



Creating a Network of Semantically Integrated Communities on the World Wide Web

Semantic Web Workshop

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The Big Question

How can we create a network of semantically integrated communities on the World Wide Web?

- What does it mean to be semantically integrated?
- Are there any fundamental limitations?
- How can we make progress?

Outline

- **Semantics and the Web**
- **A Semantic Continuum**
- **Complete Semantic Integration**
- **Architectures for Semantic Integration**
- **Conclusions**

Semantics: A Many-Splendored Thing

- “**Semantics**” means [the study of] *meaning*.
- **What has semantics? Where are they? What do they look like? How are they used?**
- **Kinds of Semantics:**
 - Real-world Semantics
 - Axiomatic Semantics
 - Model-theoretic Semantics
 - Denotational, Procedural, Operational ... Semantics

A Semantic Continuum



Pump: “a device for moving a gas or liquid from one place or container to another”



(pump has
(superclasses (...))

Shared human
consensus.

Text descriptions.

Semantics hardwired;
used at runtime.

Semantics processed
and used at runtime.

Implicit

Informal
(explicit)

Formal
(for humans)

Formal
(for machines)

Further to the right means:

- Less ambiguity
- More likely to have correct functionality
- Better inter-operation
- Less hardwiring
- More robust to change
- **More difficult!**

Shopping Agents

Requirements for Machine Usable Content

- **Machine knows what to do with the content.**
Humans hardwire the semantics into the application.
- **Humans know what to do with the content.**
From requirements of the Web application.
- **Humans know the meaning of the expected content.**
Due to shared human consensus on terms like “price” and “destination”.

A Degenerate Case of the Semantic Web

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Complete Semantic Integration

- **Agents have never ‘met’ before;**
- **Successful exchange of information;**
 - complete understanding;
 - guaranteed accuracy;
- **Fully automatic.**
 - *Only* access to meaning of terms is via the axioms in the sending agent’s ontology.
 - i.e. no access to what human ontology designer intended.

Scenario

Agent A



Intended meaning

12 inch measure



Ontology A: foot ...
<axioms>

Agent B



Intended meaning

mode of transportation



Ontology B: Fuß ...
<axioms>

**To guarantee understanding,
ontologies must have *same intended meaning*.**

How do we know the ontologies are correct?

Verified Software

Intended
Requirements



Requirements
Specification

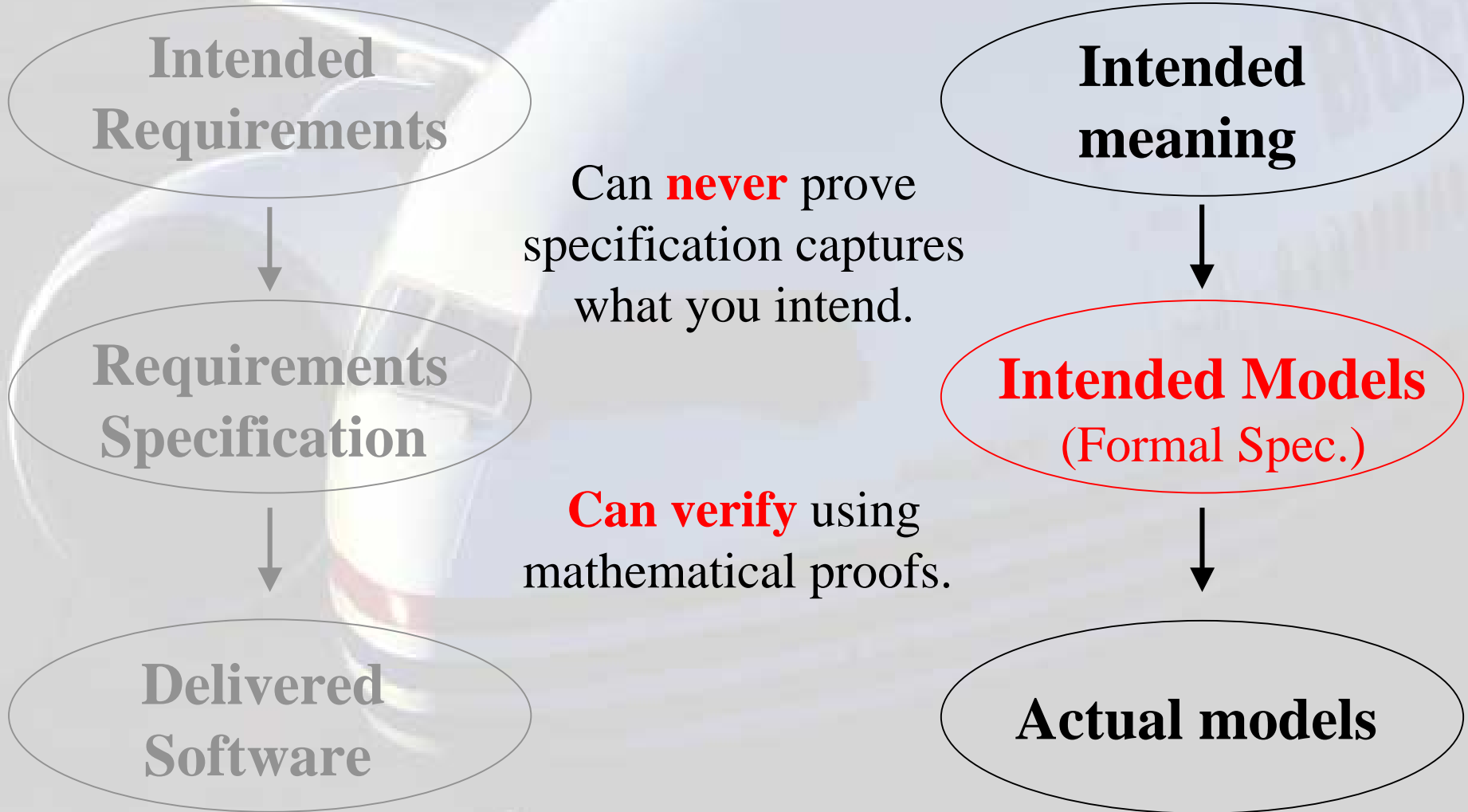


Delivered
Software

Can **never** prove requirements say what you intend.

Can prove that a program correctly satisfies a **formal** requirements specification.

Verified Ontologies



Semantic Integration Gold Standard

- Same intended meaning
- Verified Ontologies:
 - Intended meaning/models is same as actual meaning/models.
- Hypothesize and Test Mappings

Verified ontologies are required to guarantee complete semantic integration.

