Distributed (Systems) Programming
Universal Actors, SALSA, World-Wide Computer

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Worldwide Computing

- Distributed computing over the Internet.
- Access to *large number* of processors *offsets* slow communication and reliability issues.
- Seeks to create a platform for many applications.

# Overview of programming distributed systems

- It is harder than concurrent programming!
- Yet unavoidable in today's information-oriented society, e.g.:
  - Internet
  - Web services
  - Grid/cloud computing
- Communicating processes with independent address spaces
- Limited network performance
  - Orders of magnitude difference between WAN, LAN, and single machine communication.
- Localized heterogeneous resources, e.g, I/O, specialized devices.
- Partial failures, e.g. hardware failures, network disconnection
- Openness: creates security, naming, composability issues.

Actors/SALSA Revisited

- Actor Model
  - A reasoning framework to model concurrent computations
  - Programming abstractions for distributed open systems

  G. Agha, *Actors: A Model of Concurrent Computation in Distributed Systems.* MIT Press, 1986.

- SALSA
  - Simple Actor Language System and Architecture
  - An actor-oriented language for mobile and internet computing
  - Programming abstractions for internet-based concurrency, distribution, mobility, and coordination
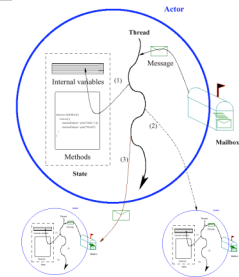
  C. Varela and G. Agha, "Programming dynamically reconfigurable open systems with SALSA", *ACM SIGPLAN Notices, OOPSLA 2001 Intriguing Technology Track*, 36(12), pp 20-34.

World-Wide Computer (WWC)

- Worldwide computing platform.
- Provides a run-time system for universal actors.
- Includes naming service implementations.
- Remote message sending protocol.
- Support for universal actor migration.

Abstractions for Worldwide Computing

- *Universal Actors*, a new abstraction provided to guarantee unique actor names across the Internet.

- *Theaters*, extended Java virtual machines to provide execution environment and network services to universal actors:
  - Access to local resources.
  - Remote message sending.
  - Migration.

- *Naming service*, to register and locate universal actors, transparently updated upon universal actor creation, migration, recollection.

Universal Naming

- Consists of *human readable* names.
- Provides location transparency to actors.
- Name to location mappings efficiently updated as actors migrate.

Universal Actor Naming

- UAN servers provide mapping between static names and dynamic locations.
  - Example:

uan://wwc.cs.rpi.edu/cvarela/calendar
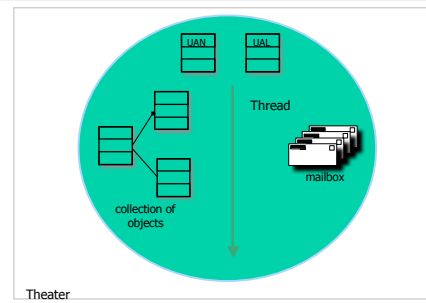
Name server
address and
port.

Actor name.

Universal Actors

- Universal Actors extend the actor model by associating a universal name and a location with the actor.

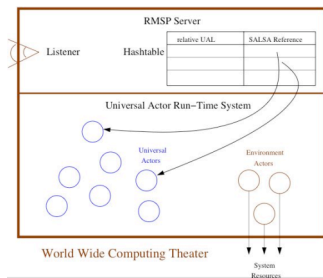- Universal actors may migrate between theaters and the name service keeps track of their current location.

Universal Actor Implementation

WWC Theaters

WWC Theaters

- Theaters provide an execution environment for actors.
- Provide a layer beneath actors for message passing and migration.
- Example locator:

rmsp://wwc.cs.rpi.edu/calendarInstance10

Theater address
and port.

Actor location.

Environment Actors

- Theaters provide access to *environment actors*.
- Environment actors perform actions specific to the theater and are not mobile.
- Include standard input, output and error stream actors.

Remote Message Sending Protocol

- Messages between remote actors are sent using the Remote Message Sending Protocol (RMSP).
- RMSP is implemented using Java object serialization.
- RMSP protocol is used for both message sending and actor migration.
- When an actor migrates, its locator (UAL) changes but its name (UAN) does not.

