Impact of Research on Middleware Technology

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About the Impact Project

- http://www.acm.org/sigsoft/impact
- History of Science project funded by

- Aim: document impact that research has had on practice
- Areas of investigation:
  - Software configuration management
  - Programming languages
  - Middleware
  - Assertions
  - Testing
  - Software development environments
  - Design methods
  - ...
Impact Middleware Report

• Detailed investigation into the research origins of successful middleware technology
  – Web services
  – Application Servers
  – Transaction Monitors
  – Distributed Object Systems
  – Message Queues
  – Remote Procedure Call Systems

• We have documented a dozen impact traces (existence proof)

• To be published in
  – ACM SIGSOFT Software Engineering Notes in Q4 06
  – ACM SIGOPS Operating Systems Review in Q1 07
  – ACM Transactions on Software Engineering Methodology in 07
Research Method

• Evidence for impact
  – Market analysis reports
  – Articles in journals & proceedings
  – PhD Theses
  – Technical Reports
  – Software
  – Standards documents
  – Minutes of standards meetings
  – Interviews
  – People movement

• Impact traces
  [A Vendor, 2006] A Product
  [Standards Body, 2004] Standard
  [Author, 2002] A Paper
Middleware License Market in 2005 [Gartner 06]
Impact on Middleware: Overview

**Market Segment**
- Standard
- Article
- PhD Thesis

**Web Services Middleware**
- [W3C 2-03] SOAP, WSDL

**Distributed Objects**
- [Sun 2003] RMI
  - [Waldo 1998] RMI

**CORBA**
- [OMG 1991]

**XML**
- [W3C 1998]

**SGML**
- [ISO 1986]

**ANSA**
- [APM 1989]

**Field**
- [Reiss 1987]

**InformationBus**
- [Skeen 1992]

**FUSE**
- [DEC 1995]

**MOMs**
- [Sun 2001] JMS
  - [Sun 2001] EJB & JTA

**Application Servers**
- [BEA 1999] [TIBCO 1999] BEA, MQ
  - [Birrel&Nelson 1993] TIB

**RPC Systems**
- [Sun 2003] RMI
  - [APM 1989] ANSA
  - [Reiss 1987] Field
  - [Birrel&Nelson 1984] RPC

**Mesa**
- [DeRemer&Kron 1976] MIL

**Distributed Transactions**
- [Moss 1980] Nested Transactions
  - [Nelson 1981] RPC

**Recoverability**
- [Dixon et al 1989] Arjuna
  - [Dixon 1988]

**Object-Oriented Technology**
- [OMG 1994] OTS

**Distributed Objects**
- [OMG 1991] CORBA

**RMI**
- [Sun 2003] RMI

**Arjuna**
- [Dixon 1988] Recoverability
Trace: Simple Object Access Protocol

[IBM 2004] WebSphere
[Microsoft 2004] BizTalkServer
[Apache 2004] Axis
[BEA 2004] WebLogicServer

[Box et al, 2001]
Soap History

[OMG, 1995]
CDR, IIOP, & GIOP

[SUN, 1988]
XDR & ONC

[Bray, 1998]
XML

[ISO, 1986]
SGML

[Reid, 1981]
Scribe

[Goldfarb, 1981]
Document Markup

[Jones, 1980]
Rigorous SW Engineering

[Reid, 1981]
Scribe

[Box, 2001]
Soap History

[Gudgin et al, 2003]
SOAP 1.2

[Box et al, 2001]
SOAP 1.1

[Winer, 1999]
XML RPC

[OpenGroup, 1995]
DCE & NDR
Trace: Web Services Description Language

[IBM 2004] WebSphere
[Microsoft 2004] BizTalkServer

[Chinnici et al, 2004] WSDL 2.0

[Christensen et al, 2001] WSDL 1.1

[Curbera et al, 2000] NASSL

[Microsoft, 1999] SDL

[Bray et al, 1998] XML

[Microsoft 1995] DCOM

[OMG 1991] CORBA

[Microsoft 1992] MS-RPCs

[BeA 2004] WebLogicServer

[Eclipse 2006] BPEL Designer

[Apache 2004] Axis

[Eclipse 2006] WebToolsProject
Trace: Business Process Execution Language

[IBM 2004] WebSphere
[Microsoft 2004] BizTalkServer
[Eclipse 2006] BPEL Designer
[ActiveEndpoints 2004] ActiveBPEL

[Andrews et al, 2003] BPEL 1.1

[Christensen et al, 2001] WSDL 1.1

[Thatte 2001] XLANG


[Barghouti, 1992] PDSEs

[Bray et al, 1998] XML

Trace: Messaging in Application Servers

- [IBM 2005] Websphere MQ
- [Sonic 2005] Sonic MQ
- [JBoss 2005] JBoss MQ
- [BEA 2005] WebLogicServer

- [Sun, 2001] JMS
- [BEA 1999] BEA MessageQ
- [OMG, 1999] CORBA Notification
- [BEA 2000] WebLogicEnterprise
- [Tibco 1999] TIB

- [DEC 1998] DEC Message Queue
- [OMG, 1994] CORBA Events
- [Teknekron 1995] Information Bus
- [Oki et al 1993] Information Bus
- [Skeen 1992] Information Bus

- [IBM 1995] MQ Series
- [IBM 1992] DEC FUSE
- [Hart et al 1995] DEC FUSE
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1987] Field
- [Reiss 1987] Field

- [Cheriton&Deering 1985] Network Multicasts
- [Birman&Thomas 1989] Replication
- [Skeen 1992] Information Bus
- [Oki et al 1993] Information Bus

- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
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- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
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- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

