

# BETTY – WG1: Foundations of Behavioural Types

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# What these slides are

- 1 An attempt to help us all point out some existing and potential research activities that can become the focus of future collaboration within the BETTY network.
- 2 Hopefully a discussion starter.

## And what they are not

- 1 They are not the final word on research in the area of behavioural types.
- 2 They do not provide a comprehensive bibliography.
- 3 And they do not constitute a tutorial on this topic.

# Part I

## Two avenues

# Type idioms and type systems for calculi/languages

- Binary session types
- Multiparty session types
- Automata-based types
- Contracts
- Expressing safety and liveness properties

# Semantic foundations

- Relating approaches via encodings
- Linear logic
- Notions of subtyping

## Part II

# Surrounded by idioms

# Session types

Session types generalize notions of channel types from process calculi with notions of non-uniformity and causality.

- Communication channels are used according to a protocol.
- There is a notion of typability.
- Very often, the language is an extended process language with special primitives for establishing session channels, selection and branching.

# Dyadic session types

The paper (Honda, 1993) introduced the basic ideas for session types, and (Honda *et al.* , 1998) was an important step on the road to session types becoming important.

# Multiparty session types

The seminal paper here is (Honda *et al.* , 2008) which introduces the notions of local and global descriptions of a system along with local and global types.

- How do we understand/synthesize local behaviour based on global behaviour (and vice versa)?
- How do we understand/synthesize local types based on a global type (and vice versa)?

# Understanding global behaviour

- (Bocchi *et al.* , 2010) shows how to add data to the theory of choreographies.
- (Carbone *et al.* , 2012) introduces global types as descriptions of whole conversation scenarios and relates them to session types.
- (Carbone & Montesi, 2013) proposes a purely-global programming model. **Marco Carbone will talk about this later.**
- (Castagna *et al.* , 2012) presents a new, streamlined language of global types equipped with a trace-based semantics and compares it with related specification languages.
- **Ivan Lanese will talk about adaptable choreographies.**

# From the local to the global – and back again

- (Lanese *et al.* , 2008) shows that different conditions are needed to make a choreography projectable onto single participants.
- (Lange & Tuosto, 2012) proposes a typing systems which allows, under some conditions, to synthesise a choreography (i.e. a multiparty global type) from a set of local session types which describe end-point behaviours (i.e. local types).

## Other work on multiparty session types

- (Bocchi *et al.* , 2012) proposes algorithms for helping the design of choreographies that use data.
- (Caires & Vieira, 2010) introduces a generalisation of session types for multiparty interaction, unifying local and global types.
- (Chen *et al.* , 2012) deals with how to correctly instrument monitors for enforcing session types in a distributed setting.

# Contracts

Session types

Contracts

$?\text{Int}.\text{?Int}.(!\text{Real} \oplus !\text{Error})$      $a.a.(\bar{b} \oplus \bar{c})$

(example borrowed from (Castagna *et al.* , 2009))

# Contracts

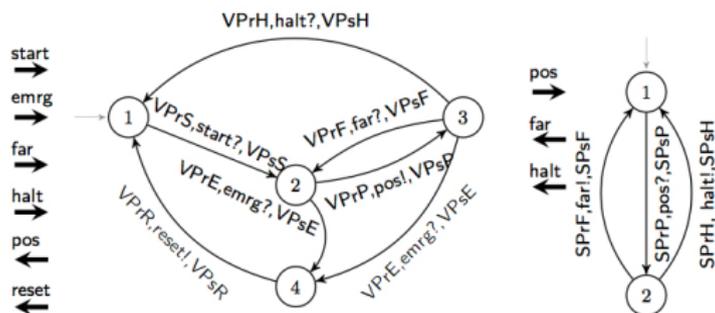
Contracts use CCS-like languages for describing an abstraction of the behaviour of a program. A notion of *conformance* describes if and how a program lives up to a contract.

- (Castagna *et al.* , 2009) describes a theory of contracts that formalizes the compatibility of a client with a service, and the safe replacement of a service with another service.
- (Bartoletti *et al.* , 2012) presents a calculus of contracting systems, allowing distributed participants to advertise behavioural contracts, reach agreements and realise them (or choose not to).

# Conforming to a contract

- (Bravetti & Zavattaro, 2007) presents a foundational theory of behavioural contracts for multi-party service composition, focusing on the conformance relation of a contract for a given role with respect to a (well-formed) choreography.
- (Bravetti & Zavattaro, 2009) presents a foundational theory of behavioural contracts for multi-party service composition, focusing on contract refinement (coarsest subcontract relation) and its relationship with (fair) testing.

# Interface automata



(from (Mouelhi *et al.* , 2009))

The interface of a component is described using an I/O-automaton. A notion of *refinement* compares abstract and concrete descriptions of a given interface.

# Interface automata

- (Mouelhi *et al.* , 2009) proposes a method to enrich the interface automata formalism.
- (Chouali & Hammad, 2011) describes an approach which combines component SysML models and interface automata in order to assemble components and to verify formally their interoperability.