Achieving Semantic Integration

- **Semantics-preserving exchanges between agents;**
- **Mapping logically equivalent concepts in different ontologies.**
- **Steps:**
 - Generate mappings;
 - Verifying correctness of mappings;
 - Use mappings to translate among ontologies.

Challenges

Semantic Heterogeneity is Pervasive!

- **Language Heterogeneities;**
- **Incompatible Conceptualizations;**
- **Term Heterogeneity;**
- **Different Modeling Styles;**
- **A Formidable Challenge:**
Cryptography, in the general case.

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Some Terminology

- **Mapping (noun):** specification of a link between similar-meaning concepts in different ontologies.
- **Create a Mapping:** i.e. mapping as a verb
- **Translation:** execution of a mapping, may translate a whole ontology, or portions thereof.

Architectures for Semantic Integration

- **Holy Grail: Ontological Negotiation**
- **Status Quo**
- **Global Ontologies**
- **Manual Mapping**
- **Interlingua Ontologies**
- **Community Ontologies**

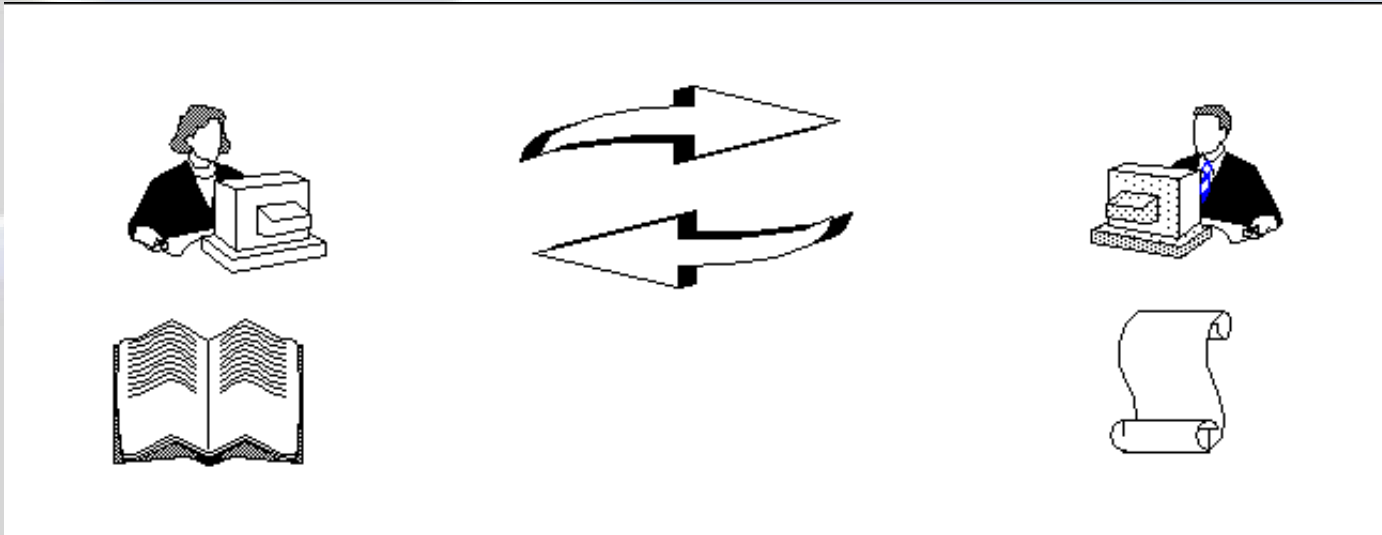
Issues to Consider

- **Who** is generating the Agent-to-Agent semantic mapping?
 - Agent designer
 - Ontology designer, agents are reusing them
 - Agents, dynamically at agent-interaction time
- **When** is the mapping between two agents' ontologies created?
 - Mappings **pre-defined**, agents execute them;
 - Automatically generated at **agent-interaction time**.

Issues to Consider

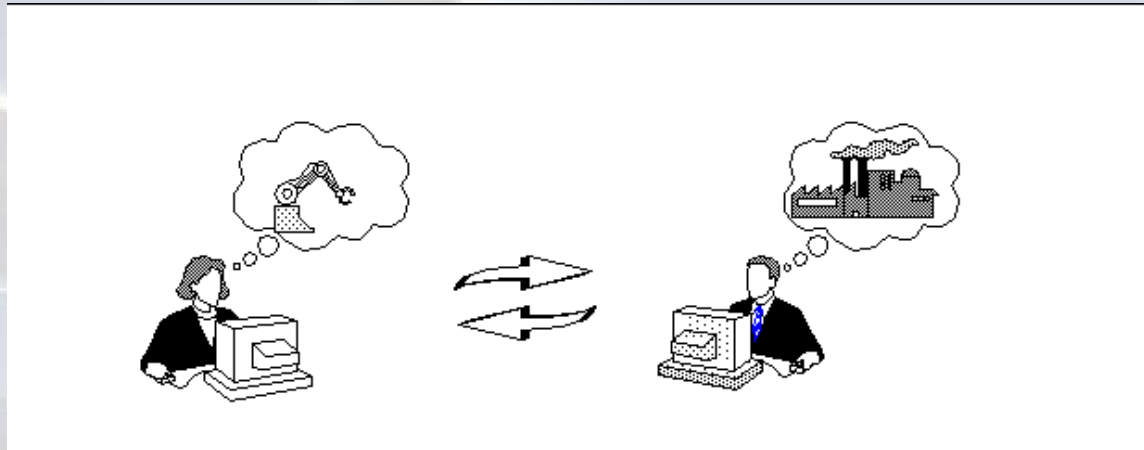
- What is the **topology** of the architecture?
 - **Point-to-Point** mappings between agent ontologies
 - **Mediated** (e.g. by a neutral ontology)
- How much **agreement** is there between the agents (or human agent/software designers)
 - Agreement on **single ontologies** within a community (possibly merged from existing ontologies)
 - Agreement on **Alignments/Mappings** - loose or strong;
 - **No *a priori* agreement.**

