Agent-Oriented Programming One Step Beyond OOP

Jürg Gutknecht
ETH Zürich
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Overview

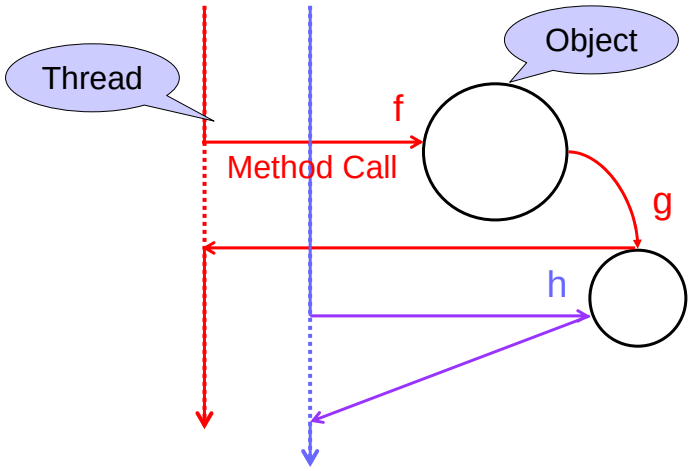
- Some goals
- The standard OOP computing model
- A new model unifying OOP and concurrency
- The experimental language *Active C#*
- Some archetypal use cases
- Remote user interfaces: a vision
- Conclusion

