

  new *C*($\overline{e}$) **in** dc;

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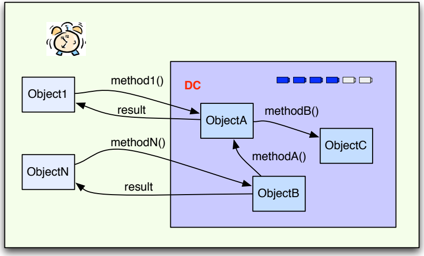
Extend the configurations with:

- Global clock
  $\langle\ t$:`Clock | Limit:`$l\ \rangle$
- Deployment components
  $\langle\ dc$:`Comp|Free:`r`, Limit:`$l\ \rangle$
- Object attribute **`mycomp`**



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Old rule:

$$\textbf{rl}\ [\mathit{skip}]:\ \langle o : C \mid \texttt{Pr:}\ \{\bar{l} \mid \texttt{skip;}\ \bar{s}\}\ \rangle$$
$$\longrightarrow\ \langle o : C \mid \texttt{Pr:}\ \{\bar{l} \mid \bar{s}\}\ \rangle\ .$$

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New rule: skip consumes a resource

$$\textbf{crl}\ [\mathit{skip}]:\ \langle o : C \mid \texttt{Att:}\bar{a}\texttt{, Pr:}\ \{\bar{l} \mid \texttt{skip;}\ \bar{s}\}\ \rangle\ \langle dc\texttt{:Comp}\ \texttt{|Free:}r\rangle$$
$$\longrightarrow\ \langle o : C \mid \texttt{Att:}\bar{a}\texttt{, Pr:}\ \{\bar{l} \mid \bar{s}\}\ \rangle\ \langle dc\texttt{:Comp}\ \texttt{|Free:}r-1\rangle$$
$$\textbf{if}\ dc = \bar{a}[\texttt{mycomp}]\ .$$

Old rule:

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\textbf{crl}\ [\textit{async-call}]:\\
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\longrightarrow \langle o : C \mid \texttt{Att:}\ \bar{a},\ \texttt{Pr:}\ \{\bar{l}\,[x \mapsto n] \mid \bar{s}\},\ \texttt{Lcnt:}\ f+1\ \rangle\\
\quad \texttt{invoc}(\llbracket e \rrbracket_{(\bar{a}\circ\bar{l}),none}, n, m, \llbracket \bar{e} \rrbracket_{(\bar{a}\circ\bar{l}),none})\ \langle n : \texttt{Fut}\ \mid \texttt{Done:false,Value:}\bot\rangle\\
\textbf{if}\ n := \texttt{label}(o, f) \wedge o \neq \llbracket e \rrbracket_{(\bar{a}\circ\bar{l}),none}\ .
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New rule consumes resources and evaluates expressions using time:

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\textbf{crl}\ [\textit{progress}]: \\
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\longrightarrow\ \{\texttt{Adv}(cn)\ \langle t + 1 : \texttt{Clock} \mid \texttt{limit} : \textit{limit} \rangle \} \\
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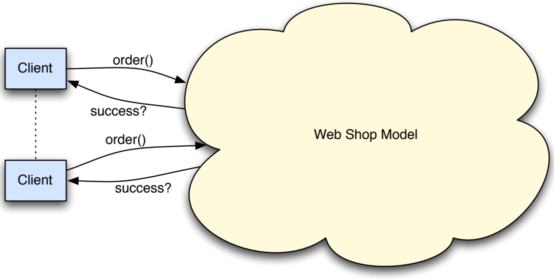
Paper: **Validating Timed Models of Deployment Components with Parametric Concurrency.**

Proc. Int. Conference on Formal Verification of Object-Oriented Software (FoVeOOS) 2010. LNCS 6528, pg. 46–60.