The Holy Grail: Ontology Negotiation



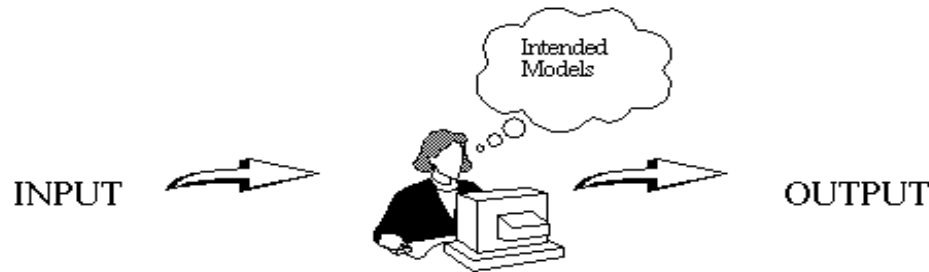
- **Agents themselves** generate mappings.
- **Agent-Agent** mappings **generated automatically** at agent-interaction time.
- **Point to Point** topology
- **No a priori agreement**

Status Quo for Software Integration



- **No explicit semantics**
 - Ambiguity, unstated assumptions,
 - lack of agreement on semantics
- **Humans build translators by ‘guessing’ what things probably mean;**
- **Very error-prone.**

Ontological Stance



“Using the ontology, I can infer the output from the input”

- *Model a software application as if it were **an inference system with a formal ontology.***
- *If it had a **particular ontology**, it would behave “**this way**”.*
- *Predict the set of sentences that the “**inference system**” will prove true. [Menzel & Gruninger 2001]*

Architectures for Semantic Integration

- Holy Grail: Ontological Negotiation
- Status Quo
- **Global Ontologies**
- Manual Mapping
- Interlingua Ontologies
- Community Ontologies

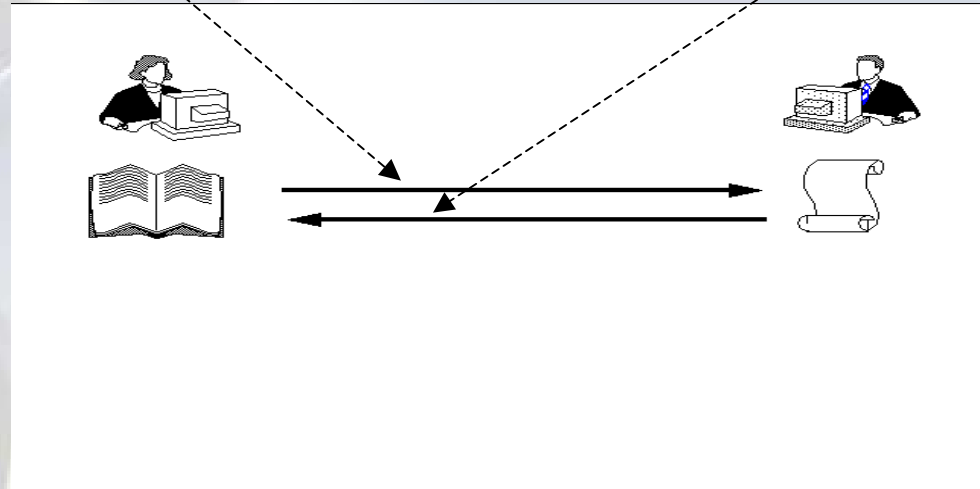
Global Ontology

- Be an Ostrich: **assume no heterogeneity**
- Universal agreement on a single ontology
- Requires a Dictator instead of Mappings
- Global Enterprise Models do not work
- Can *only* work within limited communities

Architectures for Semantic Integration

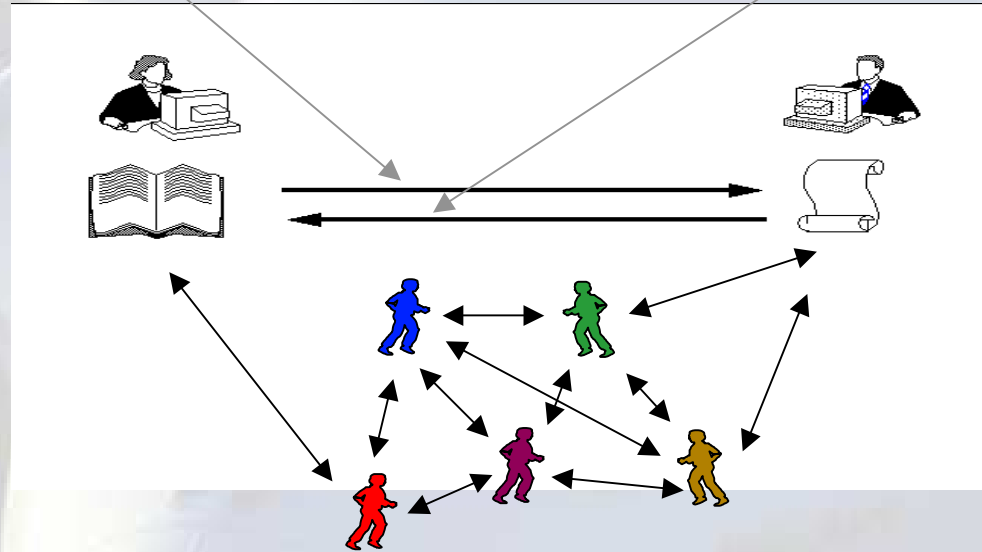
- Holy Grail: Ontological Negotiation
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- **Manual Mapping**
- Interlingua Ontologies
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Manual Mapping