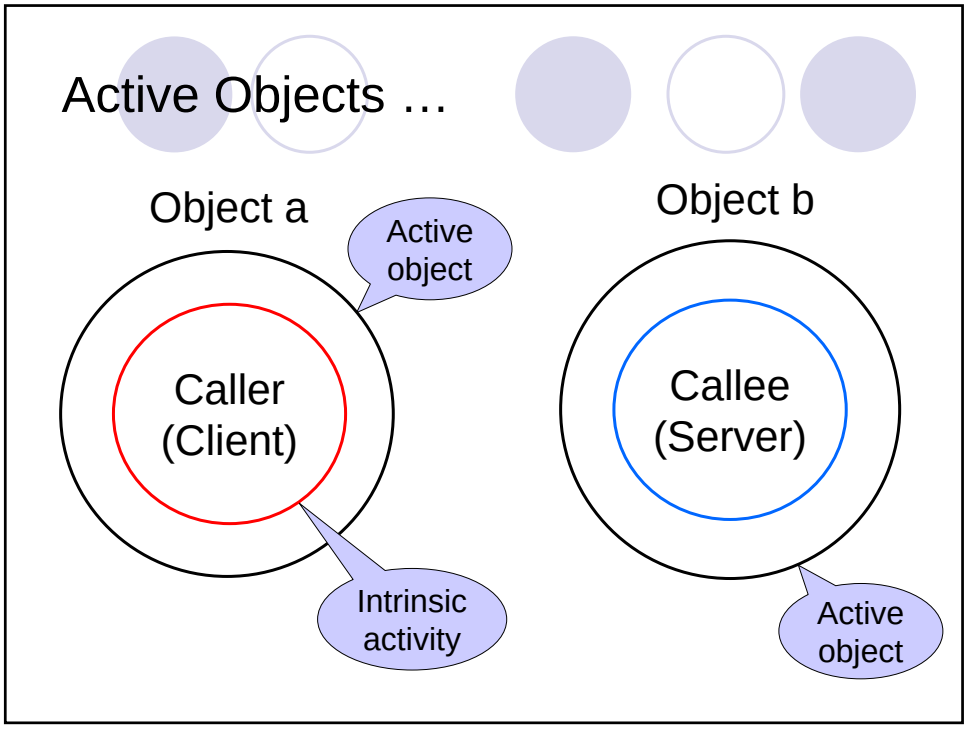
Some Goals …

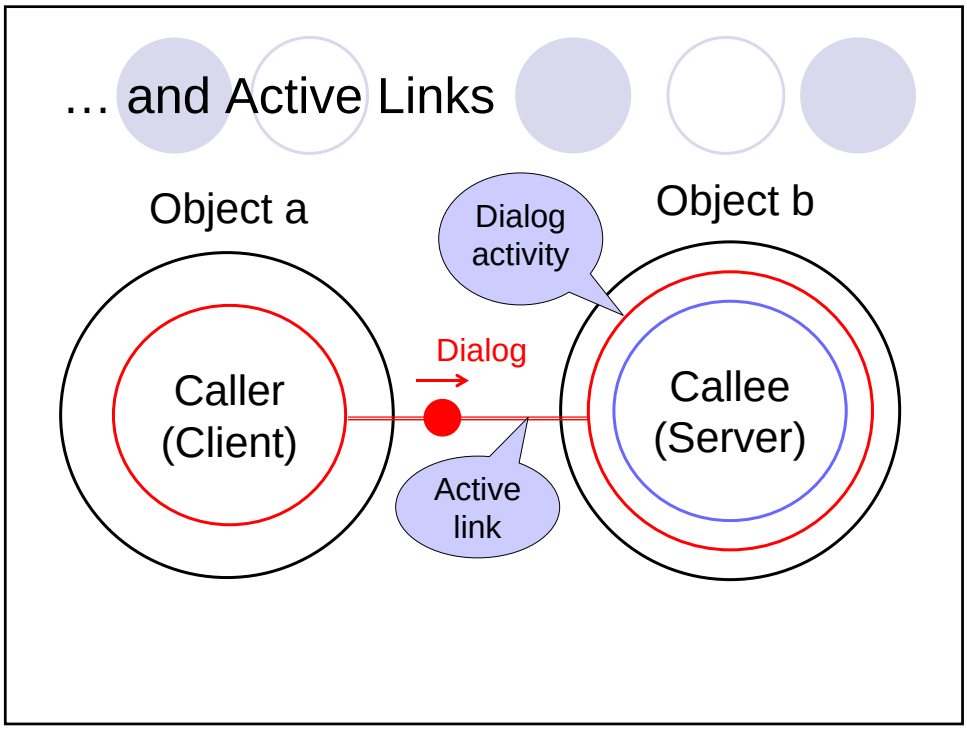
- Create a better (more „realistic“) model
- Integrate concurrency with OOP
- Puts concurrency „behind the scenes“ (language constructs replace library calls)
- Abstract from deployment details (central or distributed)
- Introduce new kind of programming-language independent interfaces or contracts
- Present active objects as self-contained units with programming-language independent interfaces
- Allow 1:1 mapping of active objects to devices

The Standard OOP Computing Model

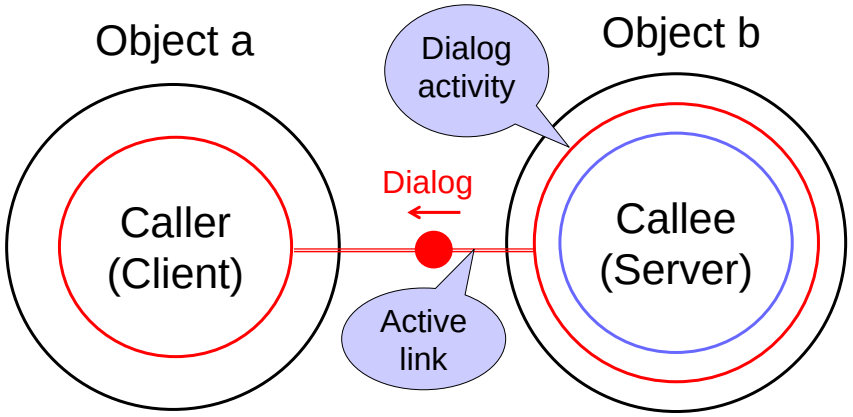
„2-Class Society“




Active Objects …
Object a
Active object
Caller (Client)
Intrinsic activity
Object b
Callee (Server)
Active object


… and Active Links
Object a
Dialog activity
Object b
Dialog
Caller (Client)
Callee (Server)
Active link

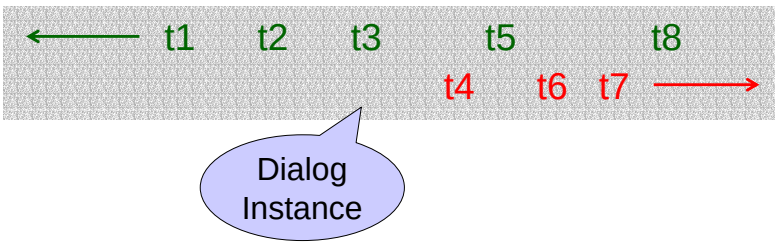
Dialogs



Dialog Syntax

Dialog Definition in EBNF

Protocol = { Token { Token } { ↓Token } }.



