Information Integration

SDSC SAN DIEGO SUPERCOMPUTER CENTER

After this video you will be able to

- Explain the data integration problem
- Define integrated views and schema mapping
- Describe the impact of increasing the number of data sources
- Appreciate the need to use data compression
- Describe Record Linking, Data Exchange and Data Fusion Tasks

A Business Case (from IBM)

"Mergers and acquisitions in the past decade have increased our customer base by 200 percent. Having a single view of the customer, we're more accurately able to target and cross-sell across our brands."

Suncorp is a diversified financial services group that offers general insurance, banking, life insurance and wealth management services. With operations in Australia and New Zealand, Suncorp has over AU$95 billion in assets, more than 16,000 employees and relationships with over nine million customers. The financial services organization maintains five operating divisions, managing 14 market brands, and is supported by corporate and shared services divisions.

Suncorp-Metway Ltd wanted a single, integrated view of its customers to ensure its marketing campaigns didn't encourage internal conflict between the brands and duplication of efforts, both of which had a negative effect on the bottom line.

Deconstructing the Case – Hypothetically

Insurance Company's Partial Schema

Policies(PolicyKey, PolicyTypeKey, Agent, Conditions)
PolicySales(PolicyKey, PolicyholderKey, StartDate, TransactKey,Premium,CoveragePeriod, CoverageLimit)
Transactions(TransactKey, Date, Time, Amount, Balance)
Policyholders(PolicyHolderKey, Name, Address, City, State, ZIP)
Claims(PolicyKey, ClaimKey, TransactKey, ClaimAmount)
ClaimDescription(ClaimKey, TypeKey, ClaimantKey, ProcCode, Description)
Claimants(ClaimantKey, Name, Address, City, State, ZIP)
ClaimTypes(TypeKey, Description)
PolicyTypes(PolicyTypeKey, Name, Description)

Bank's Partial Schema

Accounts(AcctNumber, AcctType, MemberID, MemberType, TypeID, StartDate, EndDate, InterestRate, CreditLimit)
Individuals(MemberID, FName, MI, LName, SSN, Nationality, DoB, LegalStatus, FullAddress, Phone, PhoneType, Email)
Corporations(MemberID, Name, RegisteredAddress, CorporationType, Signatory1, Signatory2, DNBNumber, Phone, Email)
Transactions(TrID, AcctNum, Date, Time, TransactionType, Description, TransactionAmount, Debit/Credit, Balance, Payoff)
AccountType(TypeID, Name, Description)
TransactionTypes(Ttype, Name, Description)
Disputes(AccntNumber, DisputeID, TrID, Date, DisputeAmt, Explanation, Valid, ValidatorID)

Integrated Views

PolicySales(*PolicyKey, PolicyholderKey, StartDate, TransactKey, Premium, CoveragePeriod, CoverageLimit)*
Policyholders(*PolicyHolderKey, Name, Address, City, State, ZIP)*

Accounts(*AcctNumber, AcctType, MemberID, MemberType, TypeID, StartDate, EndDate, InterestRate, CreditLimit)*
Individuals(*MemberID, FName, MI, LName, SSN, Nationality, DoB, LegalStatus, FullAddress, Phone, PhoneType, Email)*

- **Find current customers of the insurance company who are also customers of the bank, and create this integrated view**

discountCandidates(*custID, address, policyKey, AcctNumber)*

Schema Mapping

Policyholders(*PolicyHolderKey, Name, Address, City, State, ZIP*)

