The Power of Integrated Abstraction of Data-centric Human/Machine Computations

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Outline

1. Background
2. CyLog
3. Prototype Development
4. Related Work and Discussions
The Complementary Nature of Human/Machine Computations

- High-speed computation without errors
- Never forget things
- Work without a break

- Pattern Recognition
- Common Sense
- Gather Information Offline
- Create new ideas

Background

- Many “Crowdsourcing Systems (Applications)” have shown their success [Doan, Ramakrishnan, Halevy 2011]
  - ESP Games
  - Q&A Services
  - reCAPTCHA
  - Video Sharing
  - ...
Our Challenge: Develop a Systematic Framework to Quickly Build Programs for the Integration of Human/Machine Computations

A Natural (and Important) Question

What is a good abstraction to describe (and program) such applications of human/machine computation?

- ESP Games
- Q&A Services
- reCAPTCHA
- Video Sharing
- ...

A possibility: Since they are data-centric, database languages can be a starting point to develop such an abstraction
Our idea: Extend the DB Abstraction to deal with Cybernetic Dataspaces (1/2)

Our Idea: Extend the DB Abstraction to deal with Cybernetic Dataspaces (2/2)
Integrated Abstraction of Data-centric Human/Machine Computations: An Example of CyLog Rule

metadata(x, y) :- img(x), keyword(x, y), inDict(y)

Evaluated by data
Evaluated by humans
Evaluated by data

Many Ongoing Projects

• We saw exciting ongoing projects in publications in 2011
  – Qurk [MIT]
  – sCOOP/hQuery [Stanford & Santa-Cruz]
  – CrowdDB [UC Berkeley, ETH Zurich]
  …
• They try to achieve database functions in the presence of human data-sources
How is CyLog Different?

• Introduces the concept of rational data source, as a new type of Web data source
• Open Predicates/Attributes to model the interaction with people
• Data games for obtaining appropriate values
• Our first international presentation was in 2010!*


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1. Background
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Point 1: Datalog-like Declarative Language

metadata(x, y) :- img(x), keyword(x, y), inDict(y)

Point 2: Open Predicates (1/3) - CWA

Parent(pam, bob)
Parent(bob, pat)
Parent(kate, pat)
Parent(kate, ann)
Ancestor(X,Y) <- Parent(X,Y),
Ancestor(X,Z) <- Parent(X, Y), Ancestor(Y, Z)

?- Ancestor(pam, pat)
   yes
?- Ancestor(pam, ann)
   No
Point 2: Open Predicates (2/3)

Parent(pam, bob)
Parent(bob, pat)
Parent(kate, pat)
Parent(kate, ann)

Ancestor(X,Y) <- Parent(X,Y),
Ancestor(X,Z) <- Parent(X, Y), Ancestor(Y, Z)

Parent(X,W)/open <- Parent(X,Y), Parent(Z, Y), Parent(Z, W)

? - Ancestor(pam, pat)
yes

? - Ancestor(pam, ann)
Yes!

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Point 2: Open Predicates (3/3) - Details

- Can have open attributes
  keyword(x,y)/open<- img(x)
- Possible to actively ask people
  keyword(x,y)/open{group}:active
- Can be an open “fact”
  img(x)/open
- Open for a specified set of humans
  keyword(x,y)/open{group}
Point 3: Data Games (1/2)

Challenge: Obtaining appropriate values in the presence of human data sources.

Approaches:
• Majority Voting
• Probabilistic Approach*
• Approach Using Item-Response Theory*
  • Data Games

* Mentioned in [Parameswaran et al. 2011]

Point 3: Data Games (2/2)

• A concept to connect data flows with reward systems
• Models each human as a rational data source who behaves rationally according to the rewards given in the games.

• This framework gives a possibility to use the game theory as an analysis tool.
• We provide some built-in data games to define the reward and aggregation to produce values.
Games
A game can be described with players, their options, and payoffs

Ex1) payoff matrix of a simple ESP Game

<table>
<thead>
<tr>
<th>Player A \ Player B</th>
<th>Term A</th>
<th>Term B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term A</td>
<td>(1, 1)</td>
<td>(0, 0)</td>
</tr>
<tr>
<td>Term B</td>
<td>(0, 0)</td>
<td>(1, 1)</td>
</tr>
</tbody>
</table>

Solution

Ex2) payoff matrix of a Q&A Service Game

<table>
<thead>
<tr>
<th>Player A \ Player B</th>
<th>Best Answer</th>
<th>Worst Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Answer</td>
<td>(15, 15)</td>
<td>(30, 0)</td>
</tr>
<tr>
<td>Second Best Answer</td>
<td>(0, 30)</td>
<td>(0, 30)</td>
</tr>
</tbody>
</table>

Solution

Human-as-a-data-source

• Accept every input “as is”
• Implicit human-id attribute keywords (hid, img, keyword)
• Key attributes are important

CyLog

Human-as-a-data-source

QL

Crowd-as-a-data-source

The DB view has the values computed by combining the inputs from the crowd

Human-as-a-data-source

• Key attributes are important
## Game Aggregations

### Duplicate Game

<table>
<thead>
<tr>
<th>Player A \ B</th>
<th>Term A</th>
<th>Term B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term A</td>
<td>(1, 1) Term A</td>
<td>(0, 0)</td>
</tr>
<tr>
<td>Term B</td>
<td>(0, 0)</td>
<td>(1, 1) Term B</td>
</tr>
</tbody>
</table>

### PathTable p

<table>
<thead>
<tr>
<th>Order</th>
<th>Player</th>
<th>Relation</th>
<th>Action</th>
<th>to</th>
<th>Player</th>
<th>Payoff</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>MetadataInput</td>
<td>Term A</td>
<td></td>
<td>A</td>
<td>1</td>
<td>Term A</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>MetadataInput</td>
<td>Term A</td>
<td></td>
<td>B</td>
<td>1</td>
<td>Term A</td>
</tr>
</tbody>
</table>

### Duplicate(p) * Duplicate_v(p)

<table>
<thead>
<tr>
<th>Player</th>
<th>Payoff</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>Term A</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>Term A</td>
</tr>
</tbody>
</table>

## Built-in Game Aggregations

The following game aggregations are different to each other in what are chosen for the output values and in how payoff points are given to players.

- Duplicates (Values given by more than one player)
- Majority (Values given by the largest number of people)
- Unique (Values given by only one person)
- Intersection (Values given by everyone)
- Union (All values given by any player)
- First (The value given first)
Discussions on Data Games

- The data game concept is widely applicable beyond the real “games,” since there are many applications in which connecting dataflow with feedback to people is the key.
- How to deal with payoff points depends on applications
- We believe that the data game is a general concept
  - The games can be used to obtain the “correct” values,
  - They can be used to obtain values chosen based on other criteria
  - The data games can handle wider situations beyond the AMT-style crowdsourcing setting.

Example: Little Known Hot Spots

- Show (possibly a part of) the list of restaurant
- Label each restaurant as
  - L1: Good
  - L2: Not good
  - L3: I have never been there
- Give more points to people who labeled as “Good” those restaurants that are good on average but labeled as “I have never been there” by many people
Example: The ESP game in CyLog

Data:
- MetadataInput(file, keyword)/open <- File(file)
- Metadata(file, g(file):keyword)/game:g(file) <- File(File)

Game:
- g(file)@time(10): Duplicate, {MetadataInput}

An Attempt to Define the Semantics of Cylog Programs

Program P
- Facts
- