A research consumer's view of data integration

Arnon Rosenthal
The MITRE Corporation
Bedford MA

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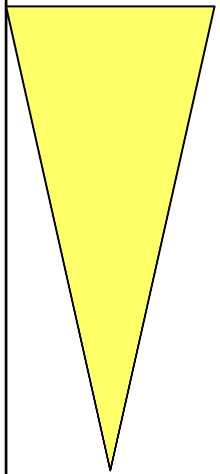
Outline

- Where we stand
- Some principles for giving research greater impact
- Ontology vs. database integration styles – strengths and weaknesses
- Open problems + sore points receiving little attention

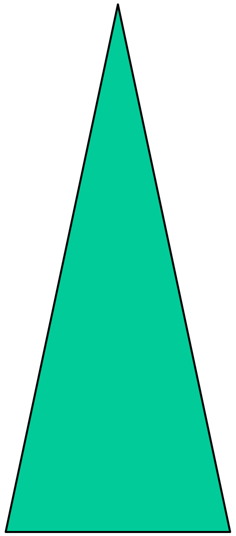
Researchers are *too* loosely coupled to practical data sharing



Research history

- Virtual db with distributed query
- Data warehouse
- Formatted messages

- Lightweight scripts (pairwise)
- Integrated packages (e.g., SAP)
- Cobbling together an exchange i/f (including data standards)



Industrial usage

Data sharing strategy

(from enterprise transformation advocates)

- Service oriented architecture
  - SOA doesn't solve your data mess, it reveals it [Gartner]
  - Lacks general ad hoc query, update, evolution help, replication support, declarative constraints, …
- Communities of interest will create shared specs ("stds")
  - Community = ?? (organization? mission thread?)
    - System implements separate interface for each mission thread to which it belongs?
  - All members will "adopt"? Implement?
  - Need clear definitions, metrics, tools to support such processes
    - E.g., what tradeoffs for community size, scope, cohesion, ...

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Data sharing real practice, in US tactical systems

- Warehouses for logistics and other “back office”
- Little federated query
- Each new application does the “integration” it needs

- Independent tactical systems, communicating by agreed message types (since 1970s, moving to XML)
  - Wrapper interfaces are plug compatible
  - But wrappers are inflexible, created manually, and redundant: (SOA limitations apply – query, update, …)

- Agree on tiny interface constituents, e.g., “what/when/where” or mashup on geo-location
  - Good return on investment, but doesn’t scale up

  Tiger teams reduce from months to weeks / days for ~15 elements

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Pervasive problems -- 1

- Lack of metrics. You can't contract for what you can't measure
  - How much useful data sharing have we enabled?
  - Agility (even w.r.t. schema changes)

- Skills are in short supply
  - Organizations can't employ a technique requiring skill in logic, ontologies or XQuery
  - Integration engineers need skills in all stages

  Move toward single-skill tasks – a "supply chain" with tools weaving the pieces together

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Pervasive problems -- 2

- **Low penetration for data technologies**
  - Database paradigm (schema, query) vs. business objects
  - Data integration tools – need cheaper, easier start up
- **Incentives are not explicit artifacts in models**
  - Systems are unusable, because someone doesn't care enough to do what's asked
  - Repositories are either unfunded, or not forced to be useful
  - Create tools that use m'data to benefit the m'data provider
  - Manage incentives, as another architectural view
- Families of systems, e.g., a system is deployed to many places, and extended separately in each

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Ideas for greater research impact

- Automate *something*, don’t just assist
- Downstream work transitions more easily
  - Evolution is a killer app for “downstream”
- Help even when the requirements can’t be met automatically

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Solve *something* -- don't just "assist"

A fully automated modular piece has greater potential for a big win (e.g., GUI-builder)

- Deploy new instances without deploying people
- When cost goes to zero, new uses will be found
- Modularity forces a clean problem definition, allows indep. Improvement
- "Assist" lets humans help when tools don't work together
- You may need human review, e.g., precise Match

- Candidates for full automation
  - Best efforts (e.g., for discovery)
  - Evolution
  - Cluster of variants on a theme