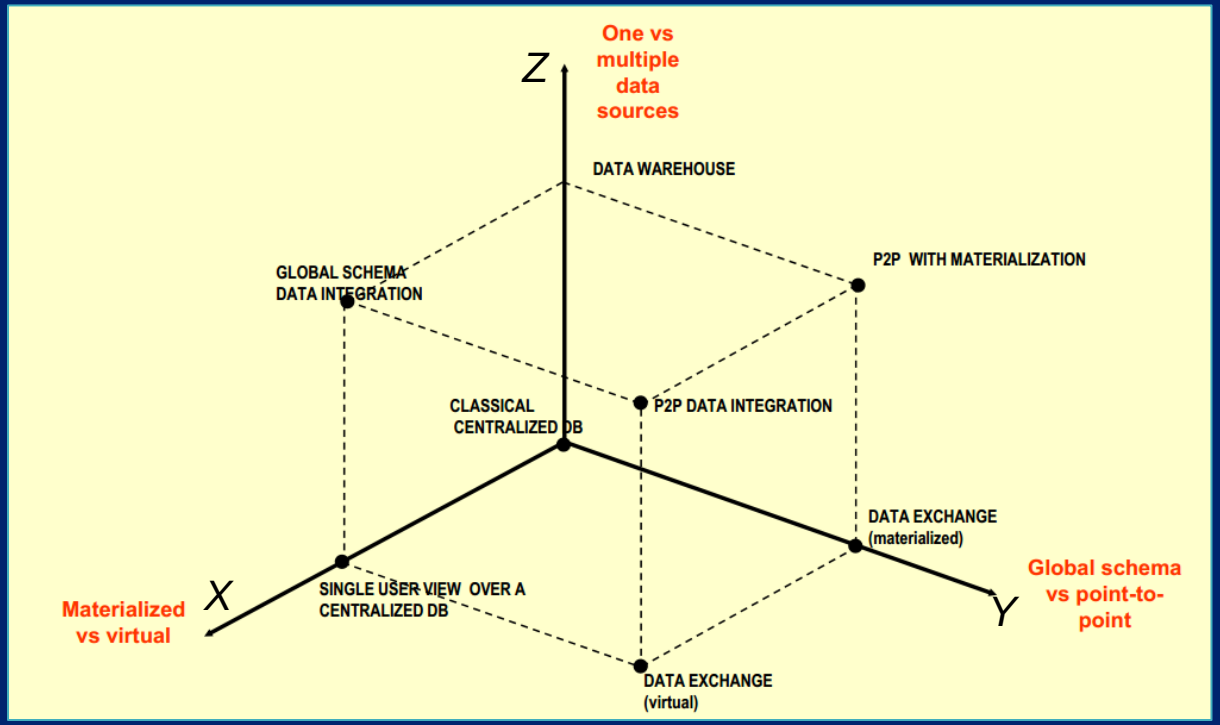
Individuals(*MemberID, FName, MI, LName, SSN, Nationality, DoB, LegalStatus, FullAddress, Phone, PhoneType, Email*)

discountCandidates(*custID, address, policyKey, AcctNumber*)

PolicySales(*PolicyKey, PolicyholderKey, StartDate, TransactKey, Premium, CoveragePeriod, CoverageLimit*)

Accounts(*AcctNumber, AcctType, MemberID, MemberType, TypeID, StartDate, EndDate, InterestRate, CreditLimit*)

Querying Integrated Data



- **Find the bank account number of a person whose policyKey is known**
  - SELECT AcctNumber FROM discountCandidates where policyKey = '4-937528734'

Record Linkage

Policyholders(*PolicyHolderKey, Name, Address, City, State, ZIP*)

Individuals(*MemberID, FName, MI, LName, SSN, Nationality, DoB, LegalStatus, FullAddress, Phone, PhoneType, Email*)

Individuals(*101, Stephen, C., Jones, 123-45-6789, US, 10/02/1983, citizen, "231 Cedar St. LA, CA 90005", 661-266-9374, landline, scjones@gmail.com*)

Individuals(*102, Elizabeth, , McFarlane, 123-54-6789, US, 06/18/1978, citizen, "4157 Elm St. LA, CA 90005", 213-266-9374, mobile, emlane@gmail.com*)