Example: A Shopping Service



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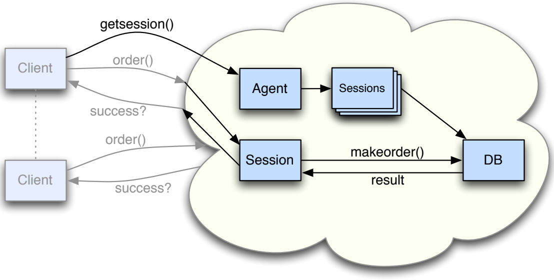

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class Database(Nat min, Nat max) implements Database {
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interface Session { Bool order(); }
class Session(Agent agent, Database db) implements Session {
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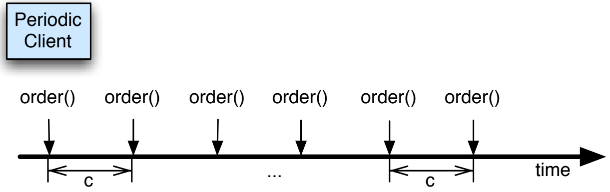
Agent

```
interface Agent { Session getSession(); Void free(Session session); }
class Agent(Database db, Set[Session] sessionPool) implements Agent {
    Session getSession() {
      if isempty(sessionPool) {
            return new Session(this, db); }
      else { session:=choose(sessionPool);
           sessionPool:=remove(session,sessionPool); return session; } }
    Void free(Session session) {sessionPool := add(sessionPool, session);
}
```

Example: Client Behavior



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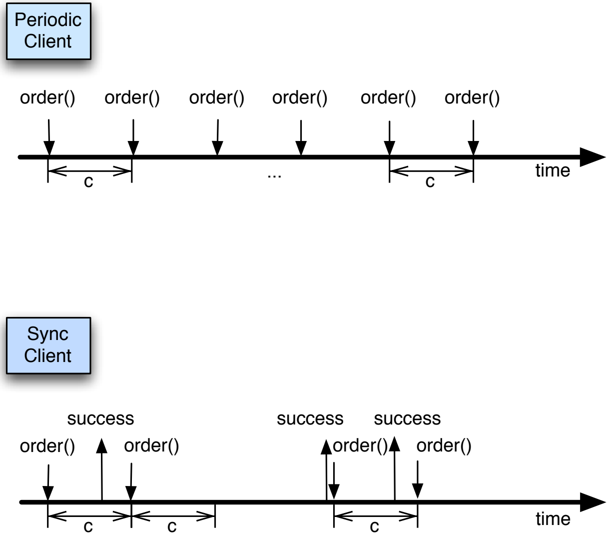


Example: Client Behavior - Abs Model

Synchronous client

```
class SyncClient(Agent a, Nat c) {
  Void run {
    Time t := now;
    Session s := a.getsession();
    Bool result := s.order();
    await now >= t + c;
    this!run(); } }
```

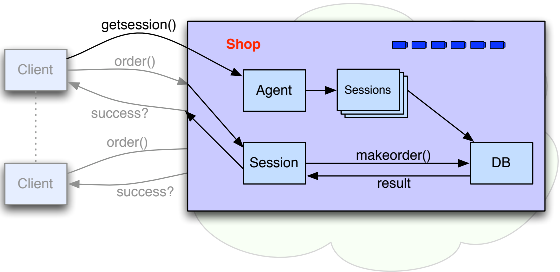
Example: Client Behavior - Abs Model

```
class SyncClient(Agent a, Nat c) {
  Void run {
    Time t := now;
    Session s := a.getsession();
    Bool result := s.order();
    await now >= t + c;
    this!run(); } }
```

Periodic client

```
class PeriodicClient(Agent a, Nat c) {
  Void run {
    Time t := now;
    Session s := a.getsession();
    Fut(Bool) rc := s!order();
    await now >= t + c;
    this!run(); } }
```

Example: Simulation



Example: Simulation and Testing - Abs Model

Different configurations:

```
Void main() {
  Component shop := component(10);
  Database db := new Database(5, 10) in shop;
  Agent a := new Agent(db, {}) in shop;
  SyncClient c := new SyncClient(a, 5); ... }
```

Example: Simulation and Testing - Abs Model

Different configurations:

```
Void main() {
  Component shop := component(10);
  Database db := new Database(5, 10) in shop;
  Agent a := new Agent(db, {}) in shop;
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```

or

Example: Simulation and Testing - Abs Model

Different configurations:

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Void main() {
  Component shop := component(10);
  Database db := new Database(5, 10) in shop;
  Agent a := new Agent(db, {}) in shop;
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or