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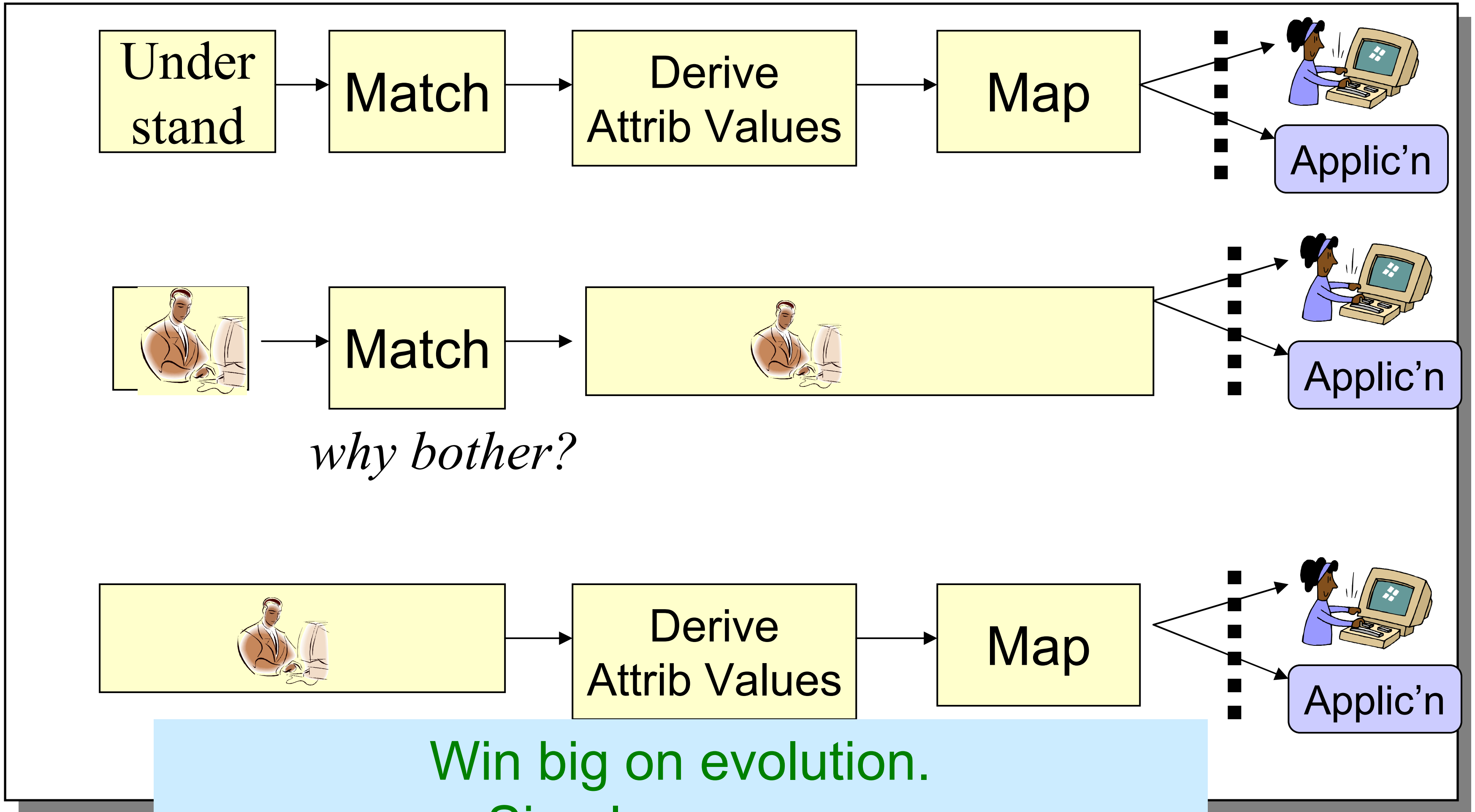
Transfer downstream first



Win big on evolution.
Simpler process
Need less skill the first time

So, what should we solve?