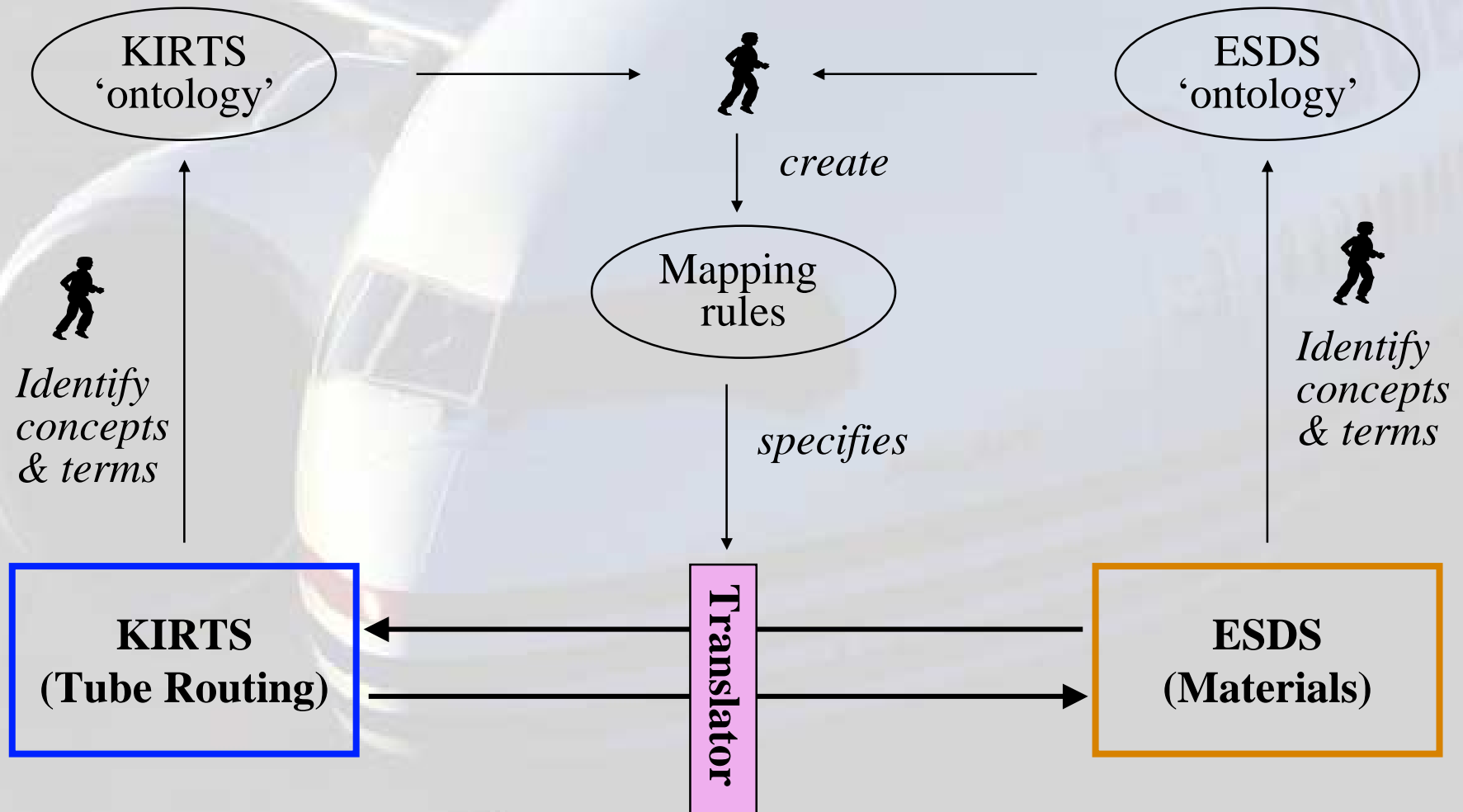
- **Agent designers** generate **Agent-Agent** mappings *manually* ...
- ... **before** agent-interaction time

Manual Mapping

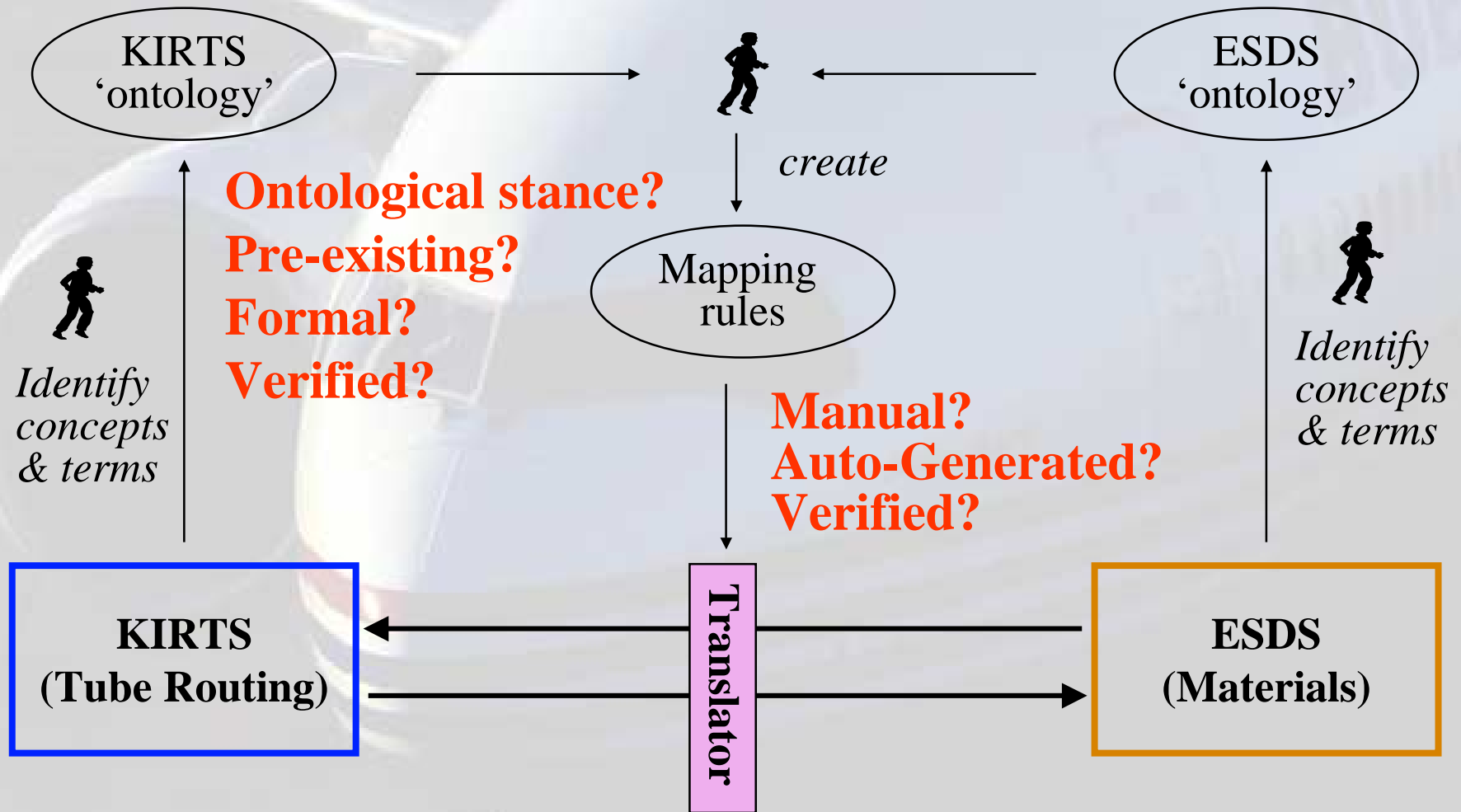


- Agent designers generate Agent-Agent mappings *manually*.
- Agent-Agent mappings generated, before agent
- **Point to Point** topology.
- **No a priori agreement**
- **Fully manual version of “ontology negotiation”**