Individuals(*103, Liz, P., McFarlane-Gray, 123-92-2318, US, 06/18/1978, citizen, "231 Cedar St. LA, CA 90005", 213-702-4343, landline, emlane@gmail.com*)

Individuals(*104, Lisa, M., Brady, 423-45-6209, US, 08/09/1975, foreign-student, "231 Cedar St. LA, CA 90005", 302-266-9374, landline, scjones@gmail.com*)

Policyholders(*3-764528104, Liz, P., McFarlane-Gray, 4157 Elm St. LA, CA, 90005*)

The "Big Data" Problem

- **Many sources**
  - Hundreds of tables
  - Schema mapping problem is a combinatorial challenge
- **Pay-as-you-go model**
  - Only integrate sources that are needed when needed
- **Probabilistic Schema Mapping**

Designing Mediated Schema

- **Customers – an integrated table**
- **Candidate designs**
  - Create the customer table to include individuals and corporations – use a flag called customer_type to distinguish. In the mediated schema
    - Individual.(FN+MI+LN), PolicyHolder.Name, Corporations.Name map to Customer_Name
    - Names of two types of customers become two different attributes
    - Ind.FullAddress, Corp.RegisteredAddress, PH.(Address+City+State+Zip) map to Customer_Address
  - Issues
    - Should the DOB, Nationality, Legal Status be included in this table?

Attribute Grouping

- **How to evaluate if two attributes should go together?**
  - How similar are the attributes
    - Individual names vs. policyholder names?
    - Individual names vs. Corporation names?
  - How likely is it that two attributes would co-occur?
    - Should the DOB put in the same schema as the individual name?
    - How about DOB and the corporation name?

Customer Transactions

BankTransactions(TransactionID (TID), TransactionBeginTime(TBT), TransactionEndTime(TET), TransactionAmount(TA), Credit-Debit(CD), TransactionParty(TP), Transaction Description(TD), Balance(B), Payoff(P))

InsuranceTransactions(TransactionID (TID), TransactionDateTime (TDT), TransactionType(TT), Amount(A), TransactionDetails(TDT))

Med1({TID}, {TBT, TET, TDT} {TA+CD, A}, {TP, TD, TDT}, {TT}, {B}, {P})
Med2({TID}, {TBT}, {TET}, {TDT} {TA+CD, A}, {TP}, {TD}, {TDT}, {TT}, {B}, {P})
Med3({TID}, {TBT, TDT}, {TET, TDT} {TA+CD, A}, {TP}, {TD, TDT}, {TT}, {B}, {P})
…

Compute pairwise attribute similarity and using a threshold plus/minus an error, put similar attributes in the same cluster

For every subset of uncertain pairs create a mediated schema

Probabilistic Mediated Schema

- **Find source schemas that are consistent with a mediated schema**
  - A source schema is consistent with a mediated schema if two different attributes of the source schema do not occur in a cluster
    - Med3({TID}, {TBT, TDT}, {TET, TDT} {TA+CD, A}, {TP}, {TD, TDT}, {TT}, {B}, {P}) is better than
    - Med1({TID}, {TBT, TET, TDT} {TA+CD, A}, {TP, TD, TDT}, {TT}, {B}, {P}) with respect to BankTransactions
- **Choose the k best mediated schema**

