Multirôle Session Types

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very preliminary, and ongoing, joint work with
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based on earlier work with
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Relationships, Objects, Roles, and Queries in Modern Programming

- Researchers in programming language design wish to bridge the gap between implementation and design. ...
- Researchers in program analysis are interested in raising the level of abstraction in programming languages.....
- Researchers in databases are keen to bridge the ``impedance mismatch'' between programs and databases...
- In the absence of language support for querying, many commonly used operations need to be expressed using nested loops and complex conditional statements. ...
- Researchers in modelling languages and knowledge representation want to clarify whether roles and relationships are dual notions,....

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Overview

- Session Types, and multiparty session types
- Multirole session types
- Design Issues & Further Work

Session Types and Multiparty Session Types

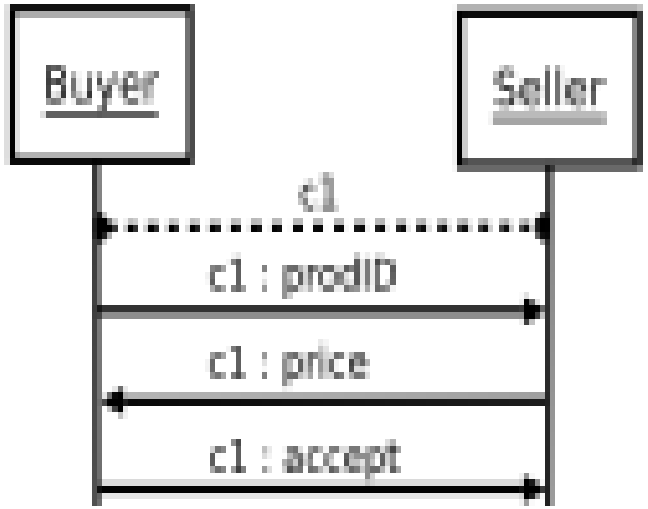
Session Types - 1

K. Honda. Types for dyadic interaction. CONCUR'93, volume 715 of LNCS

- A session is a sequence of interactions between two parties.
- It starts after a connection has been established.
- During the session, each party may execute its own local computation, interleaved with communications with the other party.
- Communications take the form of sending and receiving values over a channel.
- Throughout interaction between the two parties, there should be a perfect matching of sending actions in one with receiving actions in the other, and vice versa.

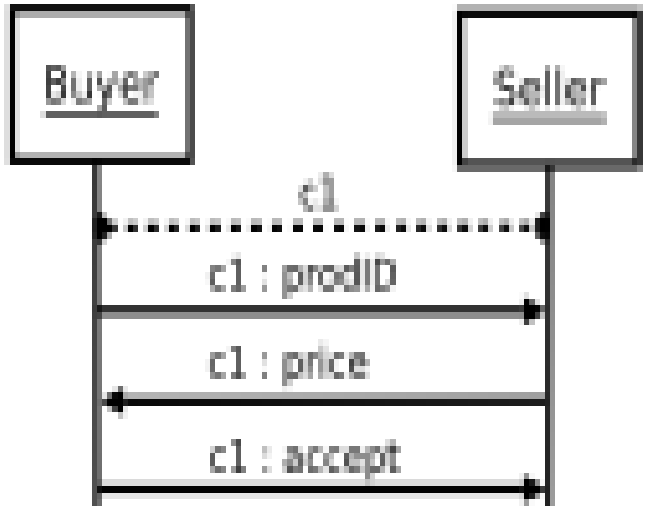
Session Types - 3

- sequence of interactions between two parties.
- … connection has been established.
- each party may execute its own local computation, interleaved with communications with the other party.
- Communications take the form of sending and receiving values over a channel.