```
Void main() {
  Component shop := component(10);
  Database db := new Database(5, 10) in shop;
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  PeriodicClient c := new PeriodicClient(a, 5); ... }
```

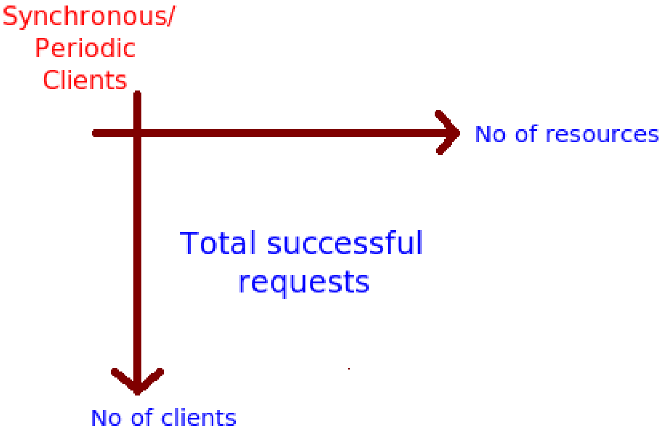

Use Maude as a language interpreter
to simulate the different scenarios

Example: Simulations in the Maude Interpreter - Results

The total and successful requests,
depending on the number of clients and resources

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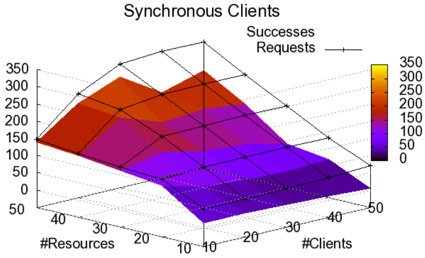
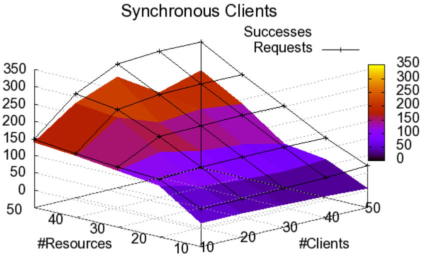
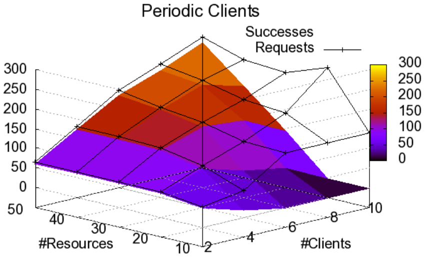
depending on the number of clients and resources

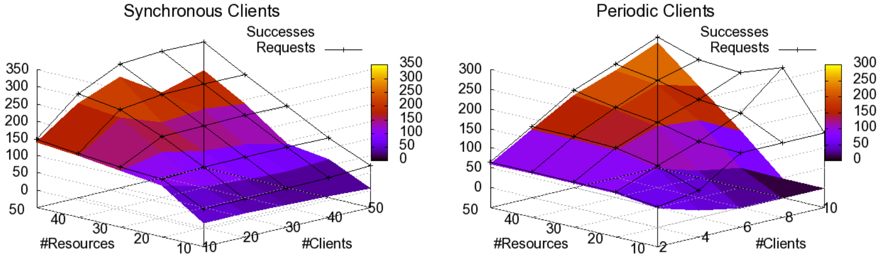


The total and successful requests,
depending on the number of clients and resources



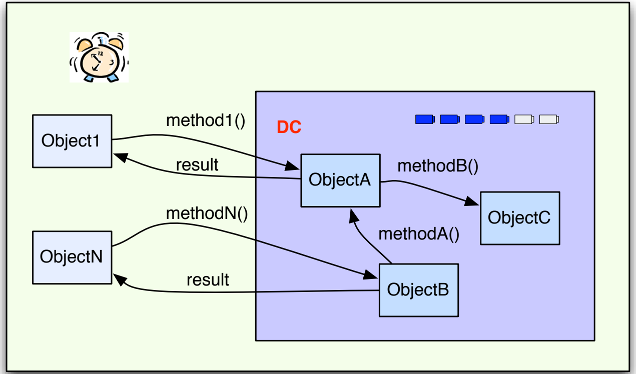


The total and successful requests,
depending on the number of clients and resources

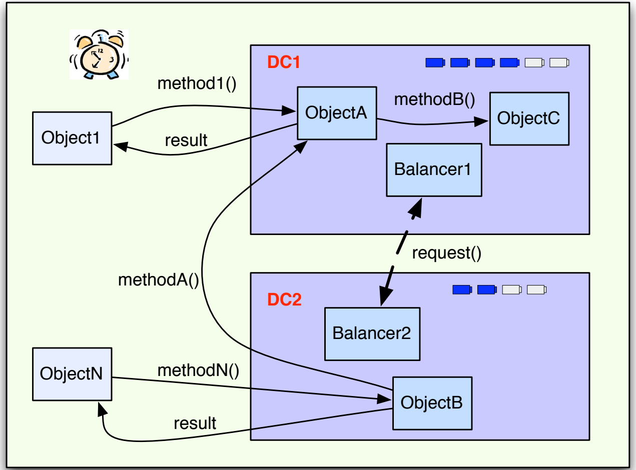


For a larger number of periodic clients, the system becomes unresponsive

Deployment Component



Dynamic Resource Reallocation



Dynamic Resource Reallocation

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- The expression **`mycomp`** returns *dc* of the object.

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More new expressions and statements in Abs