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- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
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- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
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- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
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- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events

- [SSI 1994] EzBridge
- [X/Open, 1991] ODTP XA
- [Rothermel&Mohan 1989] Aries
- [IBM 1992] Networking Blueprint
- [Cagan 1990] HP Softbench
- [Reiss 1990] Message Passing
- [OMG, 1994] CORBA Events
Trace: Distributed Objects in Application Servers

- [Sun, 2003] J2SE 1.3 RMI
- [Waldo 1998] RPC and RMI
- [Wollrath et al 1996] RMI
- [Birrel et al 1993] Network Objects
- [Liskov 1988] Arden
- [Birrel & Nelson 1984] Implementing RPC
- [Shapiro et al 1985] SOS
- [Almes et al 1985] Eden
- [Bal 1989] Shared Objects
- [Bal et al 1988] Orca
- [Hutchinson 1988] Emerald
- [Dixon et al 1989] Arjuna
- [Jul et al 1988] Emerald
- [Black et al 1987] Emerald
- [OMG, 1991] CORBA 1.0
- [OMG, 1995] CORBA 2.0
- [Microsoft, 1995] DCOM 1.0
- [OMG, 1995] CORBA 2.0
Trace: Distributed Objects in CORBA

[OMG 1992]
Object Management Architecture

[OMG 1991]
CORBA 1.0

[Sventek&Snyder 1991]
Joint Submission

[Sventek 1991]
HP CORBA Submission

[ANSA 1989]
ANSA Reference Manual

[Booch 1991]
OO Design

[Atkinson et al 1989]
OODB Manifesto

[Meyer 1988]
OO SW Construction
Trace: Remote Procedure Calls

- [Microsoft, 1995] DCOM
- [Microsoft, 1992] RPCs
- [OSF, 1991] OSF/DCE
- [Dineen et al 1987] NCA
- [Leach et al 1982] UIDs
- [Goldberg 1980] Smalltalk
- [Stroustrup 1977] C++

- [IETF, 1988] ONC RPCs
- [Microsoft, 1995] DCOM
- [Microsoft, 1992] RPCs
- [OSF, 1991] OSF/DCE
- [Dineen et al 1987] NCA
- [Leach et al 1982] UIDs
- [Goldberg 1980] Smalltalk
- [Stroustrup 1977] C++
Key findings

• Technology Transfer takes time: 15-20 years between first publication of an idea and widespread availability in products
• Inter-disciplinarity: Industry does not care about the ACM CS classification
• On the importance of PhD students: Almost all impact traces lead back to somebody’s PhD
• Technology transfer: Most successful form is people movement
• Standardization: Without wide-spread agreements on ideas there is no wide-spread adoption
Tech transfer needs time

- **RPCs**: Key ideas of Module Interconnection Languages in mid 70s, basic research on RPC systems in early 80s, release of RPC into Sun and Apollo OS in late 80s, standardization by IETF and OSF in early 90s.
- **Distributed Transactions**: Early research into non-standard transactions in early-mid 80s, standardization in mid 90s at OSF and OMG, widespread use in application servers in late 90s.
- **Distributed Objects (RMI)**: Basic research in mid 80s (Argus, Eden, Emerald), Consolidation in “network objects” in mid 90s, standardization through JCP in late 90s, widespread use in Java and .NET remoting at turn of millenium.
Interdisciplinarity

- Impact traces frequently cross boundaries between different CS disciplines.
- For middleware study:
  - Software Engineering
  - Networking
  - Programming Languages
  - Distributed Systems
  - Databases
- Impact sometimes larger in area other than that of first publication (e.g. MQs)
  - Example 1: RPC IDLs
    - Information Hiding [CACM 15(5), 1972]
    - MIL [IEEE TSE SE-2(2), 1976],
    - Mesa [ICSE-4, 1977]
    - Cedar RPCs [ACM ToCS (2(1), 1984]
    - Sun RPC [IETF RFC 1057, 1987]
  - Example 2: Transactions
    - OS - Gray 1976
    - Nested Transactions, Moss 1981
    - Concurrency Ctrl Bernstein et al 1987
    - Arjuna Dixon, 1989
    - OSF ODTP/XA, 1991
    - CORBA CCS, OTS 1994
    - J2EE JTS, JTA, 2001
Traces often lead back to PhDs

- **RPCs:**
  - Failure semantics & architecture: Nelson, (CMU 1981)
  - Orphan detection: Panzieri (Newcastle University 1985)
- **Distributed Transactions:**
  - Nested transactions: Moss (MIT 1981)
  - Object transactions: Dixon (Newcastle University, 1987)
- **Object Models for distributed computing:**
  - CORBA object model: Snyder (MIT, 1978)
- **Web services:**
  - Scribe: Reid (CMU, 1981)
People movement: The real enabler of technology transfer

- A. Herbert from U Cambridge to APM where he devised ANSA
- B. Nelson from CMU to Xerox PARC where he wrote the definitive paper on RPCs with A. Birrel
- B. Nelson and A. Birrel to DEC Research where they wrote the Network Object paper providing the basis for Java RMI.
- A. Watson from APM to OMG where he controlled CORBA standardization
- J. Waldo from UMass to HP and J. Sventek from APM to HP where they wrote CORBA 1.0 spec
- J. Waldo from HP to Sun where he wrote RMI specification
- G. Dixon from NCL to Transarc where he wrote OMG CORBA OTS and CCS service specs
Conclusions

• Be patient about exploitation of results!
• Support PhD students!
• Fund mobility not just between member states but between academia and industry!
• Facilitate out of area dissemination!
• Find ways to incentivize software engineering academics to take part in standardization!