# Typestates

Here the type of a typable entity is state-based. The state describes the operations that are permitted for an object that has this particular typestate.

(Gay *et al.* , 2010) gives a unified view of communication channels and their session types, distributed object-oriented programming, and a form of typestates supporting objects that dynamically change the set of available methods.

# Reasoning about properties

- (Bettini *et al.* , 2008) introduces a type system to prove *progress properties* for a system in which sessions can be interleaved.
- (Vieira & Vasconcelos, 2013) proposes another such system.
- **Hugo Torres Vieira will talk about this.**
- In the study of *liveness properties*, (Kobayashi, 2002) shows how to use a notion of behavioural types to reason about global properties of systems, in particular lock-freedom.
- **Marco Carbone will say more about liveness properties.**

## Part III

# Semantic foundations

# Subtyping for session types

- (Gay & Hole, 2005) is a seminal paper! This paper makes it possible to think of subtyping as a way of giving semantics to session types.
- (Barbanera & de' Liguoro, 2010) proposes a refinement and a simplification of the behavioural semantics of session types, based on the concepts of compliance and sub-behaviour from the theory of web contracts.
- (Padovani, 2011a) describes an extension of the notion of subtyping to multiparty sessions.

# Relating contracts

The notion of subtyping has its counterpart in the study of contracts.

(Castagna & Padovani, 2009) provides a semantic account of how to relate contracts, in terms of the eventual outcome (deadlock, success or indefinite progress) of every sub-component making up the contract. The underlying idea is similar to that of testing preorders.

# Linear logic

(Caires & Pfenning, 2010) develops a Curry-Howard interpretation between binary session types and linear logic propositions.

Luis Caires will talk about this.

## Relating approaches

- (Bernardi & Hennesy, 2012) gives a comparison of session types and contracts.
- (Demangeon & Honda, 2011) establishes a relationship between binary session types in the  $\pi$ -calculus and standard type systems.
- (Padovani, 2011b) shows the connection between choice operators in session types and intersection and union types in conventional type systems.
- (Hüttel, 2011) presents a general type system for  $\Psi$ -calculi that also allows for instantiations to type/effect systems.
- (Dardha *et al.* , 2012) presents a fully abstract translation of session types into a 'sessionized' version of the simply typed  $\pi$ -calculus.

## Part IV

And next...

## How can BETTY help us?

Think about this in the light of this presentation and the short presentations that follow:

- Potential for collaboration on existing topics.
- New topics for future collaborative efforts.
- Potential scientific missions.

## Item 5 on the agenda of the Management Committee



WG1 needs a *chair* (or co-chairs) and a *vice-chair*. The vice-chair should be an early-stage researcher.

## Short presentations (300 seconds each)

- Marco Carbone
- Hugo Vieira
- Ivan Lanese
- Luis Caires
- Marco Carbone

Barbanera, Franco, & de' Liguoro, Ugo. 2010.

Two Notions of Sub-behaviour for Session-based Client/Server Systems.

*Pages 155–164 of: Proc. of PPDP'10.*

Bartoletti, Massimo, Tuosto, Emilio, & Zunino, Roberto. 2012.

On the Realizability of Contracts in Dishonest Systems.

*Pages 245–260 of: COORDINATION.*

Bernardi, Giovanni, & Hennessy, Matthew. 2012.

Modelling session types using contracts.

*Pages 1941–1946 of: SAC.*

Bettini, Lorenzo, Coppo, Mario, D'Antoni, Loris, De Luca, Marco, Dezani-Ciancaglini, Mariangiola, & Yoshida, Nobuko. 2008.

Global Progress in Dynamically Interleaved Multiparty Sessions.

*Pages 418–433 of: CONCUR'08.*

Bocchi, L., Honda, K., Tuosto, E., & Yoshida, N. 2010.

A Theory of Design-by-Contract for Distributed Multiparty Interactions.

*Pages 162–176 of: Gastin, Paul, & Laroussinie, François (eds), Proc. of CONCUR 2010.*

Bocchi, Laura, Lange, Julien, & Tuosto, Emilio. 2012.

Three Algorithms and a Methodology for Amending Contracts for Choreographies.

*Sci. Ann. Comp. Sci.*, **22**(1), 61–104.

Bravetti, Mario, & Zavattaro, Gianluigi. 2007.

Towards a Unifying Theory for Choreography Conformance and Contract Compliance.

*Pages 34–50 of: SC 2007.*

Bravetti, Mario, & Zavattaro, Gianluigi. 2009.

Contract-Based Discovery and Composition of Web Services.  
*Pages 261–295 of: Formal Methods for Web Services, 9th International School on Formal Methods for the Design of Computer, Communication, and Software Systems, SFM 2009.*

Caires, Luís, & Pfenning, Frank. 2010.  
Session Types as Intuitionistic Linear Propositions.  
*Pages 222–236 of: CONCUR'10.*

Caires, Luís, & Vieira, Hugo Torres. 2010.  
Conversation types.  
*Theor. Comput. Sci.*, **411**(51-52), 4399–4440.

