Research in the Logic Group

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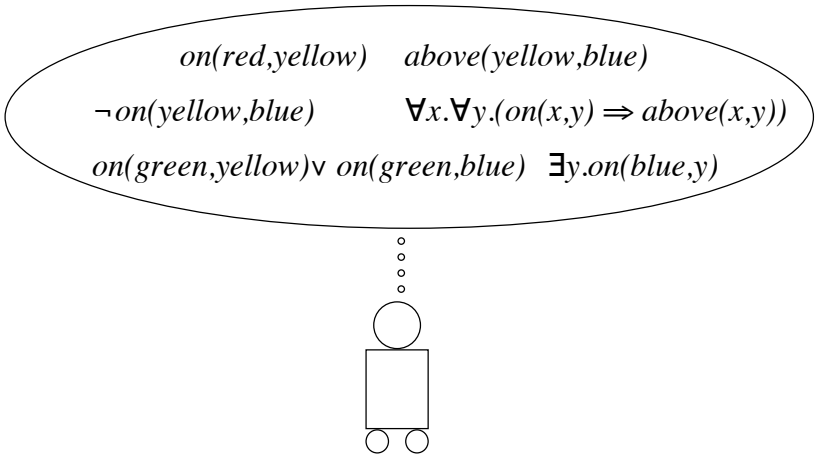
1

Computational Logic



2

Automated Theorem Proving

Group Axioms

$(x \times y) \times z = x \times (y \times z)$

$x \times e = x$

$e \times x = x$

$x \times x^{-1} = e$

Theorem

$x^{-1} \times x = e$

3

Constraint Satisfaction Systems

	6		1		4		5	
		8	3		5	6		
2								1
8			4		7			6
		6				3		
7			9		1			4
5								2
		7	2		6	9		
	4		5		8		7	

4

Deductive Database Systems

Database Tables

parent

art	*bob*
art	*bea*
bea	*coe*

parent(*art*,*bob*)
parent(*art*,*bea*)
parent(*bob*,*coe*)

Queries

query(X,Z) :- parent(X,Y) & parent(Y,Z)

Constraints

illegal :- parent(X,X)
illegal :- parent(X,Y) & parent(Y,X)

5

Sample Applications

Logical Spreadsheets

Data Integration

Web of Data

Computational Law

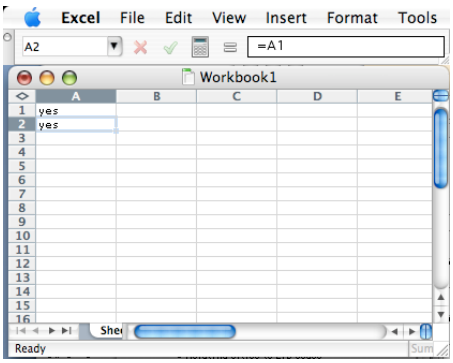
General Game Playing

6

Logical Spreadsheets

Computerized Spreadsheets

Huge Success
- individual users
- companies
- conglomerates



Good Features
- Automatic computation of values
- Ease of specification using simple math formulas

8

Limitations of Traditional Spreadsheets

Functional formulas

$$B3 = B1 + B2$$

Unidirectional Update

B1	B2	B3
2	3	5

9

Logical Spreadsheets

Extension
- Relational constraints on the values of cells

Good Features
- Automatic computation of values
- Ease of set-up (using logical formulas)

Challenges
- Automatic update
- Temporary inconsistencies
- User feedback

10

event	owner	projector	room	time
e1	art	no		
e2	bob	no		
e3	cal	yes		

	g100	g200	g300
morning			
afternoon			
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

11

Constraints

If a projector is needed, an event cannot be scheduled in a room without a projector.

```
illegal :-
  event(E,O,yes,R,T) &
  room(R,no,S)
```

Bob is not permitted to schedule events in g100.

```
illegal :-
  event(E,O,P,g100,T) &
  owner(E,bob)
```

12

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no		
e3	cal	yes		

	g100	g200	g300
morning			
afternoon			
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

13

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no		
e3	cal	yes		

	g100	g200	g300
morning	e1		
afternoon			
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