Comparison

methods	dialogs
blocking	non blocking
stateless	stateful
parameters	syntax
language dependent	language independent

Experiment Active C#

Project within MSR ROTOR initiative

- **`activity`** new class member
  - anonymous: started implicitly after constructor
  - named: started explicitly
- **`dialog`** interface entities (contracts)
  - Specify dialog syntax and keywords
  - Implemented by correspondingly named activities
- "!" and "?" send and receive operators
- **`lock`** mutual exclusion relative to object scope
- **`await cond`** waiting for condition
- **`passivate dt`**

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- **`passivate dt`**

Dialogs in Active C#

- Definition and Implementation

```
namespace N {
  dialog D { a, b, c } // definition with keywords
  class S {
    int i; …
    public S (…) { … }
    private bool f (…) { … }
    public activity A: D {
    // implementation with parser
      D kw;
      ?kw; … !2004;
    }
  }
}
```

Contract

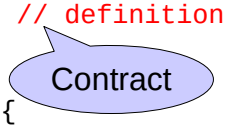
Server Code

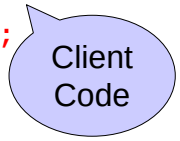
Dialogs in Active C#

- Use

```
namespace N {
  dialog D { a, b, c } // definition with keywords
  class C {
    …
    activity Behavior {
      S s = new S(…);
      dialog D d = new s.A;
      int i
      … d!D.b; … d?i;

  }
}
```





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- **`passivate dt`**

Example: Finite Buffers

```
public void Put (object x) {
  lock(this) {
    if (m == 0) { Monitor.Wait(this); }
    m--; buf[tail] = x;
    tail = (tail + 1) % size;
    n++; Monitor.Pulse(this);
  }
}
public object Get () {
  lock(this) {
    if (n == 0) { Monitor.Wait(this); }
    n--; object x = buf[head];
    head = (head + 1) % size;
    m++; Monitor.Pulse(this); return x;
  }
}
```

m = # free slots
n = # occupied slots

Finite Buffers

```
public void Put (object x) {
  lock(this) {
    if (m == 0) { Monitor.Wait(this); }
    m--; buf[tail] = x;
    tail = (tail + 1) % size;
    n++; Monitor.Pulse(this);
  }
}
public object Get () {
  lock(this) {
    if (n == 0) { Monitor.Wait(this); }
    n--; object x = buf[head];
    head = (head + 1) % size;
    m++; Monitor.Pulse(this); return x;
  }
}
```

Correct?

Analysis

- Error scenario
  - Arrival $\texttt{Get}_1$ $\texttt{Get}_2$ Put
  - Pulse Put $\rightarrow$ $\texttt{Get}_1$ $\rightarrow$ $\texttt{Get}_2$
- Correction: Replace `if` with `while`
- .NET model (without eggshell)
  - Mixed queue (containing newly entering producers and consumers)
  - Correction: Replace `Pulse` with `PulseAll`
- Eggshell model
  - Producers only or consumers only in (inner) waiting list
  - `Pulse` correct

Finite Buffer with Signals

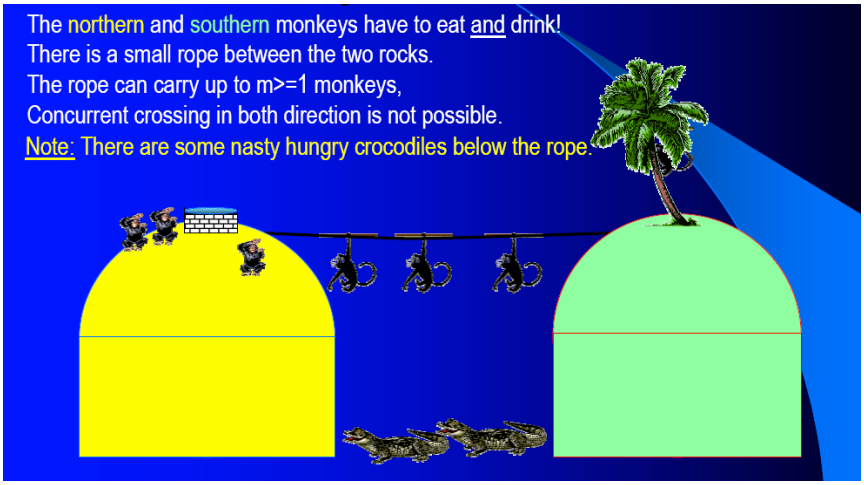
```
public void Put (object x) {
  lock(this) {
    while (m == 0) { Monitor.Wait(this); }
    m--; buf[tail] = x;
    tail = (tail + 1) % size;
    n++; Monitor.PulseAll(this);
  }
}
public object Get () {
  lock(this) {
    while (n == 0) { Monitor.Wait(this); }
    n--; object x = buf[head];
    head = (head + 1) % size;
    m++; Monitor.PulseAll(this); return x;
  }
}
```