Session Types - 3

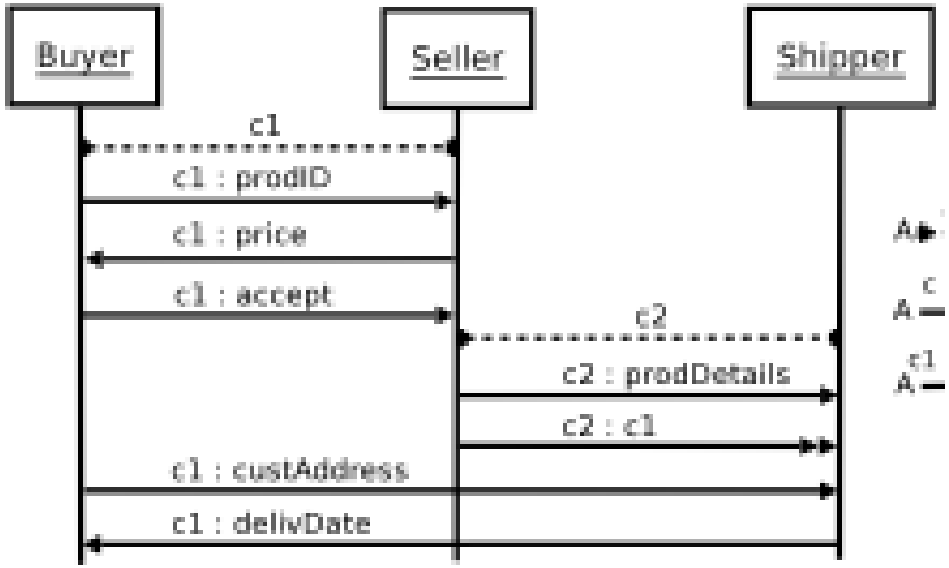
- sequence of interactions between two parties.
- … connection has been established.
- each party may execute its own local computation, interleaved with communications with the other party.
- Communications take the form of sending and receiving values over a channel.
- perfect match between sending/receiving



- Buyer's view:
  ! `ProdId` ?`Price` ! `Decision`
- Seller's view:
  ? `ProdId` !`Price` ? `Decision`

Session Types - 4

- sequence of interactions between two parties.
- … connection has been established
- each party may execute its own local computation, interleaved with communications with the other party.
- Communications take the form of sending and receiving values over a channel.
- perfect match between sending/receiving
- session composition and higher order sessions



Session Types for OO

- *Mariangiola Dezani-Ciancaglini, Dimitris Mostrous, Sophia Drossopoulou, Nobuko Yoshida,*
  Sessions Types for object oriented programmhttp://www.doc.ic.ac.uk/~yoshida/multiparty/multiparty.pdfing ,
  ECOOP 2005

- *Sophia Drossopoulou, Mariangiola Dezani-Ciancaglini, Mario Coppo,*
  Amalgamating the Session Types and the Object Oriented Programming Paradigms **Multiparadigm** Programming with OO Languages 2007 (an ECOOP workshop)

- .....

- .....

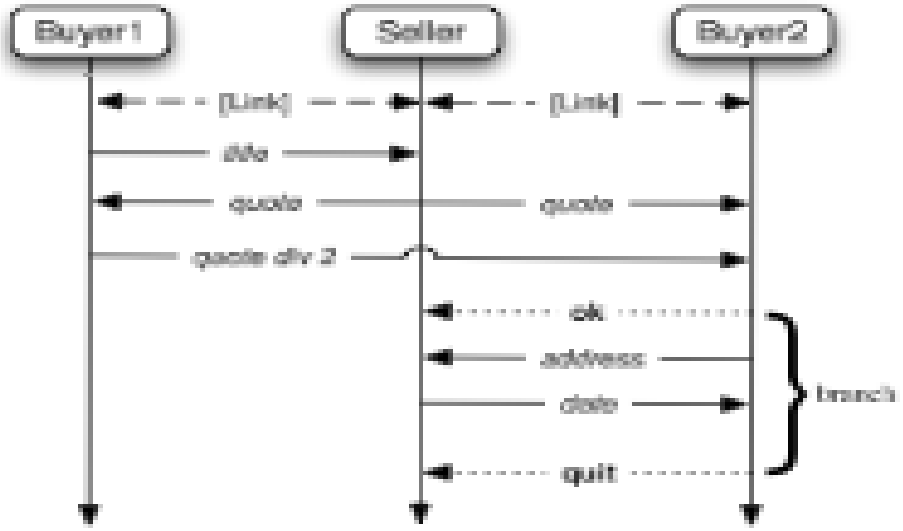
Multiparty Session Types - 1

Kohei Honda, Nobuko Yoshida and Marco Carbone
Multiplarty Asynchronous Session Types
POPL'2008