Manual Mapping Example



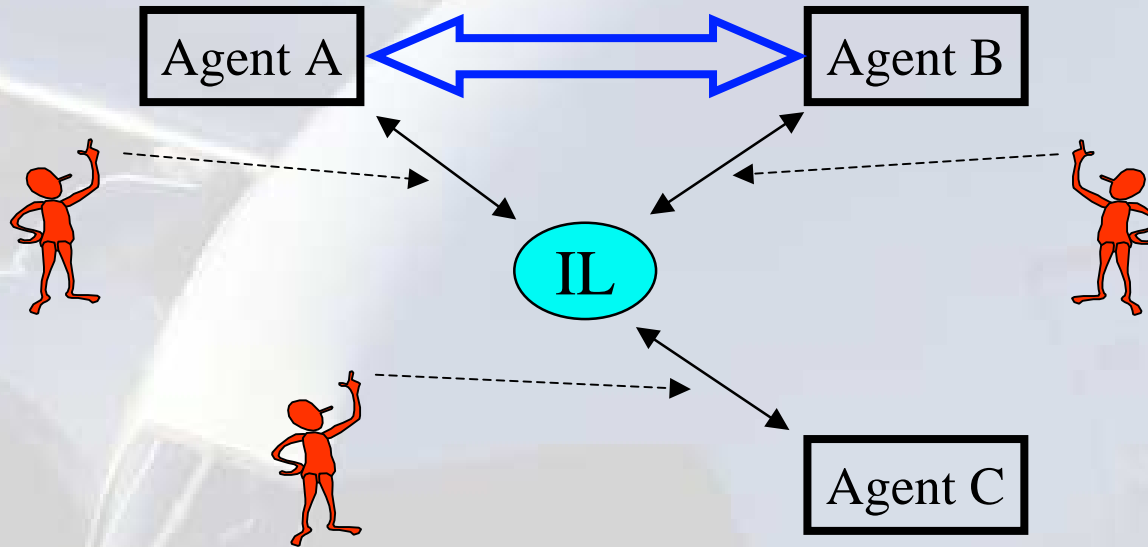
All Along Semantic Continuum



Architectures for Semantic Integration

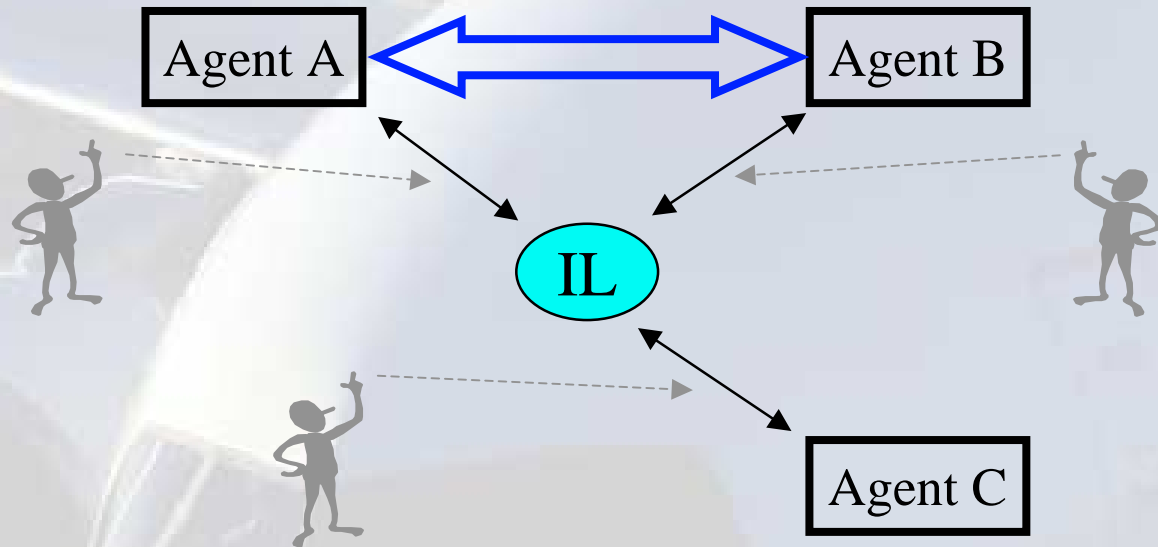
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Interlingua



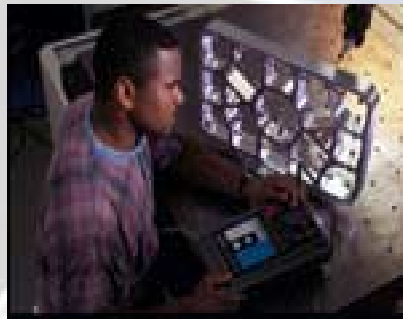
- **Agent designers** generate **Agent-Interlingua** mappings *a priori*.
- **Agent-Agent** mappings **generated automatically** at agent-interaction time.

Interlingua



- Agent designers generate Agent-Interlingua mappings *a priori*.
- Agent-Agent mappings generated automatically at agent-interaction time.
- **Mediated** via Interlingua Ontology.
- **Agreement** to use **Interlingua Ontology**.
- **Semi-automated** “ontology negotiation”

Interlingua Example



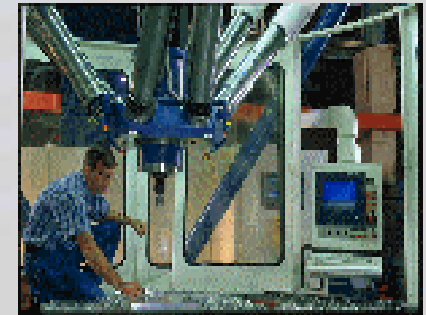
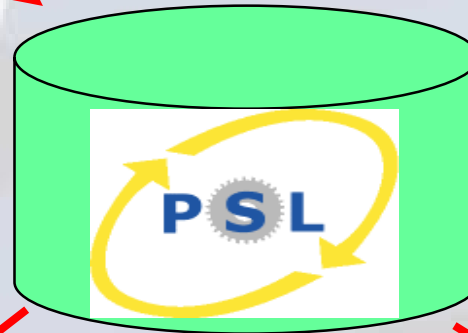
Process Modeler
(ProCAP / KBSI)



Process Planner
(MetCAPP/Agiltech)



Simulator (Quest / Dessault)