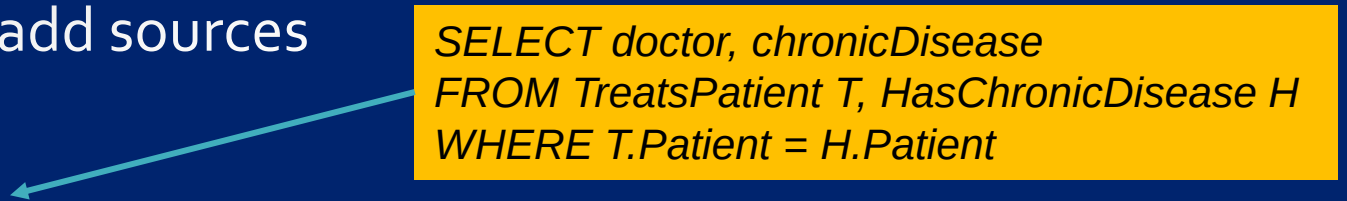
Pause

A Data Integration Scenario

- **4 data sources each with one relation**
  - S1: Treats(Doctor, ChronicDisease)
  - S2: Discharges(Doctor, Patient, Clinic)
  - S3: Treats(Doctor, ChronicDisease)
  - S4: Surgeons(SurgeonName)
- **Target schema**
  - TreatsPatient(Doctor, Patient)
  - HasChronicDisease(Patient, ChronicDisease)
  - DischargesPatientsFromClinic(Doctor, Patient, Clinic)
  - Doctors(DoctorName)
  - Surgeons(SurgeonName)

Example Schema Mapping

- **Local-as-View (LAV) mapping**
  - Mapping source schemas to target schema
  - Easier to add sources



S1.Treats(d, s)→TreatsPatient(d, p) AND HasChronicDisease(p,s)
S2.Discharges(d, p, c)→DischargesPatientFromClinic(d, p, c)
S3.Treats(d,s)→TreatsPatient(d,p) AND HasChronicDisease(p,s) AND Doctors(d)
S4.Surgeons(d)→Surgeons(d)

Query Answering

- **Query**
  - Which doctors are responsible for discharging patients?
  - SELECT DoctorName
  - FROM Doctors D1, DischargesPatientsFromClinic D2
  - WHERE D1.DoctorName = D2.DoctorName
- **Query reformulation**
  - Automatically transform query against the target schema to the simplest query against source schemas
- **Ideal Answer**
  - SELECT Doctor
  - FROM S3.Treats T, S2.Discharges D
  - WHERE T.Doctor = D.Doctor

Integration of Public Health Infrastructure

Washington DC Disease Surveillance System (WADDS)

CATEGORY	SOLUTION	DESCRIPTION
Data Exchange	Integration hub with HL7 messaging	All internal and external data moves through commercial integration hub that transforms HL7 V2 data into a consistent HL7 V3 representation.
Terminology	SNOMED LOINC	Implemented standard concept terminologies SNOMED and LOINC for coding of clinical and lab data.
Conceptual	RIM-based integrated data repository	A centralized, commercial data repository was natively designed on the HL7 RIM to normalize clinical data from disparate sources. Implemented a data quality algorithm to manage patient matching and identify duplicate records.
Architecture	PHIN architecture	Developed architecture consistent with the CDC's Public Health Information Network requirements.

*Used to enable interoperability between existing hospital and lab systems and WADSS.

Reference Information Model

Data Exchange

*Health Level-7 or **HL7** refers to a set of international standards for transfer of clinical and administrative data between software applications used by various healthcare providers.*

```
<!DOCTYPE ADT_A03 SYSTEM "hl7_v231.dtd">
<ADT_A03>
<MSH>
        <MSH.1>|</MSH.1>
        <MSH.2>^~\&amp;</MSH.2>
        <MSH.3><HD.1>LAB</HD.1></MSH.3>
        <MSH.4><HD.1>767543</HD.1></MSH.4>
        <MSH.5><HD.1>ADT</HD.1></MSH.5>
        <MSH.6><HD.1>767543</HD.1></MSH.6>
        <MSH.7>19900314130405</MSH.7>
        <MSH.9>
                <CM_MSG_TYPE.1>ADT</CM_MSG_TYPE.1>
                <CM_MSG_TYPE.2>A04</CM_MSG_TYPE.2>
        </MSH.9>
        <MSH.10>XX3657</MSH.10>
        <MSH.11><PT.1>P</PT.1></MSH.11>
        <MSH.12><VID.1>2.3.1</VID.1></MSH.12>
</MSH>
<EVN>
        <EVN.1>A01</EVN.1>
        <EVN.2>19980327101314</EVN.2>
        <EVN.3>19980327095000</EVN.3>
        <EVN.4>I</EVN.4>
        <EVN.6>19980327095000</EVN.6>
</EVN>
<PID>
        <PID.1>1</PID.1>
        <PID.3.LST>
                <PID.3><CX.1>123456789ABCDEF</CX.1></PID.3>
```