14

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no		
e3	cal	yes		

	g100	g200	g300
morning	e1		
afternoon		e2	
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

15

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no	g200	afternoon
e3	cal	yes		

	g100	g200	g300
morning	e1		
afternoon		e2	
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

16

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no	g200	afternoon
e3	cal	yes		

	g100	g200	g300
morning	e1		e3
afternoon		e2	
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

17

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no	g200	afternoon
e3	cal	yes	g300	morning

	g100	g200	g300
morning	e1		e3
afternoon		e2	
evening			

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

18

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no	g200	afternoon
e3	cal	yes	g300	morning

	g100	g200	g300
morning	e1		e3
afternoon		e2	
evening			e4

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

19

Event	Owner	Projector	Room	Time
e1	art	no	g100	morning
e2	bob	no	g200	afternoon
e3	cal	yes	g300	morning
e4			g300	evening

	g100	g200	g300
morning	e1		e3
afternoon		e2	
evening			e4

Room	Projector	Seating
g100	yes	theater
g200	no	classroom
g300	no	classroom

20

Research Topics

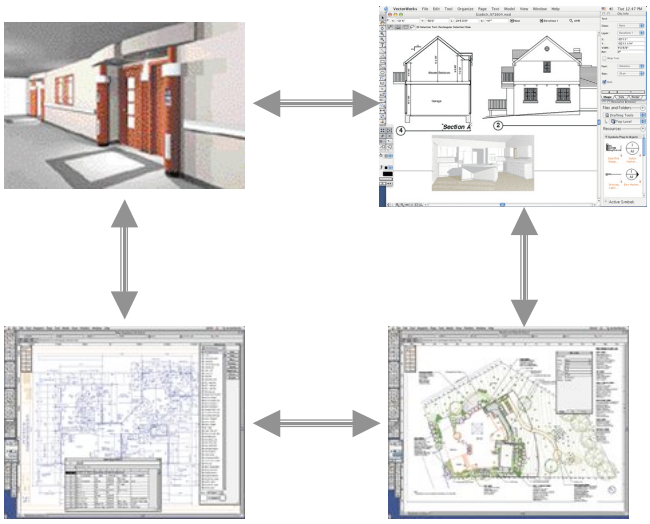
Paraconsistent Logic (Eric Kao)
reasoning with inconsistent data and constraints

Differential Logic (Mike Kassoff)
computing differences from differences
analogy with differential calculus

Dynamic Logic (Ashwin Deshpande)
constraints on transitions, not just state
privacy, security, responsibility
workflow management

21

Collaborative Spreadsheets



22

Data Integration

Structured Data Sources

Public Sources

- Company Directories
- Product Catalogs
- Product Reviews
- Weather Reports
- Airline Schedules
- Drug Studies

Enterprise Sources

- Personnel Records
- Equipment Databases
- Room Schedules
- Orders
- Inventories

24

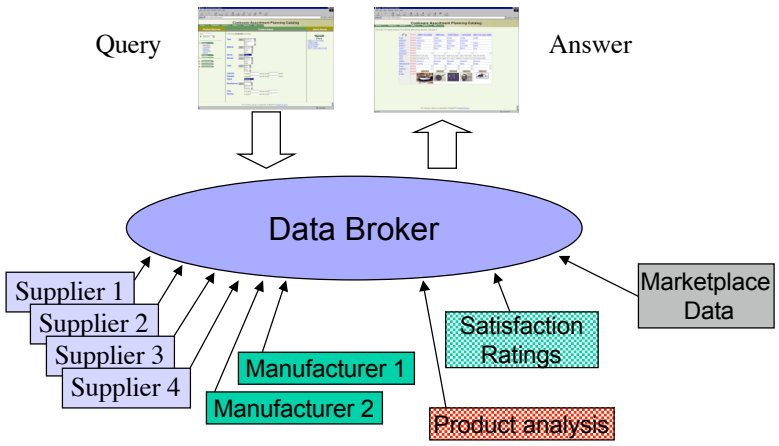
Consumers of Structured Data

Different users
- Pilots and mechanics and airline marketers
- Passengers and travel agents
- FAA and NTSB

