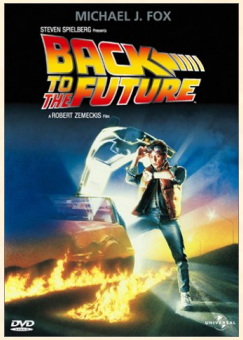
Equational Tree Automata: Past, Present and Future

Hitoshi Ohsaki
(AIST)



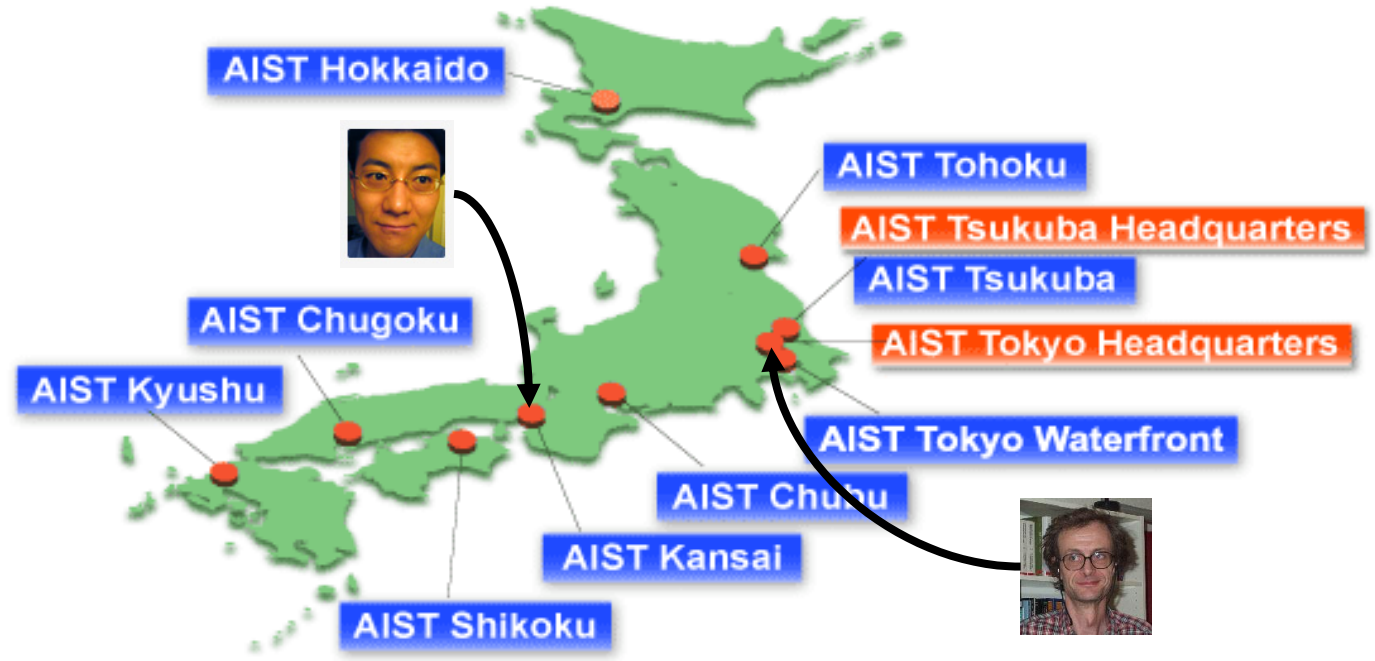
ENS de Cachan

Nov 19, 2008

What is AIST?

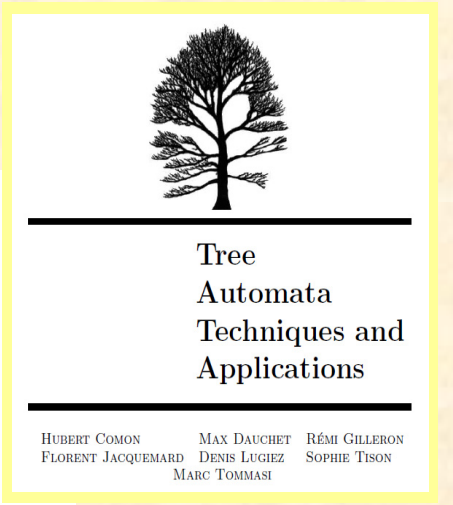
http://www.aist.go.jp

AIST: National Institute founded in 2001 by uniting 14 research organizations and 2 others. Currently we have 9 research bases in Japan, with more than 8000 researchers (including 2000 tenure).