HL-7

```
MSH|^~\&|LAB|767543|ADT|767543|19900314130405||ADT^A04|XX3657|P|2.3.1<CR>
EVN|A01|19980327101314|19980327095000|I||19980327095000<CR>
PID|1||123456789ABCDEF|123456789ABCDEF|PATIENT^BOB^S||19590520|M||
    612345 MAIN STREET^^ANYTOWN^CA^91234||714-555-1212|
    714-555-1212||||123456789ABCDEF|||U<CR>
PD1||||WELBY<CR>
PV1|1|I|0||NEW|||SPOCK<CR>
```

- Find all prescriptions and lab reports of patient #19590520 containing serum protein, along with age-specific normal values between 1/1/2012 and 9/1/2015
  - The patient went to three different clinics and four different labs in this period
  - The doctor's own office uses a relational database for EHR

Data Exchange

- Given a source database with a finite number of relations, a set of schema mappings, and a set of constraints that the target schema must satisfy, the data exchange problem is to find a finite target database such that both the schema mappings and the target constraints are satisfied.

Using Codebooks

- Logical Observation Identifiers Names and Codes (LOINC) is a database and universal standard for identifying medical laboratory observations.

2. COMPONENT	Text	255	First major axis-component or analyte
3. PROPERTY	Text	30	Second major axis-property observed (e.g., mass vs. substance)
4. TIME_ASPCT	Text	15	Third major axis-timing of the measurement (e.g., point in time vs 24 hours)
5. SYSTEM	Text	100	Fourth major axis-type of specimen or system (e.g., serum vs urine)
6. SCALE_TYP	Text	30	Fifth major axis-scale of measurement (e.g., qualitative vs. quantitative)
7. METHOD_TYP	Text	50	Sixth major axis-method of measurement
8. CLASS	Text	20	An arbitrary classification of the terms for grouping related observations together. The current classifications are listed in Table 32. We present the database sorted by the class field within class type (see field 23). Users of the database should feel free to re-sort the database in any way they find useful, and/or to add their own classifying fields to the database. The content of the laboratory test subclasses should be obvious from the subclass name.

BP.ATOM	Blood pressure atomic
BP.CENT.MOLEC	Blood pressure central molecular
BP.MOLEC	Blood pressure molecular
BP.PSTN.MOLEC	Blood pressure positional molecular
BP.TIMED.MOLEC	Blood pressure timed molecular
BP.VENOUS.MOLEC	Blood pressure venous molecular
CARD.RISK	Cardiac Risk Scales Framingham
CARD.US	Cardiac ultrasound (was US.ECHO)
CARDIO-PULM	Cardiopulmonary
CLIN	Clinical NEC (not elsewhere classified)

MOLPATH.DELDUP	Gene deletions or duplications
MOLPATH.INV	Gene inversion
MOLPATH.MISC	Gene miscellaneous
MOLPATH.MUT	Gene mutation
MOLPATH.REARRANGE	Gene rearrangement
MOLPATH.TRINUC	Gene trinucleotide repeats
MOLPATH.TRISOMY	Gene chromosome trisomy
MOLPATH.TRNLOC	Gene translocation

Using Compressed Data

- **Compression**
  - Encoded representation of data so that it uses less space
  - Dictionary encoding

Record #	Patient ID	Date	Test Code	Test Result
1	100	1/1/2012	SE-AC	14.5
2	502	1/1/2012	BP-S	123
3	301	1/2/2012	HAC	5.8
4	502	1/1/2012	BP-D	91
…	…	…	…	…
…	…	…	…	…
10M	1274	7/20/2016	SE-AC	13.8