- "Match first", with mapping left manual?
  - ≈40% saving *there to end. No revolution!*
  - *Too many skills.* Mapping will require domain expert + programmer, causing delays, misunderstandings
- Automate "map" ⇒ ≈99% saving *there to end*
  - Evolve: Change just upstream of automation ⇒ immediately runs. *Something is fast.*
  - Simpler process: Less switching between humans and tools
  - Less need for skills
- Reduce number of people in the value chain (esp. with rare skills but not unique domain knowledge)

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Scalability requisite: Avoid global assumptions

- Suppose we assume "X *always* holds", e.g.,
  - *All* participants employ enterprise standard data elements (or schemas)
  - All participants are willing to shift to use our new process framework
  - *All* Views are Select/Project/Join
  - *All* constraints are Key, Foreign Key, or unary
- If X fails, the theory becomes logically empty
- Do I then buy a separate software system?

You can't control a large enterprise (legacy, mergers, future needs, + partners)

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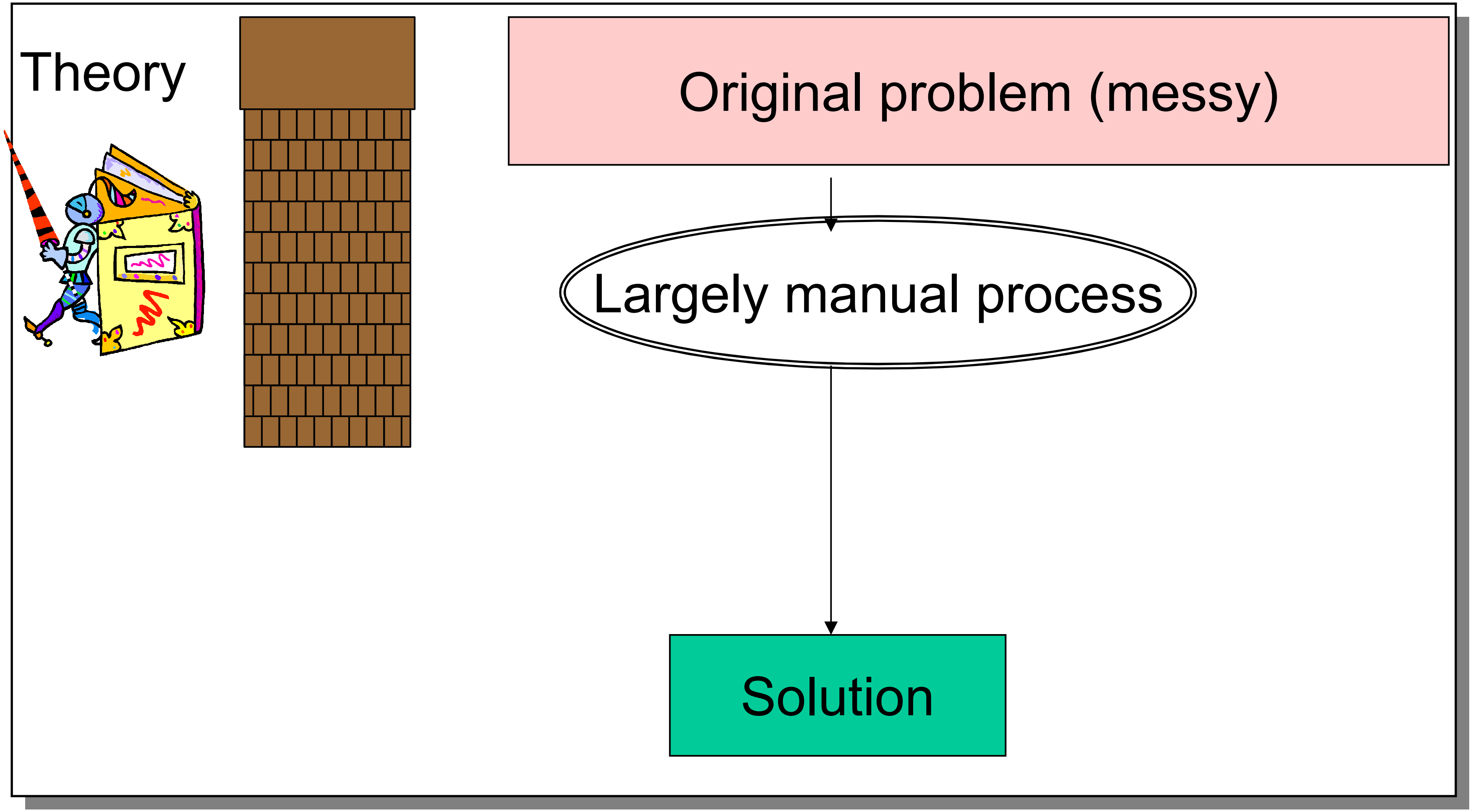
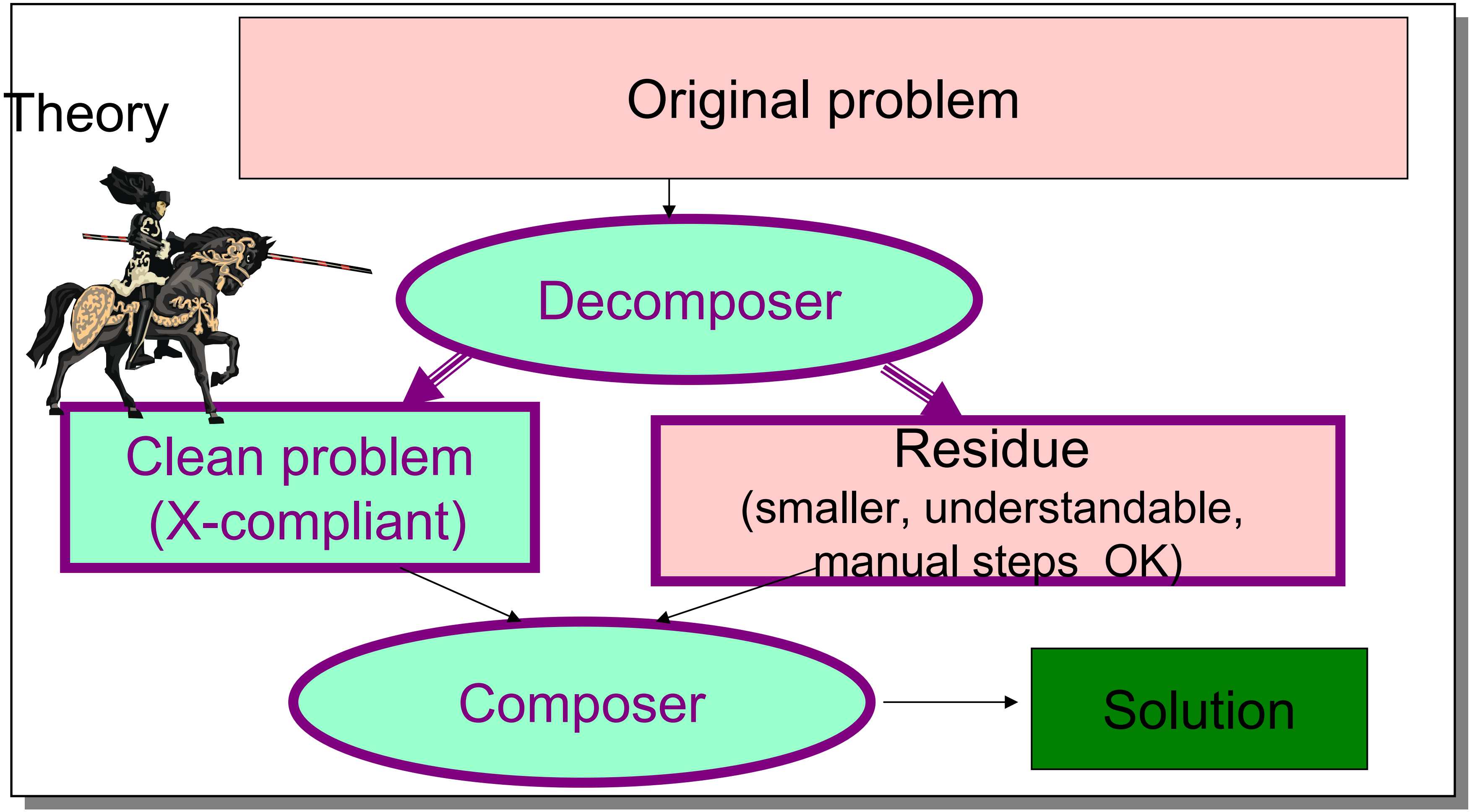
What we get with a restricted theory