Consider a variable *dc* of type `Component` and *r* of type `Resource`:

- The expression **`mycomp`** returns *dc* of the object.
- The expression **`available`** returns the number of resources currently allocated to **`mycomp`**

Dynamic Resource Reallocation

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More new expressions and statements in Abs

Consider a variable *dc* of type `Component` and *r* of type `Resource`:

- The expression **`mycomp`** returns *dc* of the object.
- The expression **`available`** returns the number of resources currently allocated to **`mycomp`**
- The expression **`load`**(e) returns the average number of used resources in **`mycomp`** during the last e time intervals

Dynamic Resource Reallocation

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- The statement **`transfer`**(*dc*, *r*) reallocates *r* resources from **`mycomp`** to another component *dc*

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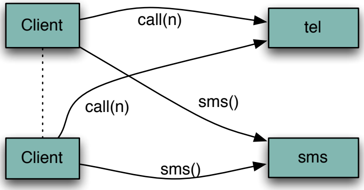
- The statement **`transfer`**(*dc*, *r*) reallocates *r* resources from **`mycomp`** to another component *dc*

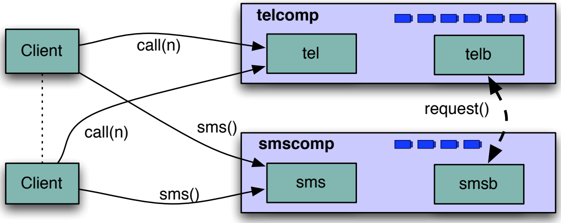
Paper: **Dynamic Resource Reallocation Between Deployment Components.**

Proc. Int. Conference on Formal Engineering Methods (ICFEM) 2010. LNCS 6447, pg. 646–661.

Example: Phone Services



Example: Phone Services



Example: Phone Services - Abs Model

Telephone Service