Different uses often require different datasets
- Airline personnel want to see their own flights
- Passengers want to see all flights for their trips

25

Data Integration



26

Complications

Distribution
- Data at different sites
- Handled through magic of networking

Format Heterogeneity
- e.g. relational databases, XML, tab-delimited text
- Handled through hand-coded translators

*Conceptual Heterogeneity
- Differences in schema and vocabulary

27

Source 1 - Carter

carter			
id	**type**	**material**	**price**
c01	skillet	aluminum	50
c02	saucepan	aluminum	40
c03	skillet	iron	30
c04	saucepan	iron	20

28

Source 2 - Mirkwood

kind	
id	**value**
m01	skillet
m02	skillet
m03	saucepan
m04	saucepan

coating	
id	**value**
m01	yes
m02	yes

price	
id	**value**
m01	60
m02	50
m03	40
m04	20

29

Source 3 - Marvel

marvel		
id	**attribute**	**value**
r01	maker	renfrew
r01	type	skillet
r01	material	aluminum
r01	msrp	50
s03	maker	superchef
s03	type	skillet
s03	material	stainless
s03	coating	teflon
s03	msrp	30

30

Source 4 - NHMA

nonstick	
id	**value**
ceramic	no
copper	no
teflon	yes

company	
id	**nation**
carter	usa
mirkwood	uk
renfrew	canada
superchef	france

country	
id	**area**
canada	america
france	europe
uk	europe
usa	america

31

Consumer 1 - Xanadu

All cookware products manufactured in the United States.

xanadu			
id	**maker**	**type**	**price**
c01	carter	skillet	50
c02	carter	saucepan	40
c03	carter	skillet	30
c04	carter	saucepan	20
r01	renfrew	skillet	50

32

Consumer 2 - Yankee

All cookware products manufactured in the United States with European types and prices in euros.

yankee			
id	**maker**	**type**	**price**
c01	carter	frypan	40
c02	carter	pot	32
c03	carter	frypan	24
c04	carter	pot	16
r01	renfrew	frypan	40

33

Consumer 3 - Zebulon

All skillets manufactured in Europe that are made from non-corrosible materials.

zebulon			
id	**maker**	**type**	**price**
m01	mirkwood	skillet	60
m02	mirkwood	skillet	50
s03	superchef	skillet	30

34

Schemas

Consumer Relations:

```
xanadu(X,Y,Z,W)
yankee(X,Y,Z,W)   values in European units
alproduct(X)
ceproduct(X)
feproduct(X)
ssproduct(X)
ncproduct(X)
```

Source Relations:

```
carter(X,Y,Z,W)  kind(X,Y)      nonstick(X,Y)
marvel(X,Y,Z)    coating(X,Y)   company(X,Y)
                 price(X,Y)     country(X,Y)
```

35

Relational Logic

Safe, Horn Rules

```
grandparent(X,Z) :- parent(X,Y), parent(Y,Z)
```

Existential Rules

```
parent(X,f(X,Z)) :- grandparent(X,Z)
```

Disjunctive Rules

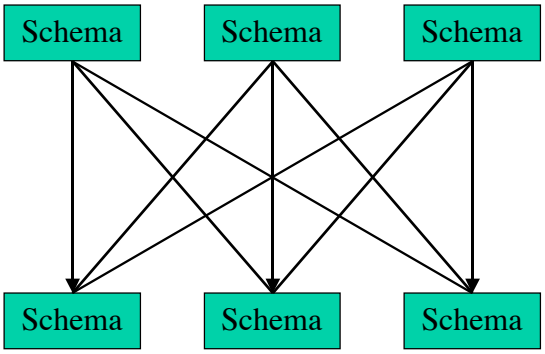
```
father(X,Y) | mother(X,Y) :- parent(X,Y)
```

Recursive Rules

```
ancestor(X,Y) :- parent(X,Y)
ancestor(X,Z) :- parent(X,Y), ancestor(Y,Z)
```