More robust:
Researcher gives formal decomposition



More robust:
Researcher gives formal decomposition

- Algorithm to extract the X-compliant portion
- Solve the clean part
- Create a clean residue problem
  - Solvable (possibly with human tasks)
  - Understood by your target integrators (don't "reduce" to logic)
  - Smaller than the original (preferably in same form, or simpler)
- Algorithm to recompose the pieces

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Example: Define a nice subproblem that you can solve

- *Tractable*: "nice" mappings to an unconstrained schema
- Intractable: many constraints on target schema, e.g., keys, null not allowed

- Null not allowed : If sources have insufficient info, they can't fill in the target
- Key constraint: Logic won't resolve conflicting source assertions
- Inclusion: Formally OK, but who has permission to insert? Non-key? [Keller 86]

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Approaches – 1
"Bad constraints" go into residue

Data cleansing is a good source of inspiration – abstract and extend its insights

- Split
  - Exchange to an tractable target

    e.g., target relation schemes, maximal target constraints implied by sources,

    *and **understandable by users***
  - Exchange from that target to desired results

- This residue problem seems
  - **Much simpler** (no structural differences)
  - **Understandable by intended users**

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Approaches – 2
"Bad data" go into residue

- Partition **data** automatically: easy $\cup$ hard
  maximize "easy"
  - Niche: situations where it's safe to exchange *part* of the data

- Violate key constraint
  - All tuples involved in violation are "hard"
- Violate inclusion (key? nonkey?)
  - Does *application* want to insert automatically?
- Violate value constraint
  - Need cleansing rules?
    Aircraft.Name alphanumeric, cleanse F-16 → F16

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Compare typical(??) DB vs. AI approaches (1)

Formalisms to describe concepts & relationships

DB (Schema)

- Basic unit: relational or tree (XML) schema
  - Record is a good chunk for storage or display
- Describe a system or a physical message
  - Plug compatible, *without mediator*

AI (Ontology)

- Basic unit: atomic concept (object or property)
  - Small chunks ⇒ easy to relate & reuse
- Describe a *neutral* domain model (more community based, e.g., science)
  - Robust for multiple uses
  - **Mediator required**

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Compare typical AI vs. DB approaches (2)

DB

- Schemas make little use of IS-A, constraints
  - Developers add much of the semantics
- Relationships among ***sets***, via query language, or logic
  - TGDs are awkward, unfamiliar to users
  - View defns are big: hard to edit and partially reuse (e.g., ETL script as view)

AI

- More use of IS-A and constraints
  - Motivated by easier query formulation, reasoning
- Relationships among ***concepts***: "Usable_for"
  - Employs formalism similar to *within* ontology (supertype of IsA property)
  - Relationship pairs are small, easy to edit (and to reuse)

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Compare typical DB vs. AI approaches (3)

What models do we connect

(for semantic relationships? for data flows)

DB (Schema)

- Between systems
  - Instant gratification (often fund one app, not integration)
  - Differences in *real data* lead to improved definitions

AI (Ontology)

- Via neutral defns or structure (msgs)
  - Reuse is easier
  - "First create an ontology" inhibits sales
  - Do admins understand "foreign" or abstract defns, well enough for precise integration?