```
interface TelephoneService { Void call(Int duration); }
class TelephoneService implements TelephoneService {
   Void call(Int duration) {
      Time t; t := now;
      await now >= t + duration; }
}
```

Example: Phone Services - Abs Model

```
interface TelephoneService { Void call(Int duration); }
class TelephoneService implements TelephoneService {
   Void call(Int duration) {
      Time t; t := now;
      await now >= t + duration; }
}
```

SMS Service

```
interface SMSService { Void sendSMS(); }
class SMSService implements SMSService {
   Void sendSMS() { skip; }
}
```

Example: Load Balancing Strategy - Abs Model

The proposed resource-related language-constructors **`available`**, **`load`** and **`transfer`** allow to express different load balancing schemes:

Example: Load Balancing Strategy - Abs Model

The proposed resource-related language-constructors **available**, **load** and **transfer** allow to express different load balancing schemes:

A simple balancer scheme

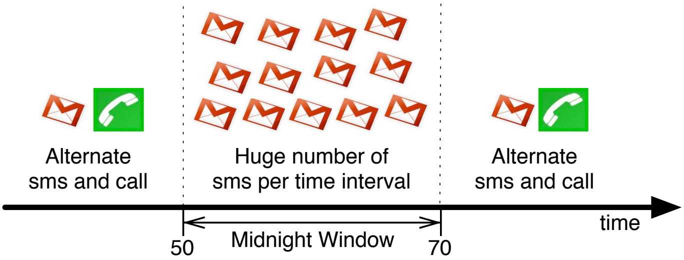
```
interface Balancer { Void setPartner(Balancer p);
                     Void request(Component comp); }
class Balancer {
  Balancer partner := null;

  Void setPartner(Balancer p) { partner := p; }

  Void request(Component comp) {
    if (load(1) < available−10) {transfer(comp,available/2);} }

  Void run () {
    Time t := now;
    await now > t;
    if (partner≠null ∧ available<load(1)*0.9) {
       partner.request(mycomp);}
    this!run(); }
}
```

Example: The New Year's Eve Client Behavior



Normal behavior of client

```
class NYEbehavior (cycle: Int, ts: TelephoneService, smss: SMSService) {
   Time created := now; Bool call := false;

   Void normalBehavior() {
      Time t := now;
      if (now > created + 50 && now < created + 70) {
         !midnightWindow();
      } else {
         if (call) ts.call(1;) else !smss.sendSMS()
         call := ~ call;
         await now >= t + cycle;
         !normalBehavior(); } }
```

Example: The New Year's Eve Client Behavior

Midnight behavior of client

```
Void midnightWindow() {
   Time t := now;
   Int i := 0;
   if (now > created + 70) {
      !normalBehavior();
   } else {
      while (i < 10) { !smss.sendSMS(); i := i+1; }
      await now > t;
      !midnightWindow(); } }
```

Example: The New Year's Eve Client Behavior

```
Void midnightWindow() {
   Time t := now;
   Int i := 0;
   if (now > created + 70) {
      !normalBehavior();
   } else {
      while (i < 10) { !smss.sendSMS(); i := i+1; }
      await now > t;
      !midnightWindow(); } }
```

Run

```
op run() { !normalBehavior(); } }
```

Example: Simulating and Testing - Abs Model

```
Void main() {
    Component smscomp := component(50);
    Component telcomp := component(50);
```

Example: Simulating and Testing - Abs Model

```
Void main() {
   Component smscomp := component(50);
   Component telcomp := component(50);

   SMSService sms := new SMSService() in smscomp;
   TelephoneService tel := new TelephoneService() in telcomp;
```

Example: Simulating and Testing - Abs Model

```
Void main() {
   Component smscomp := component(50);
   Component telcomp := component(50);

   SMSService sms := new SMSService() in smscomp;
   TelephoneService tel := new TelephoneService() in telcomp;

   Balancer smsb := new Balancer in smscomp;
   Balancer telb := new Balancer in telcomp;
```

Example: Simulating and Testing - Abs Model

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Void main() {
   Component smscomp := component(50);
   Component telcomp := component(50);

   SMSService sms := new SMSService() in smscomp;
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   Balancer smsb := new Balancer in smscomp;
   Balancer telb := new Balancer in telcomp;

   smsb.setPartner(telb); telb.setPartner(smsb);
```

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Void main() {
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   smsb.setPartner(telb); telb.setPartner(smsb);

