# Formal Algebraic Modeling and Analysis of Communication Spaces

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# **Examples of Communication Spaces**

### Internet-based



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#### facebook.





- · Smart Homes, Mobile Ad-hoc Nets
- · dynamic actors and channels

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# Skype as example Communication Space

- different communication modes:
  - direct calls
  - dynamic managed conferences
  - persisting text transmission
  - file transmission
- contact management
- status management
  - do not disturb, SkypeMe
- covers common features of Communication Spaces
  - adequate case study for modeling of Communication Spaces





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# Benefits of formal modeling

- · unambiguous system description
- · formal semantics yield
  - analysis/verification techniques for
    - consistency
    - · safety and security requirements
    - · deadlock situations
    - $\cdot$  termination
  - prototyping of tools for editing and simulation







# Well-established (formal) methods for aspects of CS

comprehensive modeling technique?

candidates regarding main aspects:

- **algebras** for modeling content and data
- Petri nets for modeling topology of Communication Spaces
  - rule-based transformation for interaction and dynamic reconfiguration



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# New formal approach

### reconfigurable AHOI Petri nets

- · extension of Petri nets:
  - reconfiguration by rule-based transformation
    - · dynamic structure
  - Algebraic (high-level)
    - · data as tokens
  - Higher-Order
    - · nested Petri nets (as tokens)
  - Individual tokens
    - $\cdot$  data with identities
    - $\cdot$  change marking with rules (technical premise)







# **Example reconfiguration**



- AHOI transformation rule  $r = L \leftarrow I \rightarrow R$ 
  - individual tokens allow change of marking
- transform a net N: apply at match m via double pushouts
- rule denotation: may omit interface if section of L and R

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# Modeling principles

- focus on observable behavior, user activities
  - due to closed source, proprietary net protocols
- AHOI net as Skype system, with user clients as components
- distinguish user actions from system reactions
  - enabled transition  $\Rightarrow$  possible user action
    - change client's state or announce request to system
  - possible rule application  $\Rightarrow$  global system task
    - enabled by a client request
    - extend/restrict client behavior or transmit data
- concise visual system representation
  - clean up unused structures



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### Overview – Skype features modeled with AHOI-nets

- representation of user clients
- · exchanging contact data
- starting/inviting to conferences
  - transmitting data in conferences
  - quitting conferences
- chats
- · multi-user chats
- forward a direct call to another contact
- shared contact groups (synchronized lists)
  - require extended AHOI transformation



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# **Request for contact**

#### in Skype:

· find people in white pages and request their contact

| Say hello to Slovadon Razonovitch   | Hello! From Max Zarraile  |
|---|---|
| Say Hello! To Slovadon Razonovitch  | Max Zarraile (songwriter22) requests your contact details.  |
| Ad Sovadon Razonovitch (sbrazonovitch) to your Contact List<br>Skype Writer<br>Hello! Please add me to your Contact List<br>Mountain View, US<br>C Allow Slovadon Razonovitch to see when you are online<br>Do not allow Slovadon Razonovitch to see when you are online<br>Mide Option | <ul> <li>Max Zarraile</li> <li>Please allow me to see when you are online</li> <li>US</li> <li>Share your contact details with this person</li> <li>Do not share your contact details with this person</li> <li>Block this person from contacting you in the future</li> <li>Add Max Zarraile (songwriter22) to my Contacts</li> <li>M C</li> <li>Hide Options</li> <li>OK</li> <li>Decide Later</li> <li>Ignore</li> </ul> |
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## Request for contact - enabling

#### in AHOI net:

 rule creates structure allowing the responder to accept/deny the contact request



# Conferences

#### in Skype:

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- make a call to another client and then invite some known contacts
  - alternatively, select directly all participants from contact list
- participants: can join if invited, or leave conference
- conference host: may invite/kick participants
- host leaves → conference will be terminated

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# **Conferences** – enabling



#### in AHOI net:

 rule creates structure to allow a callee to join the conference, respecting privacy settings



# **Conferences – transmitting**

each user is represented in a conference with a data unit token

- object Petri net with fixed structure
- *Data:* audible, textual, visual etc.
- SkypeName place for identification
- can receive and request sending (client behavior as transition firing!)



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## **Conferences** – transmitting

set of rules to transfer data tokens

· from one unit to all other units on the same place



# Conferences – inviting participants

· rule connects another client to existing conference

· RHS is also negative application condition (NAC): invite only once!



## Chats

similar to conferences (transmitting), but:

- non-exclusive: enabling rule copies data unit templates into chat structure instead of clearing Ready2Talk places
- · participants can leave and rejoin freely
- · chats are persistent  $\rightarrow$  no deletion rule, unit copies keep chat history



### New challenges of AHOI nets

#### high-level tokens:

- representation of user identities and communication data
- higher-order tokens:
  - communication sub-systems for distributed behavior
  - reconfiguration:
    - adapt system net structure
      - · for dynamic actors and channels
      - to extend/abridge client behavior

#### individual tokens

- tokens are distinguishable (even if of same value)
- reconfiguration of system structure and marking
  - · for rule-based data exchange



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# **Ongoing work**



- develop AHOI-nets as formal modeling approach including
  - flexibility (fewer, more abstract rules)
  - precision (control system behavior/reconfiguration)
  - expressiveness (extended rule matching)

#### verify system properties

- in Skype, e.g. access rights are respected
  - entries in contact lists must have been confirmed by correspondent contact's client
  - establish communication only if access is granted
- simulation of models in tool
- formal analysis, ensuring consistency
  - theory of weak adhesive high-level replacement systems:
    - parallelism, concurrency, independence (Local Church Rosser), (local) confluence
  - rules on individual nets can simulate object net firing steps
    - yields independence analysis of firing steps and transformation