Cost: unnecessary context switches

Finite Buffers in Active C#

```
public void Put (object x) {
  lock {
    await (m != 0);
    m--; buf[tail] = x;
    tail = (tail + 1) % size;
    n++;
  }
}
public object Get () {
  lock {
    await (n != 0);
    n--; object x = buf[head];
    head = (head + 1) % size;
    m++; return x;
  }
}
```

Use Case 1: Monkey Rock Problem



Monkey Rocks in Active C#

```
dialog CoordMonkeyDialog { claim, release }
class Rope {
  const NofMonkeys = 25;
  const MaxOnRope = 4;
  const CrossingTime = 100;
  static int curOnRope = 0;
    // > 0, < 0 South-North, North-South traversal
  activity CoordMonkey: CoordMonkeyDialog {
    object msg;
    while (true) { ... }
  }
  static void Main() {
    for (int i = 0; i < NofMonkeys; i++) new Monkey ();
  }
}
```

Contract

Monkey Rocks in Active C#

```
while (true) {
  ?msg; // wants South-North traversal
  lock {
    await (0 <= curOnRope) & (curOnRope < MaxOnRope);
    curOnRope++;
  }
  passivate(CrossingTime);
  lock { curOnRope--; }
  !CoordMonkeyDialog.release;
  ?msg; // wants North-South traversal
  lock {
    await (0 >= curOnRope) & (curOnRope > -MaxOnRope);
    curOnRope--;
  }
  passivate(CrossingTime);
  lock { curOnRope++;  }
  !CoordMonkeyDialog.release;
}
```

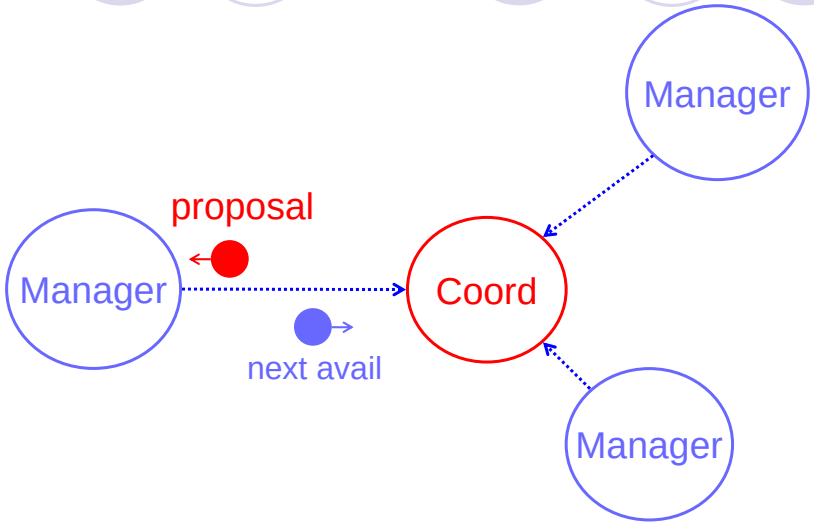
Monkey Rocks in Active C#

- **dialog CoordMonkeyDialog { claim, release }**
- **class Monkey** {

```
  static Random rnd = new Random();
  activity {
    dialog CoordMonkeyDialog d =
      new Rope.CoordMonkey;
    object msg;
    while (true) {
      passivate(rnd.Next(1000));
        // eat/drink for a random time
      d!CoordMonkeyDialog.claim;
        // send keyword claim
      d?msg; // receive whatever is sent
    }
  }
}
```