* NAIST, JAIST: *Universities* for graduate students

TATA (1997)



Exercise 13. Let $\mathcal{F} = \{f(,), a, b\}$.

1. Let us consider the set of ground terms L_1 defined by the following two conditions:
   - $f(a, b) \in L_1$,
   - $t \in L_1 \Rightarrow f(a, f(t, b)) \in L_1$.

   Prove that the set L_1 is recognizable.
2. Prove that the set (respectively $|t|_b$)
3. Let L be a recognizable tr over $\mathcal{F}$. Let us suppose that f is a commutative symbol. Let the of equations $C = \{f(x, y) (y, x)\}$. P
4. Let L be a recognizable tree language over $\mathcal{F}$. pose that f is a commutative and associative symbol. Let AC the congruence closure of set L for the set of equations $AC = \{f(x, y) = f(y, x); f(x, f(y, z)) = f(f(x, y), z)\}$. Prove that in general $AC(L)$ is not recognizable.
5. Let L be a recognizable tree language over $\mathcal{F}$. Let us suppose that f is an associative symbol. Let $A(L)$ be the congruence closure of set L for the set of equations $A = \{f(x, f(y, z)) = f(f(x, y), z)\}$. Prove that in general $A(L)$ is not recognizable.

Q1. AC(L) : regular if L is regular ?

Q2. A(L) : regular if L is regular ?

"AC" does not preserve regularity

Q1. AC(L) : regular if L is regular ?

A1. No.

Cf. commutative closure of CFL is not CFL.

Q2. A(L) : regular if L is regular ?

A2. No, but it 's not trivial ...

Remark

There was no general framework for dealing with equational closure of tree languages.

Tree automata as ground TRS

$$f(p_1, \ldots, p_n) \rightarrow q$$

Trees with accepted derivation modulo AC	$\Leftrightarrow$	Accepted trees modulo AC

Equational rewriting

= equational reasoning + term rewriting

= equational reasoning + transition

Equational tree automata

Equational Tree Automata

$A = ((F, E), Q, Q_{fin}, T)$

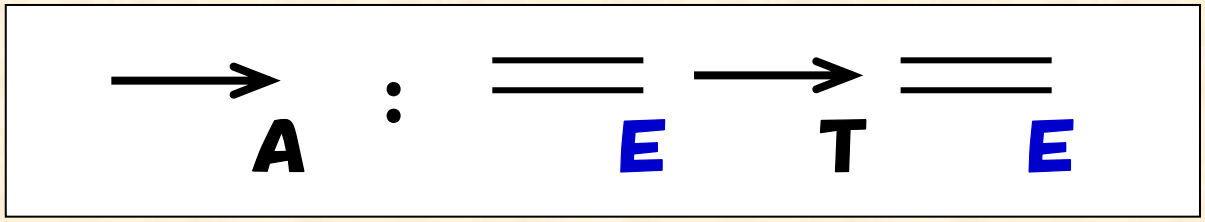
F : signature

E : equations

Q : states

Q_{fin} : final states

T : transition rules



September 2001

Equational Tree Automata for Associative and Commutative Theories

Hitoshi Ohsaki

CSL' 01 (organized by LSV) in Paris

2 days before my talk

1. (**Commutation Lemma**)

   $L(A / =_E) = L(A) / =_E$ **if E is linear**

2. (**Monotone Rules**)

   $f(p_1, \ldots, p_n) \rightarrow f(q_1, \ldots, q_n)$

3. **Closedness under Union & Intersection, etc.**

Tree Automata Modulo (2002-2003)

- **Presburger Tree Automata**
  (Seidl et al.)

  Tree automata for XML database

- **Multi-tree Automata**
  (Dal Zilio & Lugiez)

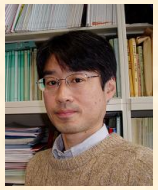
  AC tree automata = Presburger tree automata

- **Two-way Alternating AC Tree Automata**
  (Verma)

  $L(A/=_E) = L(A)/=_E$ ~~if E is linear~~

Project ETA

Naoki Kobayashi



Hiroyuki Seki

Ralf Treinen

Tohoku Univ (Sendai)

NAIST(Nara)

AIST (Osaka)

Theory

LIFL (Lille)