Universal Actor Naming Protocol
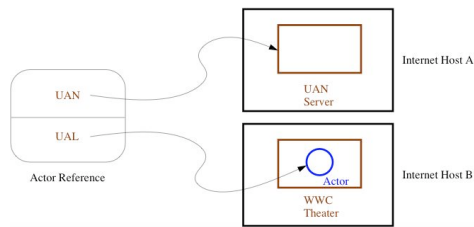
Universal Actor Naming Protocol

- UANP includes messages for:
  - Binding actors to UAN, UAL pairs
  - Finding the locator of a universal actor given its UAN
  - Updating the locator of a universal actor as it migrates
  - Removing a universal actor entry from the naming service

- SALSA programmers need not use UANP directly in programs. UANP messages are transparently sent by WWC run-time system.

UANP Implementations

- Default naming service implementation stores UAN to UAL mapping in name servers as defined in UANs.
  - Name server failures may induce universal actor unreachability.

- Distributed (Chord-based) implementation uses consistent hashing and a ring of connected servers for fault-tolerance. For more information, see:

  Camron Tolman and Carlos Varela. *A Fault-Tolerant Home-Based Naming Service For Mobile Agents*. In Proceedings of the XXXI Conferencia Latinoamericana de Informática (CLEI), Cali, Colombia, October 2005.
  Tolman C. *A Fault-Tolerant Home-Based Naming Service for Mobile Agents*. Master's Thesis, Rensselaer Polytechnic Institute, April 2003.

SALSA Language Support for Worldwide Computing

- SALSA provides linguistic abstractions for:
  - Universal naming (UAN & UAL).
  - Remote actor creation.
  - Message sending.
  - Migration.
  - Coordination.

- SALSA-compiled code closely tied to WWC run-time platform.

Universal Actor Creation

- To create an actor locally

```
TravelAgent a = new TravelAgent();
```

- To create an actor with a specified UAN and UAL:

```
TravelAgent a = new TravelAgent() at (uan, ual);
```

- At current location with a UAN:

```
TravelAgent a = new TravelAgent() at (uan);
```

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Message Sending

```
TravelAgent a = new TravelAgent();

        a <- book( flight );
```

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Remote Message Sending

- Obtain a remote actor reference by name.

```
TravelAgent a = (TravelAgent)
  TravelAgent.getReferenceByName("uan://myhost
  /ta");

a <- printItinerary();
```

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Reference Cell Service Example

```
module examples.cell;

behavior Cell implements ActorService{
  Object content;

  Cell(Object initialContent) {
      content = initialContent;
  }

  Object get() {
      standardOutput <- println ("Returning:"+content);
      return content;
  }

  void set(Object newContent) {
      standardOutput <- println ("Setting:"+newContent);
      content = newContent;
  }
}
```

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Reference Cell Client Example

```
module examples.cell;

behavior GetCellValue {

  void act( String[] args ) {
    if (args.length != 1){
      standardOutput <- println("Usage:
        salsa examples.cell.GetCellValue <CellUAN>");
      return;
    }

    Cell c = (Cell)
      Cell.getReferenceByName(new UAN(args[0]));

    standardOutput <- print("Cell Value") @
    c <- get() @
    standardOutput <- println(token);
  }
}
```

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Migration

- Obtaining a remote actor reference and migrating the actor.

```
TravelAgent a = (TravelAgent)
   TravelAgent.getReferenceByName
              ("uan://myhost/ta");

a <- migrate( "rmsp://yourhost/travel" ) @
a <- printItinerary();
```

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Moving Cell Tester Example

```
module examples.cell;

behavior MovingCellTester {

    void act( String[] args ) {

      if (args.length != 3){
          standardOutput <- println("Usage:
             salsa examples.cell.MovingCellTester <UAN> <UAL1> <UAL2>");
          return;
      }

      Cell c = new Cell("Hello") at (new UAN(args[0]), new UAL(args[1]));

      standardOutput <- print( "Initial Value:" ) @
      c <- get() @ standardOutput <- println( token ) @
      c <- set("World") @
      standardOutput <- print( "New Value:" ) @
      c <- get() @ standardOutput <- println( token ) @
      c <- migrate(args[2]) @
      c <- set("New World") @
      standardOutput <- print( "New Value at New Location:" ) @
      c <- get() @ standardOutput <- println( token );
    }
}
```

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Agent Migration Example

```
behavior Migrate {

    void print() {
       standardOutput<-println( "Migrate actor is here." );
    }

    void act( String[] args ) {

      if (args.length != 3) {
         standardOutput<-println("Usage: salsa migration.Migrate  <UAN> <srcUAL>
                                        <destUAL>");
         return;
      }

      UAN uan = new UAN(args[0]);
      UAL ual = new UAL(args[1]);

      Migrate  migrateActor = new Migrate() at (uan, ual);

      migrateActor<-print() @
      migrateActor<-migrate( args[2] ) @
      migrateActor<-print();
    }
}
```

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Migration Example

- The program must be given *valid* universal actor name and locators.
  - Appropriate name services and theaters must be running.