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Compare typical AI vs. DB approaches (4)

DB	AI
• Exchange semantics: precise, relevant, complex, justified? – Hard to learn or communicate – Works with whole tuples. Discards partial info if *some* field can't be decided (??)	• Exchange semantics: Whatever *my* engine infers !!! – How to separate the easy cases (no join) – How to explain the (in)signficance of the problem to ontologists and managers

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“Usable for” relationship

- Ontology formalism can be used to describe either systems or domain models
- *Usable_for* is directional, to relate concepts that are not the same
- Usable_for does not force inheritance – one system may have fewer attributes
  - A super-type of the IS-A property

Compare typical AI vs. DB approaches (5)

DB	AI
• Homegrown logic – Reason well about crucial integration constructs – Even simple Datalogs won't interoperate – Extensible	• OWL has a larger developer community – Extensible
• Execute popular query language in robust server – Efficient, parallel, **deployable**	• Execute by inference engine
• **Change mgt is *sometimes* careful**	• Change mgt tends to be ad hoc

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Communicating with Muggles

- Our sponsors don't use the researchers' distinction of integration vs. exchange
- Info integration = (?)
  - Given a data need (target schema + constraints), populate it from available source(s) +
  - Given multiple sources, create a product that combines some of their data

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Data sharing >> Info Integration

- Data sharing at MITRE brings in and social scientists and security folks
  - Nontechnical barriers (resistance, incentives, obligations)
    [My website has several papers -- Seligman, Swarup]
  - *Suitably* assure that no data leaks across boundaries – Retain flexibility

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Open problems
(at least, for products)

- Integrate applications, at data, business object, and display tiers (i.e., multiple system views, simultaneously)
  - Long term goal: Capture more of system descriptions as data
  - Integration capability can be a big incentive
- Examples
  - Integrate data *and also* declaratively-defined displays [Ceri…., Raghu]
  - Data + Style sheet?
- Other complex types with multiple system views, e.g.,
  - Business process descriptions, …
  - Social networks