Sophie Tison

Jean-Marc Talbot

Yves Roos

Application

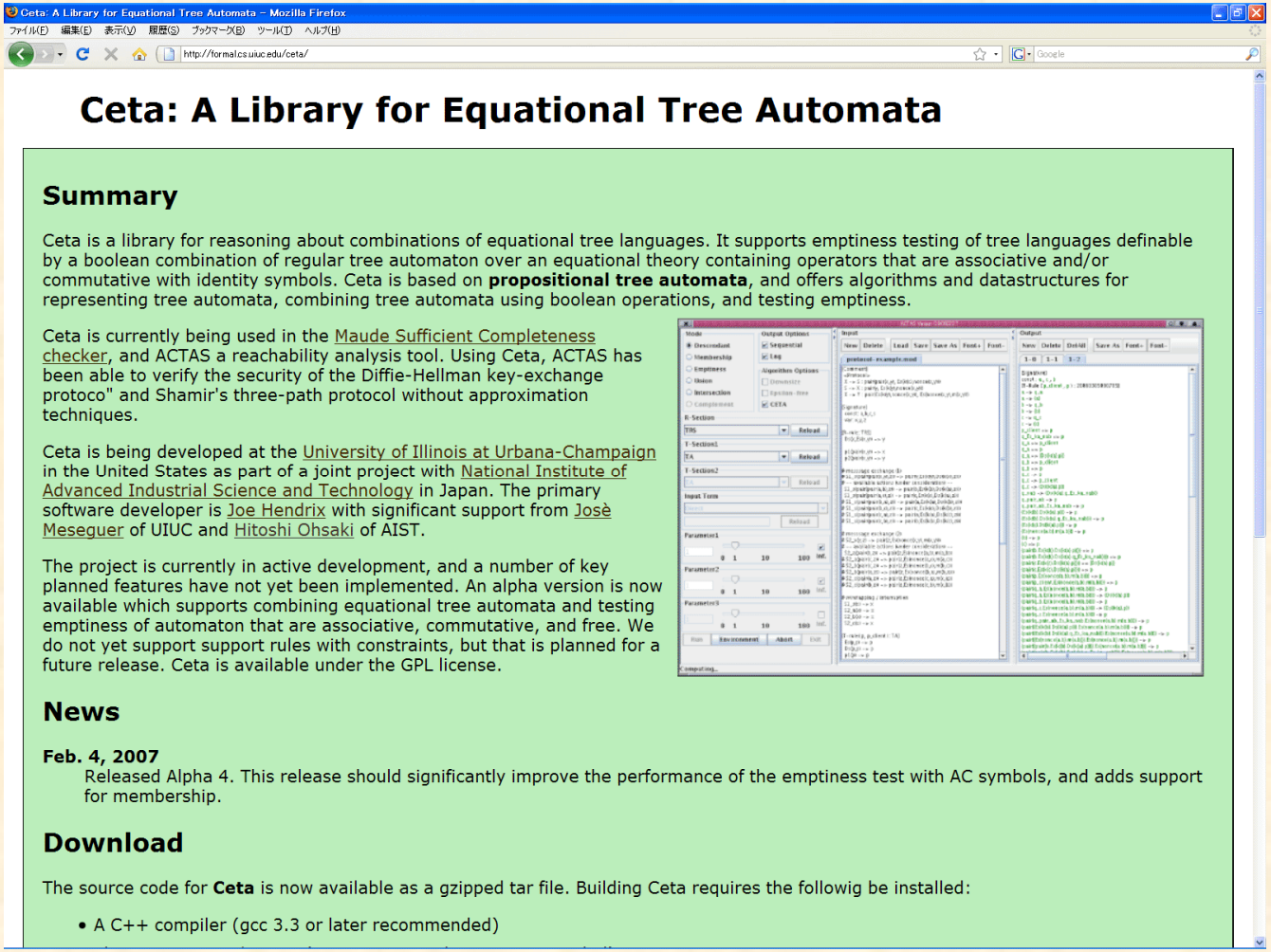
ENS de Cachan (Paris)

Implementation

Univ of Illinois (Urbana-Champaign)

(next)