36

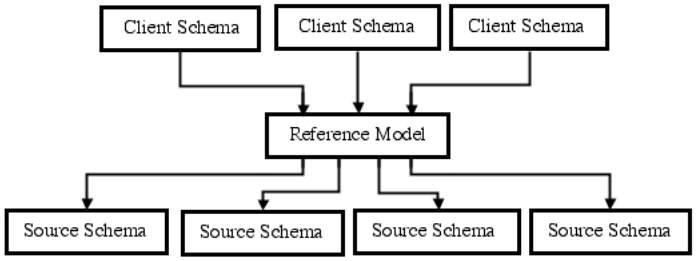
Direct Mapping



37

Source-Based Integration

Sometimes called Global-As-View Integration



38

Relationships Among Sources

Replicated data
- Cached data
- Materialized views (as in data warehouses)

Heterogeneity (different schemas or vocabularies)
- values in euros versus values in dollars
- French instead of English
- different numbers of tables or attributes

Real World Constraints
- Physical laws
- Governmental laws
- Business rules

39

Collaborative Data Management

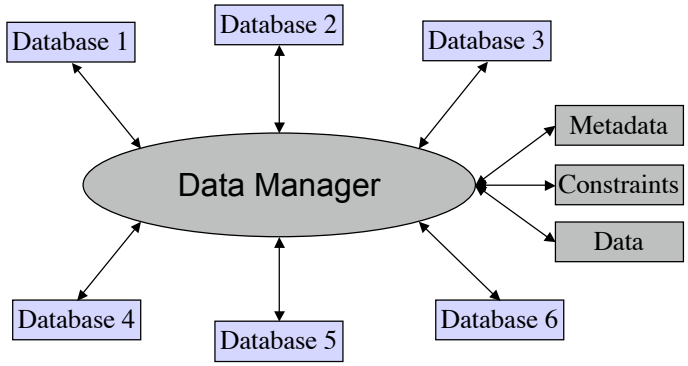
When sources are independent, they can be updated independently.

In the face of interrelationships among sources, individuals performing updates must collaborate (explicitly or implicitly) to ensure correct updates.

Collaborative Data Management must replace independent data management.

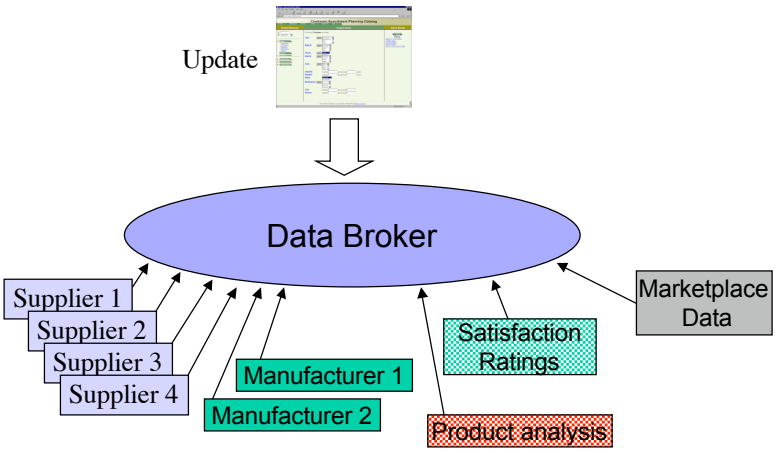
40

Data Manager



41

Update Integration



42

Web of Data

Future - Web of Data

World Wide Web

Collaborative **Document** Management System
Interlinked Documents
Keyword Search, Lists of documents as answers
Individual source update, source ownership

Web of Data

Collaborative **Data** Management System
Objects/relations and constraints
Query not Search, Answers instead of Documents
Single Entry Principle, data ownership

44

Showcase - Digital Department

Goal - Enterprise Data Management for Stanford

Components

Multiple Departments
University Databases

Areas

Room reservations
Event Management (Equipment, Food, Mail lists)
Office Assignments
Curriculum (prerequisites, requirements, policies)
Programs (Undergraduate, Masters, Doctoral)

45

Showcase - Digital Government

Goal - Enterprise Data Management for governments

Components

Federal Agencies
States
Local Governments

Output

Government people and organizations
Bills, votes, laws

Input

Taxes, licenses, reports, court proceedings, results
Online Turbotax for everything

46

47