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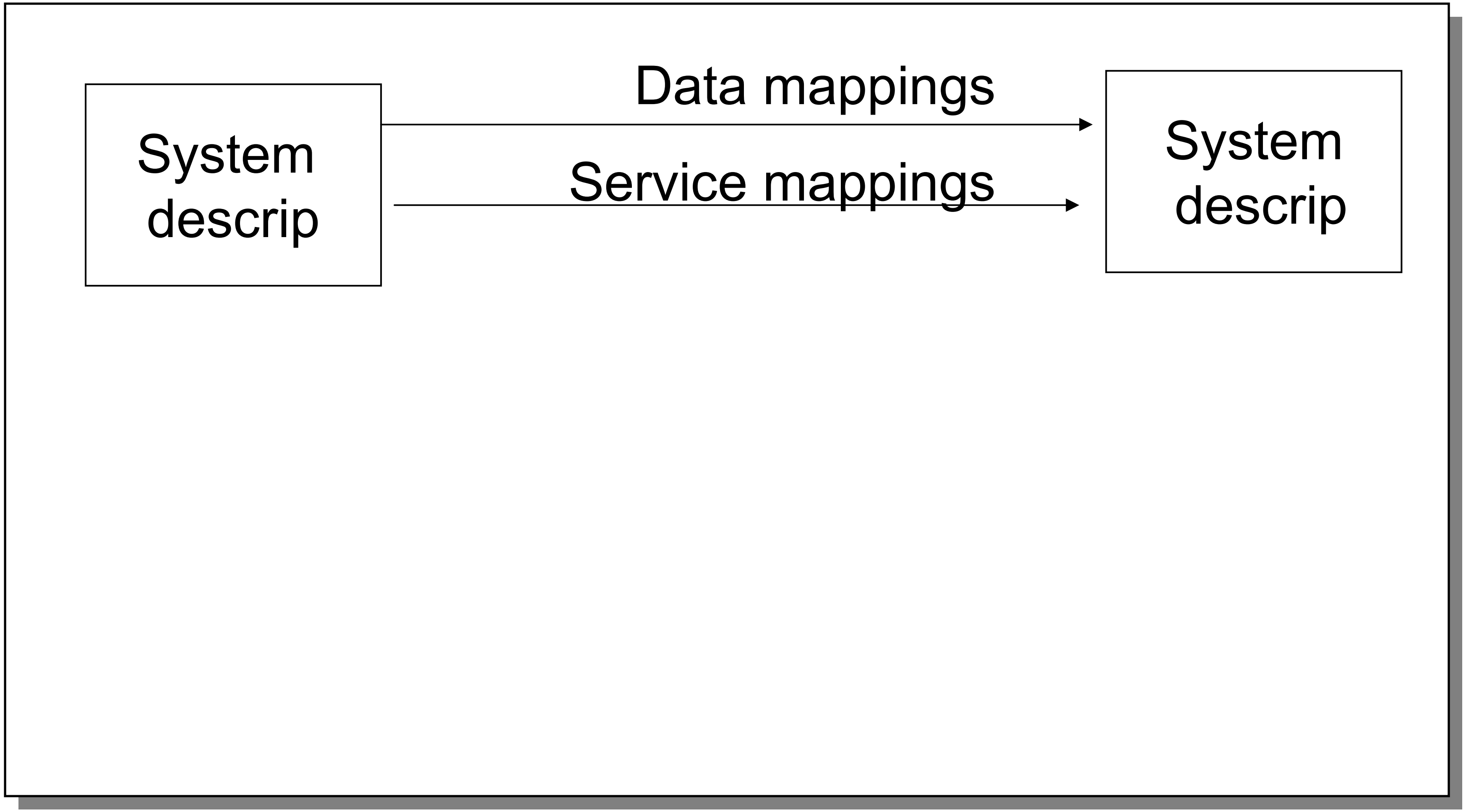
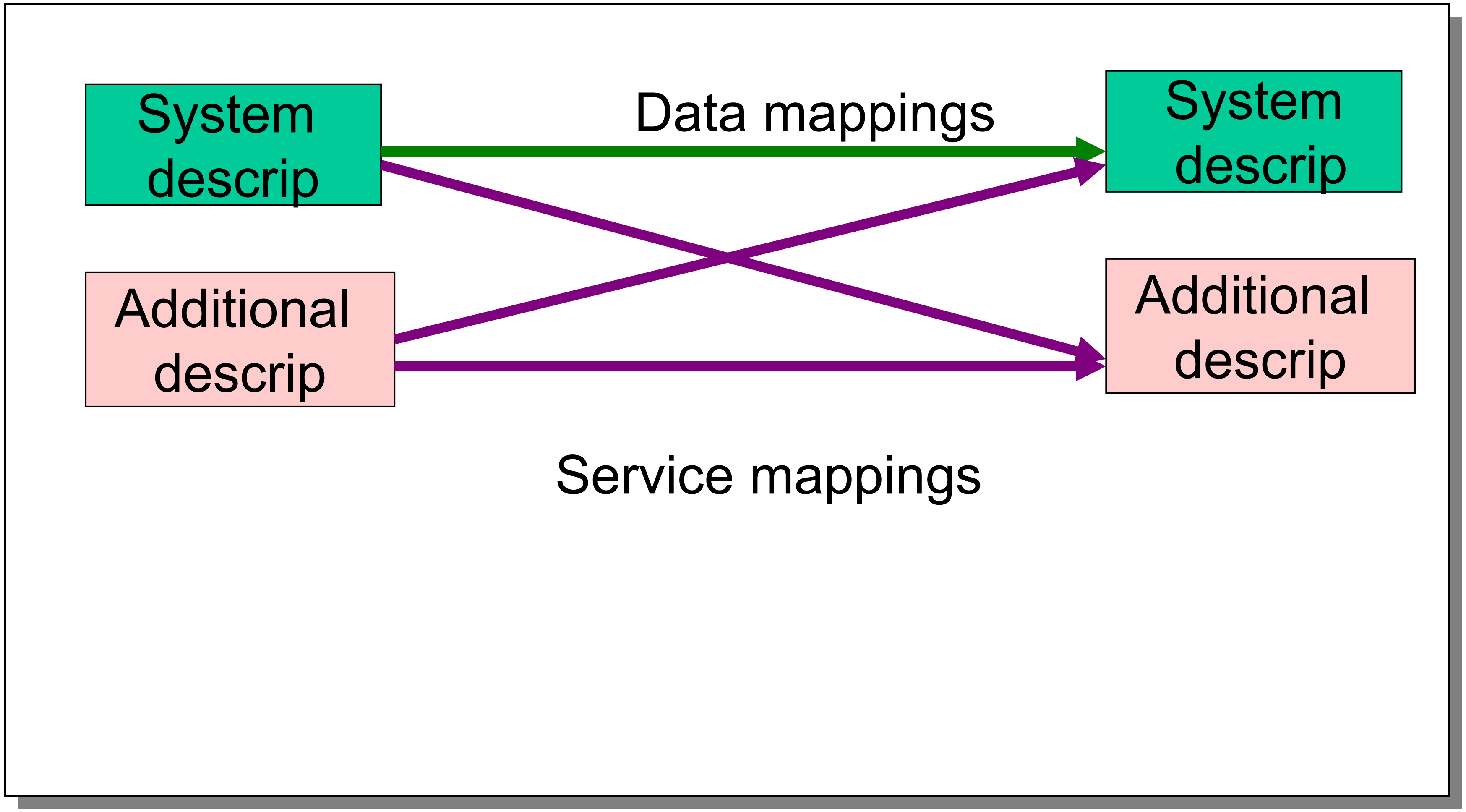