Software Development



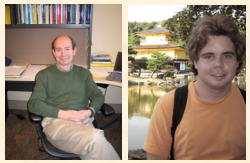
José Meseguer

Joe Hendrix

ACTAS(reachability analysis tool) and CETA

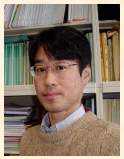
1+3 Frameworks in Research

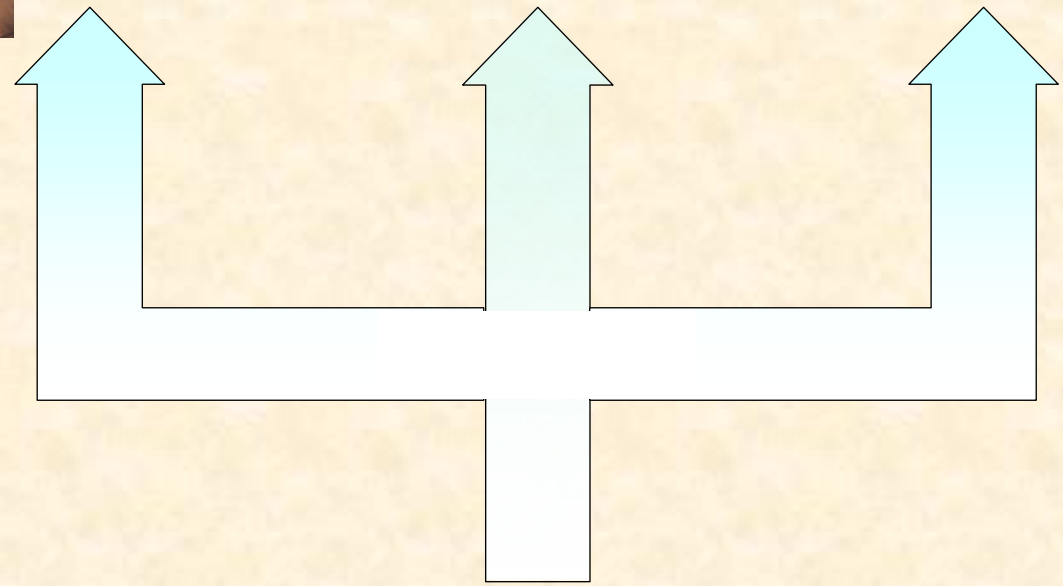
PTA
(Propositional TA)



Monotone ETA

TAN
(TA with Normalization)





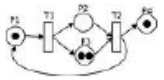
(Regular) Equational Tree Automata

Monotone AC Tree Automata

$f(p_1, \ldots, p_n) \to q$ [regular]

$p \to q$ [epsilon]

$f(p_1, \ldots, p_n) \to f(q_1, \ldots, q_n)$ [monotone]

	monotone AC-TA	Petri-nets 
$t \in L$?	PSPACE-complete	EXPSPACE-hard
$L = \varnothing$?	EXPSPACE-hard (?)	(decidable)

(✓ : positive – : negative)

closed under $\cup$	✓	✓
closed under $\cap$	✓	✓
closed under $(\ )^c$	–	–

… for Non-linear Arithmetic

decidable | **undecidable**

Monotone AC tree automata

Monotone exponential Diophantine arithmetic

$$\begin{array}{lll} \mathsf{M} & ::= & \mathsf{E}(\vec{x}_n) \geqslant \mathsf{L}(\vec{x}_n) \mid \mathsf{C}\ \text{(Presburger formula)} \mid \mathsf{M} \vee \mathsf{M} \mid \mathsf{M} \wedge \mathsf{M} \\ \mathsf{E}(\vec{x}_n) & ::= & a \mid x_i \mid \mathsf{E}(\vec{x}_n) + \mathsf{E}(\vec{x}_n) \mid \mathsf{E}(\vec{x}_n) \times \mathsf{E}(\vec{x}_n) \mid \mathsf{E}(\vec{x}_n)^{\mathsf{E}(\vec{x}_n)} \end{array}$$

$x^{x^x} \geqslant y$

Diophantine arithmetic

Every formula in ▭ is definable by monotone AC tree automata

RTA'08 Best Paper Award

Open Questions

1. Universality problem of monotone AC-TA

- The emptiness is decidable, but the inclusion is not.
- The question is in RTA Open Question List (#101).

2. The class of monotone AC-TA is closed under projection?

- Or, every Petri-net definable language is definable by monotone AC tree automata?

3. Emptiness problem of $AC(L) \cap NF\{f(x,x) \to x\}$

Solved

Decidable (Hendrix & Ohsaki RTA '08)

Tree Automata with $f(x,x)=x$

ETA

Tree automata modulo $f(x,x) = x$ axiom
are not closed under complement

TAN

Tree automata with $f(x,x) \to x$ normalization
are closed under complement

Moreover, this class of tree languages
is closed under all Boolean operations,
and the emptiness problem is decidable.