Scheduler
(ILOG Scheduler)

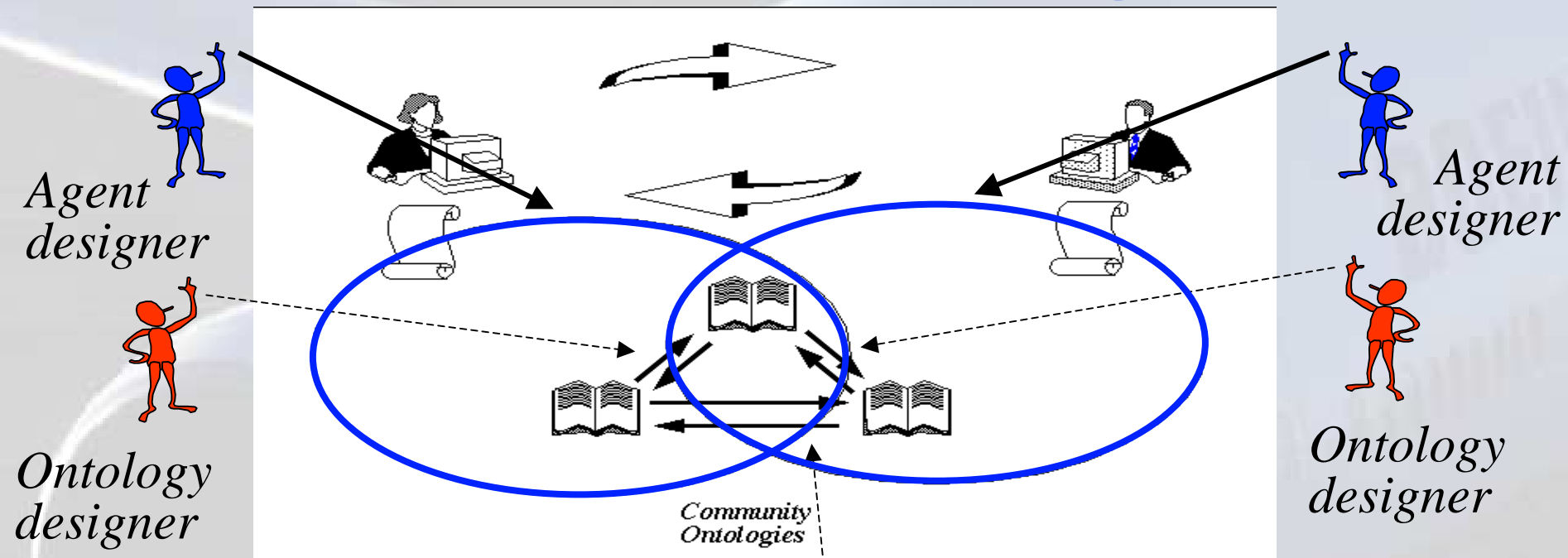
Architectures for Semantic Integration

- Holy Grail: Ontological Negotiation
- Status Quo
- Global Ontologies
- Manual Mapping
- Interlingua Ontologies
- **Community Ontologies**

Community Ontologies

*“... I envision a complex web of semantics ruled by the same sort of anarchy that currently rules the ... Web. Rather than a **few large, complex, consistent ontologies, shared by [many] users,** I envision **[many] small ontological components largely created of pointers to each other ...**”. [Hendler 2001]*

Community Ontologies

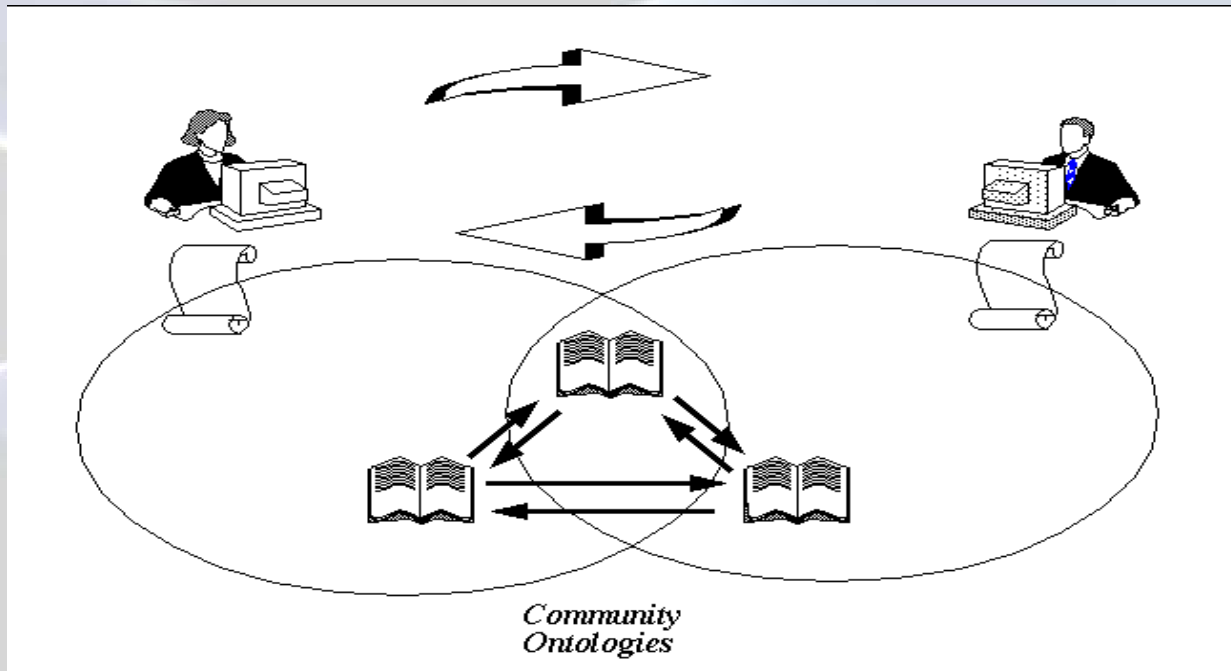


- **Ontology designers** generate **alignment mappings** between existing community ontologies.
- **Agent designers** re-use these mappings when creating agents.



*Ontology
designer*

Community Ontologies



- Ontology designers generate alignment mappings between existing community ontologies.
- Agent designers compose ontologies using these mappings
- **Agent-Agent** mappings **generated automatically** at agent-interaction time
- **Mediated** via Community Ontology(ies)
- **Agreement on alignments** of community ontologies

Community Ontologies Examples

- **Ontolingua?**
 - Compose ontologies from existing modules.
 - Is there any semantic mapping or alignment, per se?
- **DAML ontologies -- Hender's vision**
- **Perhaps still just an idea...**

Anyone know of any good examples?