Using Compressed Data

- **Compression**
  - Encoded representation of data so that it uses less space
  - Dictionary encoding

Record #	Patient ID	Date	Test Code	Test Result
1	100	1/1/2012	32	14.5
2	502	1/1/2012	125	123
3	301	1/2/2012	174	5.8
4	502	1/1/2012	126	91
…	…	…	…	…
…	…	…	…	…
10M	1274	7/20/2016	32	13.8

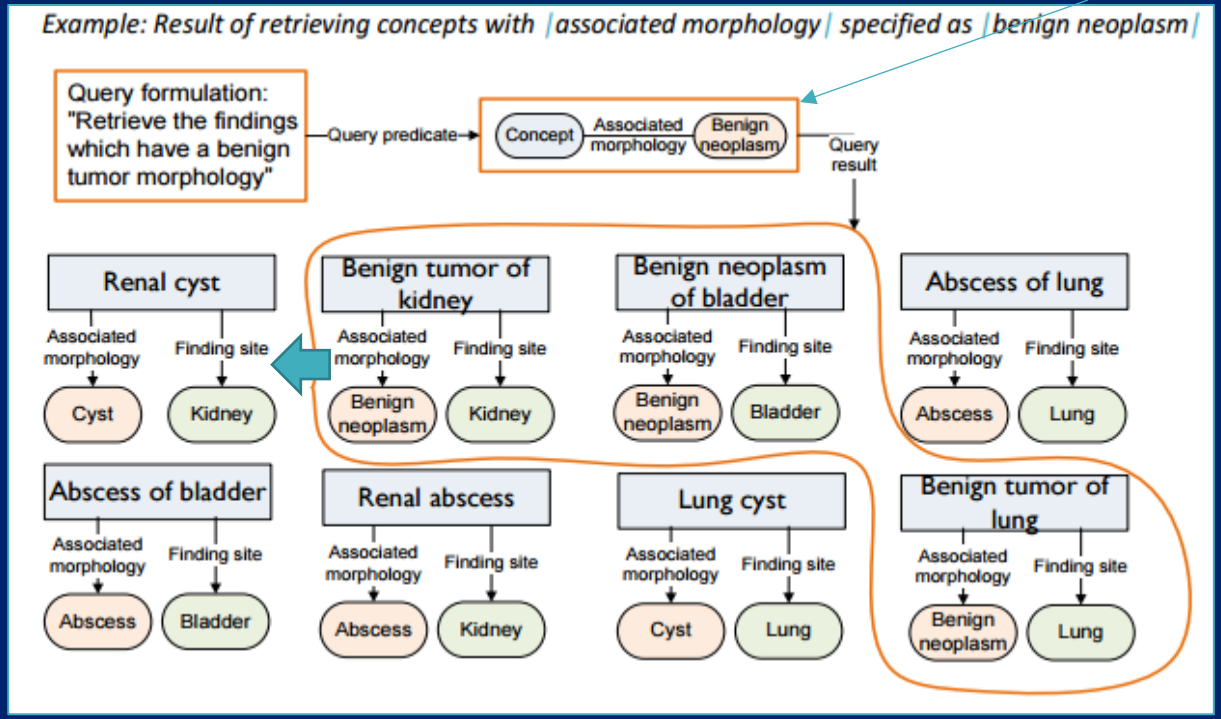
Dictionary

Orig. Test Code	Encoded Test Code
SE-AC	32
BP-S	125
HAC	174
BP-D	126
…	…
…	…
SE-AC	32

Data compression is an important technology for big data.