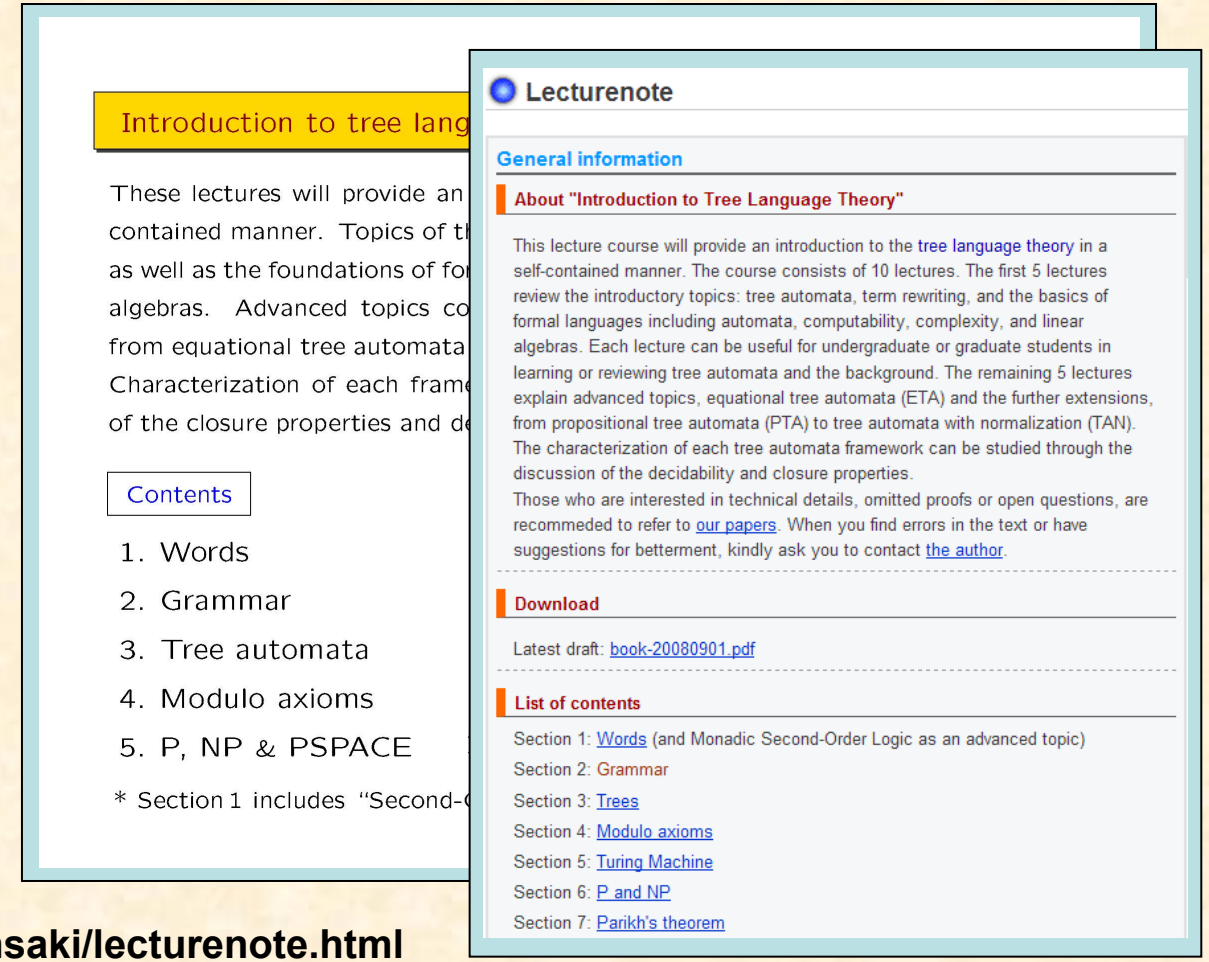
Lecture note on Tree Language Theory

10 lectures from basics to advanced topics

Activities:

Seminar talks at UIUC, Illinois (October 2007).

Lecture course at Track(B), 4th ISR (June 2009).