Let's Make One Up



Simple Task:

Find documents about mechanical devices.

The purpose of this review is to remind operators of the

existence of the Operations Manual Bulletin 80-1, which provides

information regarding flight operations with low fuel quantities,

and to provide supplementary information regarding main tank

boost pump low pressure indications.

747 **FUEL PUMP** LOW PRESSURE INDICATIONS

When operating 747 airplanes with low fuel quantities for short

Machine Processible Semantics



Hey, I know this ontology, so now I know something about *Fuel Pump*.

What the heck is a *Fuel Pump*?

The purpose of this review is to remind operators of the existence of the Operations Manual Bulletin 80-1, which provides information regarding flight operations with low fuel quantities, and to provide supplementary information regarding main tank boost pump low pressure indications.747 <concept id=fuel-pump>**FUEL PUMP**</concept> LOW PRESSURE INDICATIONS

When operating 747 airplanes with low fuel quantities for short

Semantic Markup

<concept id=fuel-pump>**FUEL PUMP**</concept>

(**fuel-pump** has (superclasses **SHR**, **pump**))

Shared Hydraulics Repository (SHR)

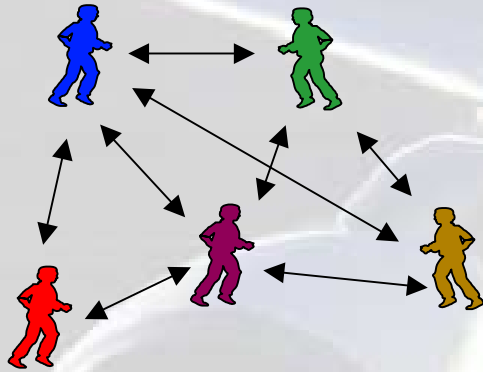
(pump has
 (superclasses (mechanical-device))
 (text-def (“A device for ...”))
 (thesaurus-term (|Pumps|)))

(every **pump** has
 (physical-parts (piston, valve, cylinder))
 (device-purpose (Pumping-A-Fluid)))

Recall: The Big Question

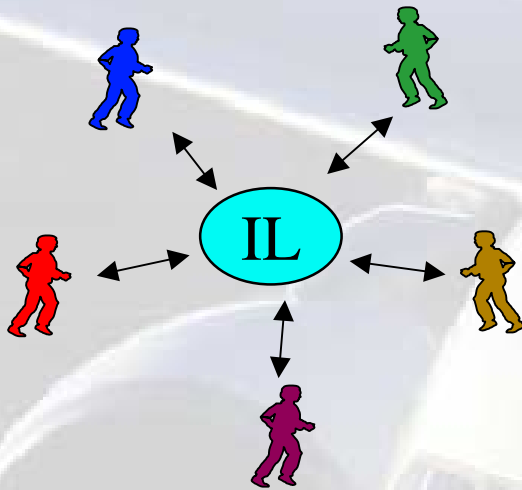
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A Semantically Integrated Web



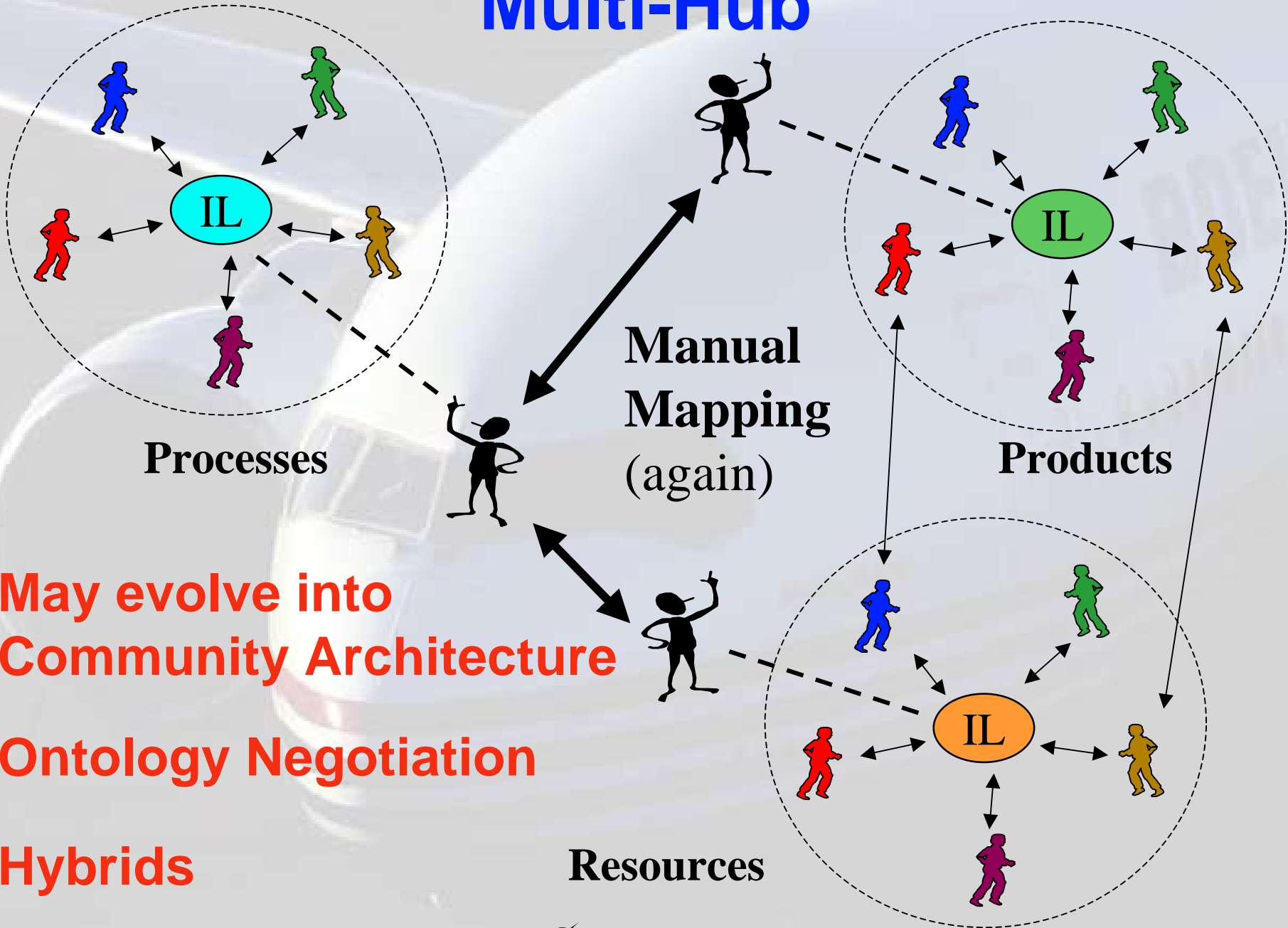
Manual Mapping on ad hoc basis.