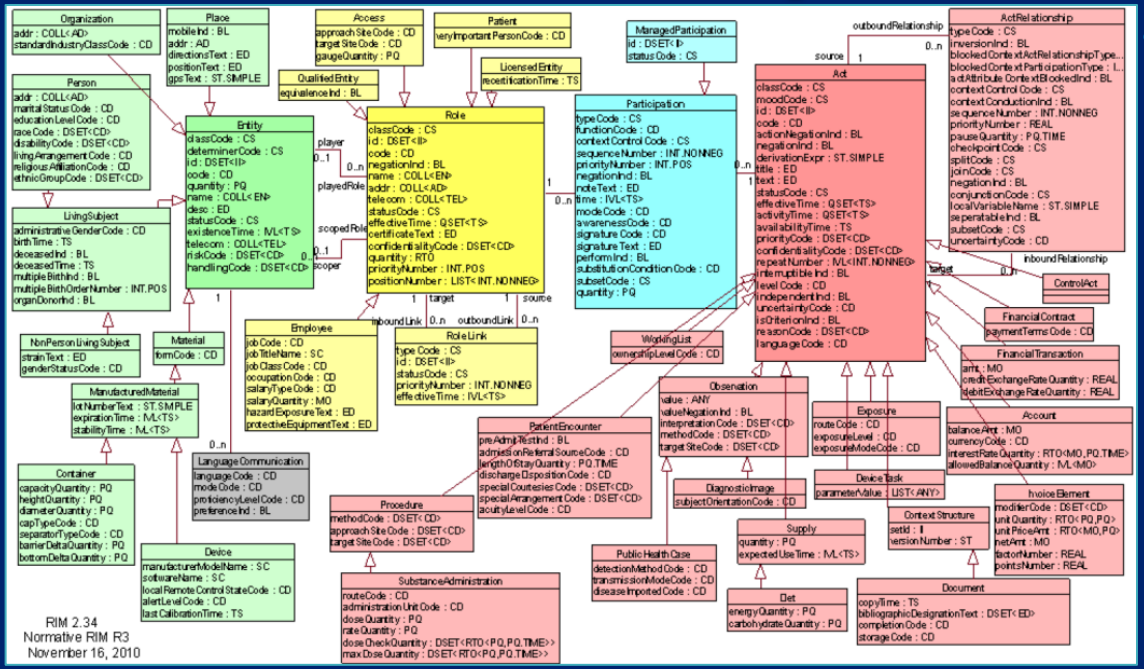
Ontological Data

Ontology queries are graph queries



- Ontology
  - A set of terms of a domain
  - Relationships between the terms
- SNOMED
  - A medical ontology used for clinical data

The Takeaway Points



- **Integration across multiple data models**
  - Global Schema – RIM
  - Data Exchange
    - Format conversions
    - Constraints
    - Compressed Data
    - Model transformation
    - Query transformation

Pause

Integration for Multichannel Customer Analytics

- **Customer analytics**
  - processes and technologies that give organizations the customer insight necessary to deliver offers that are anticipated, relevant and timely
- **Questions one would like to ask**
  - Is our product launch going well?
  - Is there an emerging product issue?
  - Where should the product team focus its development dollars?
  - Are there more effective methods for positioning current products?
  - Which services have the best chance of surviving a turbulent market?
  - Is there a product defect in the market?

Data Fusion

- **Data sources**
- **Data Items**
  - A product
  - A part of a product
  - A feature of a product
  - The utility of a product feature
  - …

value

- **Using data from a subset of sources find the true value or a true value distribution of a data item**
- **Assemble all such values for the real-world entity represented by the data items**

Too Many Sources

- **Too many sources = too many values**
- **Voting to select the "right" value**
  - Simple voting can be problematic – Veracity problem
    - Source Reliability
    - Copy Detection
  - Statistical techniques to estimate
    - Trustworthiness of sources
    - Bias introduced by copies
    - True distribution of values for data items

Source Selection

- **The problem**
  - Choose only useful sources
  - Adding sources first improves integration accuracy then reduces it
- **The solution**
  - Order candidate source based on a measure of "goodness"
  - Add sources until the marginal benefit is less than the marginal cost
  - Current techniques scale well