Use Case 2: Next Meeting Time

Jay Misra



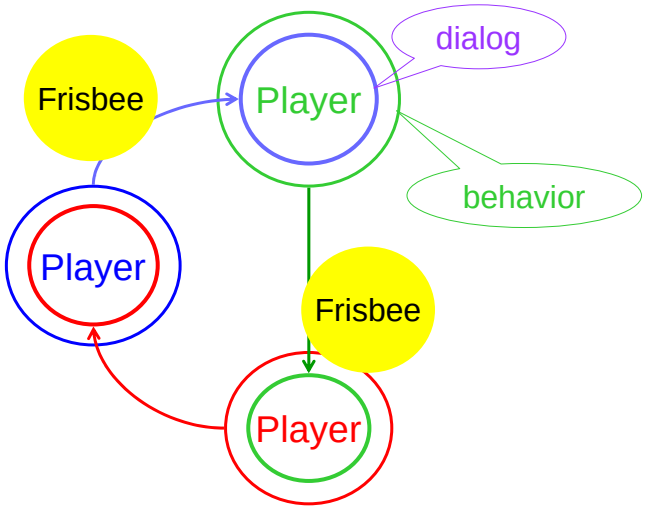
Next Meeting Time in Active C#

```
dialog MeetingDialog {} // no keywords
class Coordinator {
  const int NofManagers = 20;
  static int proposal = 0;
  activity AllocMeeting: MeetingDialog {
    int t;
    while (true) {
      !proposal; ?t;
      lock {
        if (t > proposal) proposal = t;
        await(proposal > t);
      }
    }
  }
  static void Main() {
    for (int i = 0; i < NofManagers; i++)
      new Manager ();
  }
}
```

Next Meeting Time in Active C#

```
class Manager {
  private int NextPossibleTime (int t) {
    // check agenda
  }
  activity {
    dialog MeetingDialog d =
      new Coordinator.AllocMeeting;
      int proposal, t;
      while (true) {
        d?proposal; d!NextPossibleTime(proposal);
      }
    }
  }
}
```

Use Case 3: Frisbee Fun



Frisbee Fun in Active C#

```
dialog FrisbeeDialog { request, take }

class Player {
    dialog FrisbeeDialog d = null;
    int nofFrisbees = 0;
    public Init (Player next; int nofFrisbees) { ... }
    activity ManageFrisbees: FrisbeeDialog { ... }
    activity { ... }
    static Random rnd = new Random();
    static void Main() { ... }
   }
```

Frisbee Fun in Active C#

```
activity ManageFrisbees: FrisbeeDialog {
   object msg;
   while (true) {
     lock { await (nofFrisbees == 0); }
     !FrisbeeDialog.request; ?msg;
     lock { nofFrisbees = 1; }
   }
 }
 activity {
   object msg;
   while (true) {
     lock { await (nofFrisbees != 0); }
     d?msg; d!FrisbeeDialog.take;
     lock { nofFrisbees = 0; }
   }
 }
```

Frisbee Fun in Active C#

```
public Init (Player next; int nofFrisbees) {
  lock {
    d = new next.ManageFrisbees;
    this.nofFrisbees = nofFrisbees;
  }
}

static void Main() {
  const int NofPlayers = 11;
  Player last = new Player (), q = last;
  for (int i = 1; i < NofPlayers; i++) {
    Player p = new Player ();
    p.Init(q, rnd.next(2)); q = p;
  }
  last.Init(q, 0);
}
```

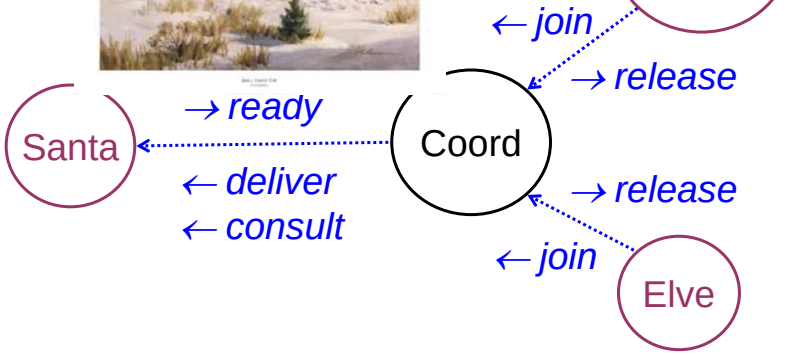
Use Case 4: Santa Claus

- Santa Claus sleeps at the North pole until awakened by either all of the nine reindeer, or by a group of three out of ten elves. He performs one of two indivisible actions:
  - If awakened by the group of reindeer, Santa harnesses them to a sleigh, delivers toys, and finally unharnesses the reindeer who then go on vacation.
  - If awakened by a group of elves, Santa shows them into his office, consults with them on toy R&D, and finally shows them out so they can return to work constructing toys.
- A waiting group of reindeer must be served by Santa before a waiting group of elves. Since Santa's time is extremely valuable, marshalling the reindeer or elves into a group must not be done by Santa.