A Semantically Integrated Web



Interlingua architecture.

Multi-Hub



May evolve into
Community Architecture

Ontology Negotiation

Hybrids

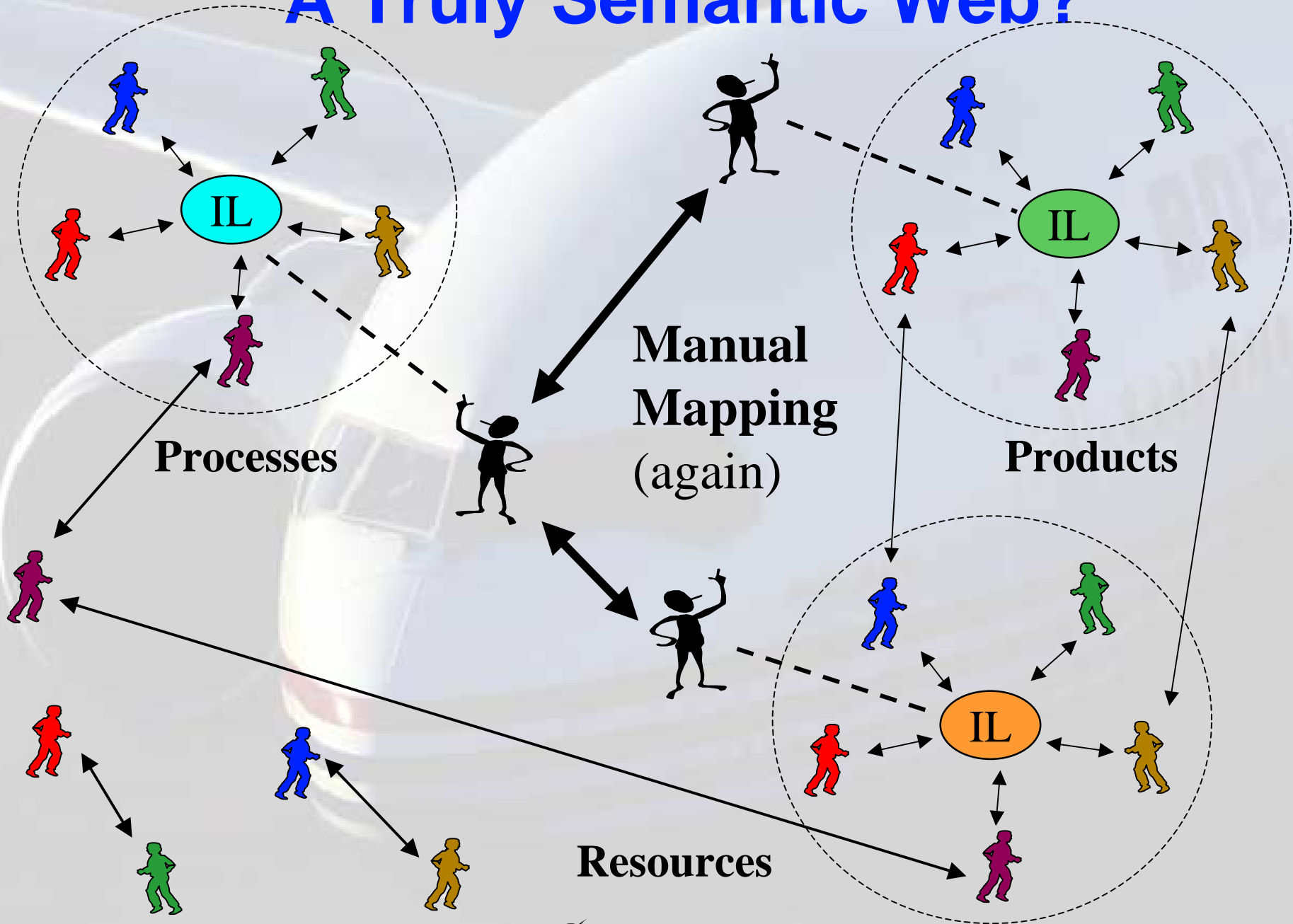
Manual
Mapping
(again)

Resources

Processes

Products

A Truly Semantic Web?



Semantic Integration Architectures

Questions <i>Architecture</i>	Who generates the mappings?	When define Agent to Agent mapping?	Topology	Degree of Agreement
Global ontology	<i>no mappings</i>	<i>no mappings</i>	Point-to-point	Agree on Everything
Manual mapping	Agent designers	Before agents interact.	Point-to-point	No <i>a priori</i> agreement
Interlingua ontologies	Agent designers	Auto-generated at agent interaction time.	Mediated	Agree on Interlingua ontologies
Community ontologies	Ontology designers	Auto-generated at agent interaction time.	Mediated	Agree on alignment mappings
Ontology Negotiation	Agents themselves	Auto-generated at agent interaction time.	Point-to-point	No <i>a priori</i> agreement

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The Evolving Semantic Web

Progress will occur by:

- **Moving along the semantic continuum;**
- **Reducing the amount of hardwiring by increasing machine-processing of semantics;**
- **Increasing the amount of public standards and ability to specify agreements;**
- **Developing semantic mapping and translation technologies for resolving semantic heterogeneity.**

No Need for Semantics Envy

- **Machine processible semantics not necessarily better.**
- **Different communities have different needs;**
- **Will be a role for approaches on all points along the semantic continuum;**
- **Many tradeoffs.**

A Law of the Semantic Web?

**The more agreement there is,
the less there is a need for
machine-processible semantics!**

- Look at Shopping Agents, NewsML
- Too much tech-push!!
- Who really needs a Semantic Web?
- Who will pay?

References

- **[Menzel & Gruninger 2001]** *A formal foundation for process modeling*, Formal Ontology in Information Systems 2001, Ogunquit, Maine.
- **[Hendler 2001]** Hendler, J. *Agents on the Semantic Web*. IEEE Intelligent Systems, 16, 2, March/April.