Draft available:

http://staff.aist.go.jp/hitoshi.ohsaki/lecturenote.html

International School on Rewriting (ISR)

Tree Automata

Program	Monday, 22/06/2009	Tuesday, 23/06/2009	Wed, 24/06/2009	Thursday, 25/06/2	
08:30h – 09:00h	Registration	Traditional and non Traditional Typed λ-calculi Fairouz Kamareddine		Traditional and non Tradi λ-calculi Fairouz Kamaredd	
09:00h – 09:30h	Opening				
09:30h – 10:00h	Introduction to Term Rewriting Franz Baader (Dresden – Germany)				
10:00h – 10:30h		Coffee-Break		Coffee-Break	Coffee-Break
10:30h – 11:00h	Coffee-Break				
11:00h – 11:30h	Introduction to Term Rewriting Franz Baader (Dresden – Germany)	Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)		Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)	Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)
11:30h – 12:00h					
12:00h – 14:00h	Lunch	Lunch	Excursion	Lunch	Lunch
14:00h – 14:30h	Introduction to Term Rewriting Franz Baader (Dresden – Germany)	Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)		Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)	Equational Tree Automata Hitoshi Ohsaki (Osaka - Japan)
14:30h – 15:00h					
15:00h – 15:30h	Coffee-Break				
15:30h – 16:00h	Introduction to Term Rewriting Franz Baader (Dresden – Germany)				
16:00h – 16:30h					
16:30h – 17:00h	Coffee-Break				
17:00h – 17:30h	Introduction to Term Rewriting Franz Baader (Dresden – Germany)				
17:30h – 18:00h					

Track(B)

Program	Monday, 22/06/2009	Tuesday, 23/06/2009	Wed, 24/06/2009	Thursday, 25/06/2009	Friday, 26/06/2009
08:30h – 09:00h	Registration	Conditional Rewriting Bernhard Gramlich (Wien – Austria)		Higher-Order Rewriting with Resources Delia Kesner (Paris - France)	Nominal Rewriting Maribel Fernandez (London - UK)
09:00h – 09:30h	Opening				
09:30h – 10:00h	Advanced Topics in Termination Aart Middeldorp (Innsbruck – Austria)				
10:00h – 10:30h		Coffee-Break		Coffee-Break	Coffee-Break
10:30h – 11:00h	Coffee-Break				
11:00h – 11:30h	Conditional Rewriting Bernhard Gramlich (Wien – Austria)	Advanced Topics in Termination Aart Middeldorp (Innsbruck – Austria)		Nominal Rewriting Maribel Fernandez (London - UK)	Higher-Order Rewriting with Resources Delia Kesner (Paris - France)
11:30h – 12:00h					
12:00h – 14:00h	Lunch	Lunch		Lunch	Lunch
14:00h – 15:00h	Extensions of Typed λ-calculi with Applications in Logic, Programming Languages and Formalisation of Mathematics Fairouz Kamareddine (Edinburgh – Scotland)	Extensions of Typed λ-calculi with Applications in Logic, Programming Languages and Formalisation of Mathematics Fairouz Kamareddine (Edinburgh – Scotland)	Excursion	Advanced Topics in Termination Aart Middeldorp (Innsbruck – Austria)	Advanced Topics in Termination Aart Middeldorp (Innsbruck – Austria)
15:00h – 16:00h	Extensions of Typed λ-calculi with Applications in Logic, Programming Languages and Formalisation of Mathematics Fairouz Kamareddine (Edinburgh – Scotland)	Extensions of Typed λ-calculi with Applications in Logic, Programming Languages and Formalisation of Mathematics Fairouz Kamareddine (Edinburgh – Scotland)		Conditional Rewriting Bernhard Gramlich (Wien – Austria)	Conditional Rewriting Bernhard Gramlich (Wien – Austria)
16:00h – 16:30h	Coffee-Break	Coffee-Break		Coffee-Break	Coffee-Break
16:30h – 17:30h	Parametric Lambda Calculus Luca Paolini (Torino - Italy)	Parametric Lambda Calculus Luca Paolini (Torino - Italy)		Parametric Lambda Calculus Luca Paolini (Torino - Italy)	Parametric Lambda Calculus Luca Paolini (Torino - Italy)

Track(A)

Lecturers of ISR '09

- Franz Baader (Dresden)
- Bernhard Gramlich (Wein)
- Fairouz Kamareddine (Edinburgh)
- Delia Kesner (Paris)
- Aart Middeldorp (Innsbruck)
- Hitoshi Ohsaki (Osaka)
- Luca Paolini (Torino)

Past ⇨ Present …

Collaborative Research with Companies

(PA)

(SAT)

(Model checking)