System descrip
Data mappings
Service mappings
System descrip

“Design patterns” for progressing



More open problems

- Variations on a theme (e.g., the many extensions of a popular system)

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Smarter synthesis: Don't just integrate what fate has provided

- 95% of our research examines integration of existing data or interfaces
- 80% (?) of tactical data sharing involves
  - Hammering out shared specifications (msg formats, view interfaces)
    - Otherwise, source may not capture the info you need (e.g., landing time = ? leave runway)
  - Reusing the same specification in interfaces to multiple systems (e.g., "what/when/where" XML fragment)

Mismatch

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Community-created specifications

- Proper direction: Groups (communities?) create specifications
- Someone decides to incentivize their use
  - How to measure? How to manage? What mechanisms?
- Researchers can start by clarifying definitions and abstract problems
  - Define and justify metrics and best practices
  - Create operators to synthesize new products from a variety of agreed ones

  Plenty of applicable theory, but not synthesized for this purpose

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Exploit uncoordinated progress

Niche: Many integration efforts, with limited coordination

- A popular system will be deployed many places
- Individuals will extend each one differently
- Examples
  - Spreadsheet definitions are widely copied, and extended by recipients
  - A major intelligence DB is set up in separate countries, sharing most of the schema, some data
- When is it safe to share their extensions, without harming applications?
  - May not have the framework to manage views to shield
  - XML is tougher, e.g., when add nodes within paths [Mork]

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Frameworks are needed

- How will we combine all the emerging ideas? (and those from folks outside the room)
  - Today, each idea needs to be reimplemented in each tool
  - Poor business model for small players

  Result(?): General purpose integration environments are costly (Db import may not be, e.g., SQL Server)
- Need (open source) frameworks
  - Macro: “Network effects” in integration drives consolidation. Big ones need one to combine the software they acquired.
  - Micro: Frameworks for execution, testing, tuning can improve learning steps (e.g., alignment)

Learning, for each component problem

- Reuse collaborative experience
  - When several integration efforts occur in parallel, someone may have answered your question already
  - Many more sophisticated cases

  Show stopper: Our sponsors rarely have suitable repositories

- Learn by analogy
  - Learn about data sources (e.g., recognize units and formats)
  - Data conversions

    F-16 → F16; F-15 → F15
  - Entity matching and data cleaning rules

  Many users can do instances, few can specify rules

  [Miller et. al., for outerjoins etc.]

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Backup

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Multi-$Billion data integration industry, uses little research*

- E.g., ETL, configuration, memorandums of understanding
- * Exceptions
  - Federated query
  - IBM info integration (from CLIO)?
  - ADO.Net entity framework?

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DARPA may join the party

- Many folks from the AI side
- More for nonstandard applications, perhaps to support non-IT folks