- generalize binary sessions to multiparty asynchronous sessions

Multiparty Session Types - 2

- generalize binary sessions to multiparty asynchronous sessions

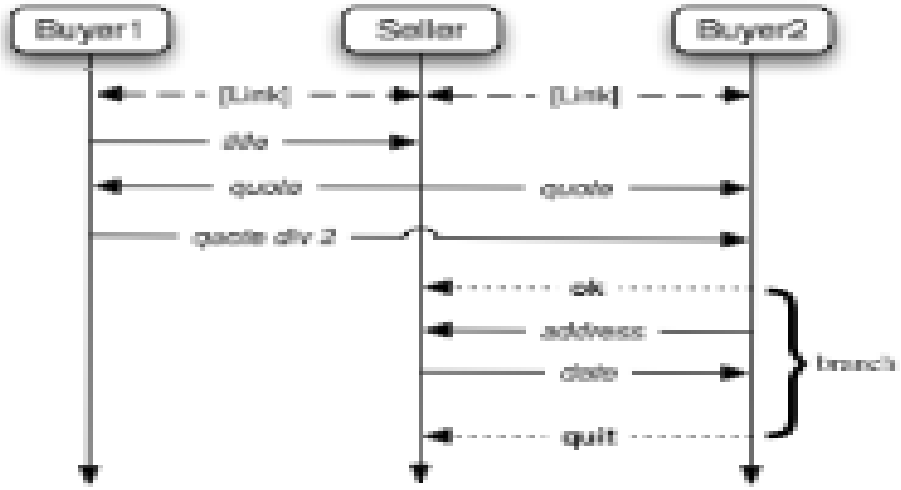


- three participants; they all talk to each other; two buyers collaborate to buy an item.

Multirole Session Types

Multirole session types – why?

- We revisit the two-buyers example from earlier



- Why just two buyes?
- Seller aware of how many/who individual buyers are …
- Could number of buyers vary statically/dynamically?

Multirole session types – why? -2

- The concept of several participants playing the same role is natural.

Multirole session types - when

- **Auction** (several bidders, one auctioneer, several secretaries)
  one conversation, auction of n items
  participants may join/leave dynamically
- **Virtual PC meeting** (PC chair, PC members, reviewers and subreviewers)
  n sub-conversations for n papers,
  participants may play different roles in different conversations
- **Court** (judge, jury, prosecutor, investigator)
  ….
- **Discussion Forum** (moderator, participant)
  …
- **Electronic commerce**
  ….

Multirole session types - what

- Conversations group related communications/actions
- Two or mote roles in one conversation
- One or more participants per role
- Conversation instances created
- Roles communicate with other roles on a channel
- Participants belong to one or more roles
- Participants send/receive messages on the channels corresponding to their role
- Conversations may be nested
- ….
- on top of an oo language

Conversations – e.g.

```
conversation Auction{

    roles  Auctioneer, Bidder, Secretary;

    channel ch1 for Auctioneer to Bidder:
              (  ! Item. (! Price.? Bid)* )*

    channel ch2 for Auctioneer to Secretary:
              ( ! Item. (!keep or !Price.!BidId ) )*

}
```

Design Issues and Further Work

Design Issues

- Of what kind are the participants of a role? Objects or processes?
- May a participant play more than one role?
- How does a participant join a role? Push/pull/authenticate?
- Is communication synchronous/asynchronous?
- Is there a global clock?
- Do all participants in a role send/receive in sync with each other? or according to a "leader"? or according to another role?
- Can a participant join/leave a role while a conversation is running?
- What if a role is empty?
- Which message is read when receiving messages from a role with more than one participant: the "first" message, an arbitrary message, all messages?

Design Issues - 2

- Of what kind are the participants of a role? Objects or **Processes?**
- May a **Process** play more than one role? **YES**
- How does a participant join a role? **Push/**Pull/authenticate?
- Is communication synchronous/**asynchronous**?
- Is there a global clock? **NO**
- Do all participants in a role send/receive in sync with each other? **NO** according to a "leader"? **NO**, or according to another role? **NO**
- Can participant join/leave role while conversation is running? **NOT YET**
- What if a role is empty? **NOT YET**
- Which message is read when receiving messages from a role with more than one participant: the "first" message, an arbitrary message, all messages? **IT DOES NOT MATTER THAT MUCH!**