ENS Cachan

UIUC

LIFL

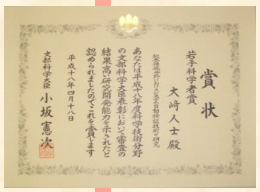
NAIST

Tohoku

Visiting Research Partners

ETA

RTA'05

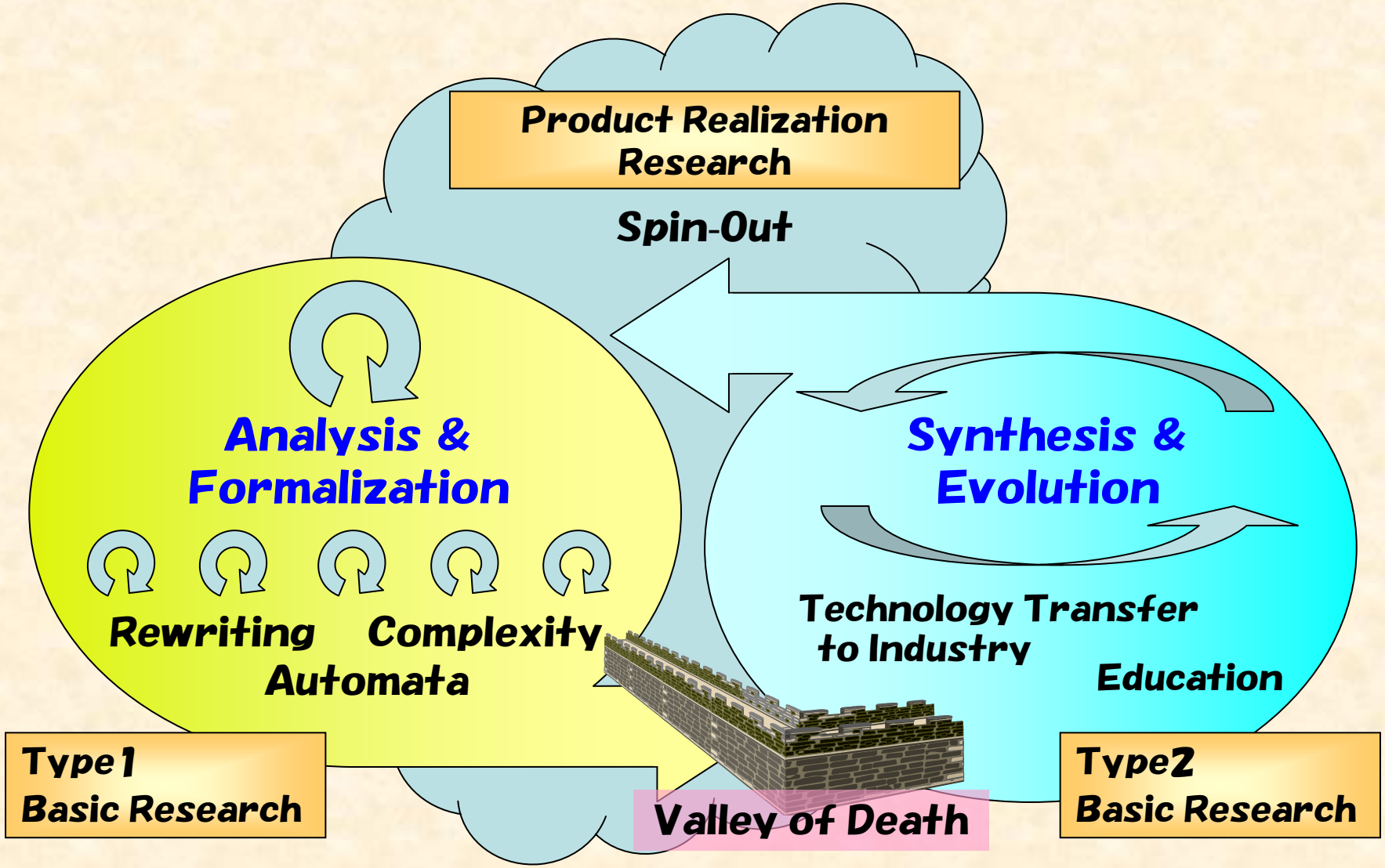


Young Researcher Award

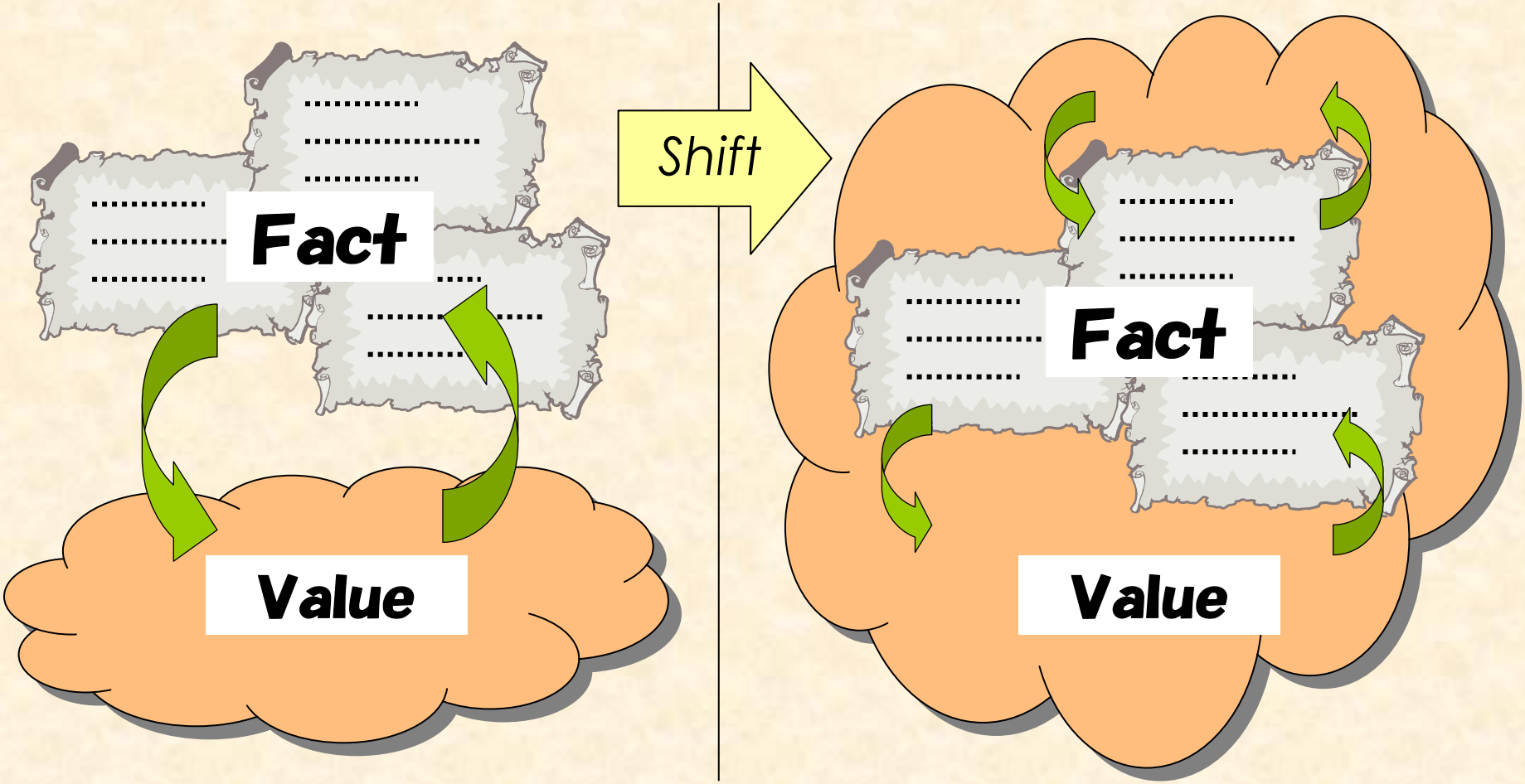
Best Paper Award

2001 2003 2005 2007 2009

Three Research Types in AIST



Collapsing Fact&Value Dichotomy



(Hilary Putnam, 2002)

AIST Journal "Synthesiology"

Synthesiology = "*synthesis*" + "*-ology*" (*disciplines*)

The Aim of Launching "Synthesiology"

… Technology integration research (Type 2 Basic Research) activities have been kept as personal know-how. They have not been formalized as universal knowledge of what ought to be done. … Each paper in this journal will present scenarios selected for their social value, identify elemental knowledge and/or technologies to be integrated, and describe the procedures and processes to achieve this goal.

More about "Synthesiology"

Articles (PDF files) are available:

http://www.aist.go.jp/synthesiology/

Anyone can submit aricles.

Cf. *On the Launch of "Synthesiology": Discussion with Japanese Researchers at UIUC*

Ohsaki (AIST) & Sato (Hosei Univ)

Editorial, Synthesiology **1**(3), *pp.* 222–228 (2008)

Any question or comment is welcome:

ohsaki@ni.aist.go.jp