   Client c := new NYEbehavior(1,tel,sms); . . .}
```

Example: Simulating and Testing - Abs Model

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Void main() {
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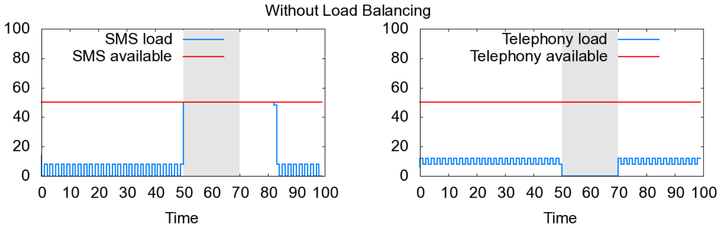
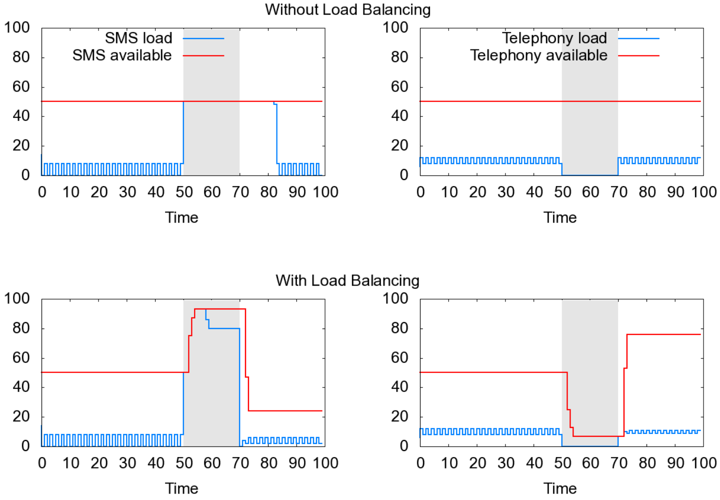
Example: Simulation in the Maude Interpreter

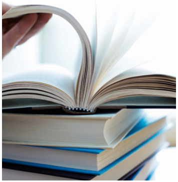


Example: Simulation in the Maude Interpreter



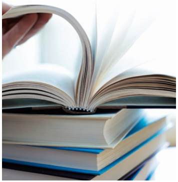
Conclusions

- Modern software is designed to be deployed in different architectures



Conclusions

- Modern software is designed to be deployed in different architectures
- Need analysis support which ranges over different deployment scenarios



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- Modern software is designed to be deployed in different architectures
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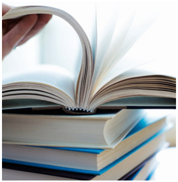
- We proposed deployment components with parametric concurrent resources



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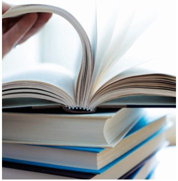
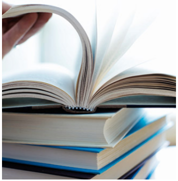


- Abstract notion of resource, reflecting the execution capacity of a component in a given time interval

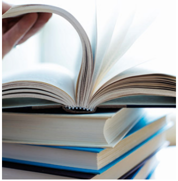
Conclusions

- Dynamic reallocation of resources



Conclusions

- Dynamic reallocation of resources
- Software controlling allocation and reallocation of resources can be completely separated from the rest of the code



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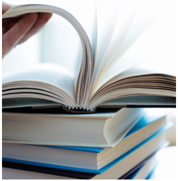

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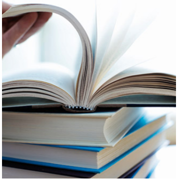

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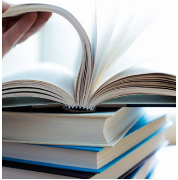

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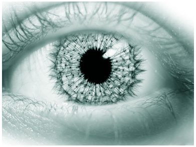
- Different reallocation strategies can be expressed in terms of **`load`**(e), **`available`** and **`transfer`**(dc, r)
- It is easy to replace different reallocation strategies for different components
- Possible to express interesting non-functional system properties

Ongoing/Future Work

- Reallocation between deployment components (eg. load balancing) using object mobility



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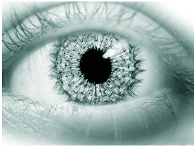

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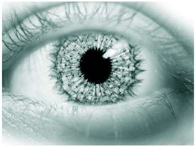

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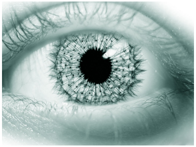

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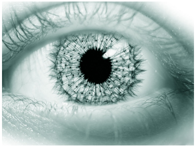
- Resource adjustments frameworks using hierarchical strategies
- Stronger analysis methods
  - Symbolic analysis
  - Static analysis
- Memory resources for deployment components
- Scheduling
  - Priority scheduling: Processes can dynamically increase or decrease in priority according to their waiting time
  - Deadlines to method calls



THANK YOU