Carbone, Marco, & Montesi, Fabrizio. 2013.  
Deadlock-freedom-by-design: multiparty asynchronous global programming.  
*Pages 263–274 of: POPL.*

- Carbone, Marco, Honda, Kohei, & Yoshida, Nobuko. 2012.  
Structured Communication-Centered Programming for Web Services.  
*ACM Trans. Program. Lang. Syst.*, **34**(2), 8:1–8:78.
- Castagna, Giuseppe, & Padovani, Luca. 2009.  
Contracts for Mobile Processes.  
*Pages 211–228 of: Proceedings of CONCUR 2009.*
- Castagna, Giuseppe, Gesbert, Nils, & Padovani, Luca. 2009.  
A theory of contracts for Web services.  
*ACM Trans. Program. Lang. Syst.*, **31**(5).
- Castagna, Giuseppe, Dezani-Ciancaglini, Mariangiola, & Padovani, Luca. 2012.  
On Global Types and Multi-Party Session.  
*Logical Methods in Computer Science*, **8**(1).

- Chen, Tzu-Chun, Bocchi, Laura, Denilou, Pierre-Malo, Honda, Kohei, & Yoshida, Nobuko. 2012.  
Asynchronous Distributed Monitoring for Multiparty Session Enforcement.  
*Pages 25–45 of: Bruni, Roberto, & Sassone, Vladimiro (eds), Trustworthy Global Computing. Lecture Notes in Computer Science, vol. 7173.*
- Chouali, Samir, & Hammad, Ahmed. 2011.  
Formal verification of components assembly based on SysML and interface automata.  
*ISSE, Special issue of the International NASA Journal on Innovations in Systems and Software Engineering, 7(4), 265–274.*
- Dardha, Ornela, Giachino, Elena, & Sangiorgi, Davide. 2012.  
Session types revisited.

*Pages 139–150 of: PPDP.*

Demangeon, Romain, & Honda, Kohei. 2011.

Full Abstraction in a Subtyped pi-Calculus with Linear Types.

*Pages 280–296 of: CONCUR.*

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Subtyping for session types in the pi calculus.

*Acta Inf.*, **42**(2-3), 191–225.

Gay, Simon J., Vasconcelos, Vasco Thudichum, Ravara, António, Gesbert, Nils, & Caldeira, Alexandre Z. 2010.

Modular session types for distributed object-oriented programming.

*Pages 299–312 of: POPL.*

Honda, K., Yoshida, N., & Carbone, M. 2008.

Multiparty asynchronous session types.

*Pages 273–284 of: Proc. of POPL'08.*  
ACM Press.

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Types for Dyadic Interaction.

*Pages 509–523 of: Best, Eike (ed), CONCUR '93*

Honda, Kohei, Vasconcelos, Vasco Thudichum, & Kubo, Makoto.  
1998.

Language Primitives and Type Discipline for Structured  
Communication-Based Programming.

*Pages 122–138 of: Hankin, Chris (ed), Programming  
Languages and Systems - ESOP'98.*

Hüttel, Hans. 2011.

Typed  $\Psi$ -calculi.

*Pages 265–279 of: Katoen, Joost-Pieter, & Knig, Barbara  
(eds), CONCUR 2011.*

Kobayashi, Naoki. 2002.

A Type System for Lock-Free Processes.

*Inf. Comput.*, **177**(2), 122–159.

Lanese, I., Guidi, C., Montesi, F., & Zavattaro, G. 2008.

Bridging the Gap between Interaction- and Process-Oriented Choreographies.

*Pages 323–332 of: Cerone, Antonio, & Gruner, Stefan (eds), Proc. of SEFM'08.*

IEEE Computer Society Press.

Lange, Julien, & Tuosto, Emilio. 2012.

Synthesising Choreographies from Local Session Types.

*Pages 225–239 of: CONCUR.*

Mouelhi, Sebti, Chouali, Samir, & Mountassir, Hassan. 2009.

Refinement of Interface Automata Strengthened by Action Semantics.

*Pages 111–126 of: FESCA'09 proceedings.*

ENTCS, Electronic Notes in Theoretical Computer Science, vol. 253-1.

Padovani, Luca. 2011a.

Fair Subtyping for Multi-Party Session Types.

*Pages 127–141 of: Proceedings of the 13th Conference on Coordination Models and Languages, vol. LNCS 6721.*

Springer.

Padovani, Luca. 2011b.

Session Types = Intersection Types + Union Types.

*Pages 71–89 of: Proceedings of the 5th Workshop on Intersection Types and Related Systems (ITRS'10), vol.*

EPTCS 45.

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*Typing Progress in Communication-Centred Systems.*  
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