Expressions are …

- this | e.m(e) | e.f | e.f := e' | **new** C — usual oo stuff
- **spawn** e | **suspend** e — usual concurrent stuff
- **new** cv — create a conversation
- e.r.**join** | e.r.**leave** — join/leave a role in conversation
- e.**start** — start a conversation
- e.ch.**send**(e') | e.ch.**receive** — send/receive one message
- e.ch.**receiveAll(**x**)**{ e' } — repeatedly receive messages and execute e'

Modelling challenge

Communication is

- Asynchronous
- Multicast (potentially in both ways)
- Different participants in the same role may be in different "stages" of communication

For this we introduced

- a noticeboard per conversation instance and channel, which contains the values sent so far per "communication stage"
- a status per process, conversation and channel consisting of
  - Read stage
  - Read index
  - Write stage

runtime organization

- Object == ClassId x (FldId → Value)
- Value == true | false | null | Addr
- Heap == Addr → (Object or Conversation)
- Conversation ==

  ConvId x

  (RoleId → ProcAddr*) x participants per role

  (ChId x stage → Value*) noticeboard per channel

- Heap == Addr → (Object or Conversation) and

  (ProcAddr x ConvAddr x ChanID

  →

  stage x int x stage)

  read stage, read index, write stage

Receiving

???

---

k.ch.receive, p, h ➔ ???

where h is a heap, p/k are process/convers. addr.

Receiving

h(p,k,ch) = (rdStage, rdIndx, wrStg)

---

k.ch.receive, p, h ➔ v, p, h'

where h is a heap, p/k are process/convers. addr.

Read the progress status of p, k, ch

Receiving

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'= h[p,k,ch |-> (rdStage+1, rdIndx, wrStage)]

---

k.ch.receive, p, h ➔ v, p, h'

where h is a heap, p/k are process/convers. addr.

Increment the read stage of p, k, ch

Receiving

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'= h[p,k,ch |-> (rdStage+1, rdIndx, wrStage)]

h(k,chId)=vals vals[rdStage] = … v …

k.ch.receive, p, h ➔ v, p, h'

where h is a heap, p/k are process/convers. addr.

Read arbitrary value from the noticeboard of k, ch of rdStage

Receiving

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'= h[p,k,ch |-> (rdStage+1, rdIndx, wrStage)]

h(k,chId)=vals vals[rdStage] = … v …

k.ch.receive, p, h ➔ v, p, h'

where h is a heap, p/k are process/convers. addr.

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'= h[p,k,ch |-> (rdStage, rdIndx+1, wrStage)]

h(k,chId)=vals vals[rdStage,rdIndx] = v

k.ch.receiveAll(x){e}, p, h ➔ e[v/x]; k.ch.receiveAll(x){e}, p, h'

Sending

???

---

k.ch.send(v), p, h ➔ ???

Sending

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'' = h[p,k,ch |-> (rdStage, rdIndx, wrStage+1)]

---

k.ch.send(v), p, h ➔ null, p, h'

Sending

h(p,k,ch) = (rdStage, rdIndx, wrStg)

h'' = h[p,k,ch |-> (rdStage, rdIndx, wrStage+1)]

h' = h''[k,ch,wrStage|-> h(k,ch,wrStage)::v]

k.ch.send(v), p, h ➔ null, p, h'

Design Issues - 3

- …
- Can participant join/leave role while conversation is running?
  AT FIXED POINTS OF THE CONVERSATION
- What if a role is empty?
  THROW EXCEPTION WHEN TIMEOUT
- Undo session part / failure of subconversation
- Do we want to indicate/restrict the possible number of parameters in a role (eg exactly one auctioneer)
- Garbage collect noticeboards no longer needed

Design Issues - 4

From **channel-centric** session types:

```
conversation Auction{
    …
    channel ch1 for Auctioneer to Bidder:
            (  ! Item. (! Price.? Bid)* )*
    channel ch2 for Auctioneer to Secretary:
            ( ! Item. (!keep or !Price.!BidId ) )*
}
```

to **participant-centric** session types

```
conversation Auction{
   …
 communications Auctioneer:
    ( ! Bidder.Item. ! Secretary.Item.
      (! Bidder.Price.? Bidder.Bid)*.
         Secretary.(!keep or Secretary.!Price.!BidId ) )*
}
```

Further Work

- Types
- Soundness proof
- Examples
- Advanced Features
- Case Studies
- Implementation
- Integration with GUI builder

Thank you!

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