Santa Claus

- Invented by John Trono in "J. A. Trono. A new exercise in concurrency. SIGCSE Bulletin, 1994". Solved using semaphores and corrected later.
- Discussed and solved by Ben-Ari with Rendez-Vous (in Ada95) and monitors (in Java) in "How to Solve the Santa Claus Problem, M. Ben-Ari, Wiley & Sons, 1997".

Santa Claus



Problem Extension: Negotiation

- Before joining, elves should be informed about the expected waiting time and be given the opportunity to withdraw
- Extension of dialog syntax

EBNF

```
CoordElf = join ( Negotiation  | ↓reject ).
Negotiation = [ ↓wait join ] ↓release  | ↓wait release.
```

Counter Traffic

Reindeers as Active Objects

- **dialog Contact** { join, release }
- **class Reindeer** {

```
 activity {
  object t;
  Contact c = new Coordinator.CoordReindeer;
  while (true) {
   passivate (Christmas.Rnd());
   c!Contact.join;
   c?t;
  }
 }
}
```

Elves as Active Objects

- **dialog XContact** { join, reject, wait, release }
- **class Elf** {

```
 activity {
  object t;
  XContact c = new Coordinator.CoordElves;
  while (true) {
   Thread.Sleep(Christmas.Rnd());
   c!XContact.join;
   c?t;
   if (XContact)t == XContact.wait)
    if (Christmas.Rnd % 3) == 0)
     c!XContact.release;
    else { c!XContact.join; c?t; }
  }
 }
```

Santa as Server

- **dialog Service** { deliver, consult, done }
- **class Santa** {

```
 const int consultTime = 10, deliverTime = 20;
 public static activity Work: Service {
  object t;
  while (true) {
   ?t;
   if (Service)t == Service.deliver) {
    Console.WriteLine("Santa delivering");
    passivate (deliverTime); }
   else {
    Console.WriteLine("Santa consulting");
    passivate (consultTime); }
    !Service.done
  }
 }
}
```

Coordinator as Active Server

- **class Coordinator** {

```
 static int rGo = 0, rBuild = 0, rSize = 0;
 static int eGo = 0, eBuild = 0, eSize = 0;
 public static activity CoordReindeer: Contact { }
 public static activity CoordElves: XContact { }
 static activity {
  lock {
   object t;
   Service s = new Santa.Work;
   while (true) {
    await ((rBuild > rGo) || (eBuild > eGo));
    if (rBuild > rGo) {
     s!Service.deliver; s?t; rGo++; }
    else {
     s!Service.consult; s?t; eGo++; }
   }
  }
 }
```

Reindeer Coordination

```
public static activity CoordReindeer: Contact {
 lock {
  object t;
  int groupNo;
  while (true){
   ?t;
   groupNo = rBuild; rSize++;
   if (rSize == Christmas.reqReindeer) {
    rSize = 0; rBuild++;
   };
   await (rGo > groupNo);
   !Contact.release;
  }
 }
}
```

Elf Coordination

```
public static activity CoordElves: XContact {
 lock {
  object t; int groupNo = -9999;
  while (true)
   ?t;
   if (eBuild <= groupNo + 2)
    !XCoord.reject;
   else {
    if (eGo < eBuild) { !XContact.wait; ?t; };
    if (XCoord)t == XCoord.join) {
     groupNo = eBuild; eSize++;
     if (eSize == Christmas.reqElves) {
      eSize = 0; eBuild++; };
     await (eGo > groupNo);
     !XContact.release;
    }
   }
 }
}
```

Christmas Scenario

```
public class Christmas {
  public const int nofReindeer = 9;
  public const reqReindeer = 9;
  public const int nofElves = 10;
  public const int reqElves = 3;
  static Random rnd = new Random();
  public static int Rnd () {
   return rnd.Next(1000); }
  static void Main() {
   for (int i = 0; i < nofReindeer; i++)<
    new Reindeer ();
   for (int i = 0; i < nofElves; i++)>
    new Elf ();
  }
}
```