- After remotely creating the actor. It sends the `print` message to itself before migrating to the second theater and sending the message again.

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Compilation and Execution

```
$ java salsac.SalsaCompiler Migrate.salsa
SALSA Compiler Version 1.0:  Reading from file Migrate.salsa . . .
SALSA Compiler Version 1.0:  SALSA program parsed successfully.
SALSA Compiler Version 1.0:  SALSA program compiled successfully.
$ javac Migrate.java
$ java Migrate
$ Usage: java Migrate <uan> <ual> <ual>
```
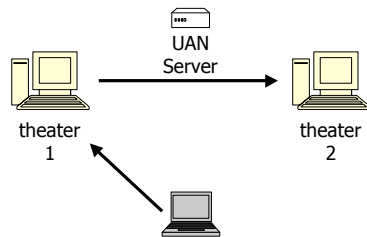
- Compile Migrate.salsa file into Migrate.java.
- Compile Migrate.java file into Migrate.class.
- Execute Name Server
- Execute Theater 1 and Theater 2 Environments
- Execute Migrate in any computer

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Migration Example

UAN Server

theater 1   theater 2

The actor will print "Migrate actor is here." at theater 1 then at theater 2.

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World Migrating Agent Example

Host	Location	OS/JVM	Processor
yangtze.cs.uiuc.edu	Urbana IL., USA	Solaris 2.5.1 JDK 1.1.6	Ultra 2
vulcain.ecoledoc.lip6.fr	Paris, France	Linux 2.2.5 JDK 1.2pre2	Pentium II 350Mhz
solar.isr.co.jp	Tokyo, Japan	Solaris 2.6 JDK 1.1.6	Sparc 20

Local actor creation	386us
Local message sending	148 us
LAN message sending	30-60 ms
WAN message sending	2-3 s
LAN minimal actor migration	150-160 ms
LAN 100Kb actor migration	240-250 ms
WAN minimal actor migration	3-7 s
WAN 100Kb actor migration	25-30 s

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Address Book Service

```
module examples.addressbook;

behavior AddressBook implements ActorService {
    Hashtable name2email;
    AddressBook() {
        name2email = new HashTable();
    }
    String getName(String email) { … }
    String getEmail(String name) { … }
    boolean addUser(String name, String email) { … }

    void act( String[] args ) {
        if (args.length != 0){
            standardOutput<-println("Usage: salsa -Duan=<uan> -Dual=<ual>
                                    examples.addressbook.AddressBook");
        }
    }
}
```

Address Book Add User Example

```
module examples.addressbook;

behavior AddUser {
    void act( String[] args ) {
        if (args.length != 3){
            standardOutput<-println("Usage: salsa
               examples.addressbook.AddUser <BookUAN> <Name> <Email>");
            return;
        }
        AddressBook book = (AddressBook)
            AddressBook.getReferenceByName(new UAN(args[0]));
        book<-addUser(args(1), args(2));
    }
}
```

Address Book Get Email Example

```
module examples.addressbook;

behavior GetEmail {
    void act( String[] args ) {
        if (args.length != 2){
            standardOutput <- println("Usage: salsa
               examples.addressbook.GetEmail <BookUAN> <Name>");
            return;
        }
        getEmail(args(0),args(1));
    }

    void getEmail(String uan, String name){
        AddressBook book = (AddressBook)
            AddressBook.getReferenceByName(uan);
        standardOutput <- print(name + "'s email: ") @
        book <- getEmail(name) @
        standardOutput <- println(token);
    }
}
```

Address Book Migrate Example

```
module examples.addressbook;

behavior MigrateBook {
    void act( String[] args ) {
        if (args.length != 2){
            standardOutput<-println("Usage: salsa
               examples.addressbook.Migrate <BookUAN> <NewUAL>");
            return;
        }
        AddressBook book = (AddressBook)
            AddressBook.getReferenceByName(new UAN(args[0]));
        book<-migrate(args(1));
    }
}
```

Exercises

78. How would you implement the join continuation linguistic abstraction considering different potential distributions of its participating actors?

79. Download and execute the Agent.salsa example.

80. Modify the lock example in the SALSA distribution to include a wait/notify protocol, as opposed to "busy-waiting" (or rather "busy-asking").

81. VRH Exercise 11.11.3 (pg 746). Implement the example using SALSA/WWC.