Automated Rental System: Server

```
dialog Negotiate { Accept, Return };

using System, System.Dialog;
public class RentalStation {
  static int nofFree;
  static bool [] free;
  static Rental ()  { // constructor }
  static activity RentalService: Negotiate {
    // dialog implementation
  }
  private static int Next (int obj) { }
  private static void Free (int obj) { }
  static void Main() { // main activity }
}
```

Automated Rental System: Server

```
static RentalStation () {
  free = new bool [100];
  for (int i = 0; i < free.Length; i++) {
    free[i] = true;
  }
  nofFree = 100;
}

static void Main() {
  DialogManager.Start(typeof(Rental),
    new TCPTransportManager());
}
```

Automated Rental System: Server

```
static activity RentalService: Negotiate {
  Negotiate msg;
  int obj = -1;
  do {
    obj = Next(obj); !obj; ?msg;
    if (msg != Negotiate.Accept) Free(obj);
  } while (msg != Negotiate.Accept);
  ?msg; // return
  Free(obj)
}
```

Automated Rental System: Server

```
private static void Next (int obj) {
  lock {
    await (nofFree > 0);
    while (!free[obj++ % 100]) {};
    free[obj] = false; nofFree--;
    return obj;
  }
}

private static void Free (int obj) {
  lock {
    free[obj] = true; nofFree++;
  }
}
```

Automated Rental System: Client

```
dialog Negotiate { Accept, Return };

using System, System.Dialog;
class Client {
  static void Main(string[] args) {
    DialogManager.Start(new TCPTransportManager(args[0]));
    dialog Dialog d = DialogManager.Open(
      "RentalStation", "RentalService", typeof(Negotiate));
    do { d?obj;
      bool suitable = Check(obj);
      if (!suitable) d!Negotiate.Return;
    } while (!suitable)
    d!Negotiate.Accept;
    // now use rental object
    d!Negotiate.Return;
  }
  DialogManager.Stop(true);
}
```

Distributed Application!

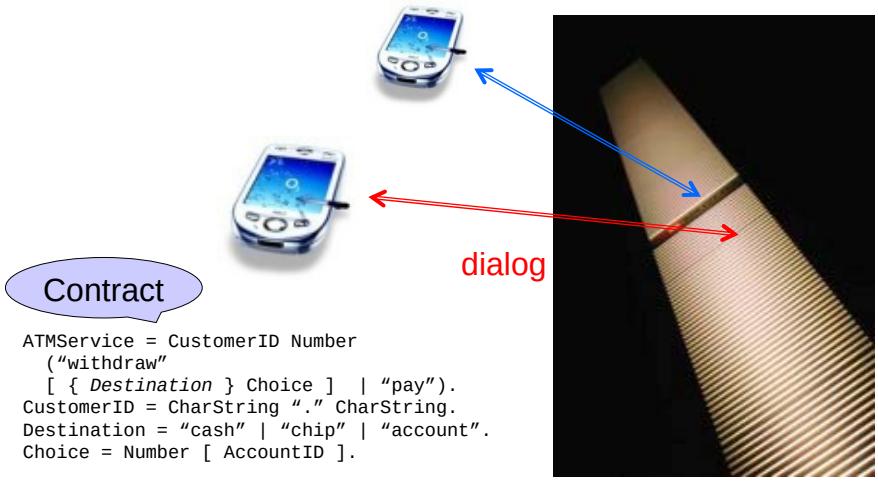
Automatic Parser Generator

- Use attributed syntax
- Treat it as C# attributes of a dialog declaration

```
[ syntax
  "Negotiate = int @Eval {↓Return int @Eval}
  ↓Accept @Use ↓Return."
]
dialog Negotiate { Accept, Return };
```

A Vision: From Local UI ...

A Vision: ... To Remote UI



Contract

```
ATMService = CustomerID Number
  (“withdraw”
  [ { Destination } Choice ]  | “pay”).
CustomerID = CharString “.” CharString.
Destination = “cash” | “chip” | “account”.
Choice = Number [ AccountID ].
```

Summary

- The New Model
  - Meets the goals stated at the beginning
  - Has proved ist suitability in numerous case studies
  - Suggests new modes of interoperability
  - Is implemented in the form of Active C#, available from http://www.avocado.ethz.ch/ActiveCSharp/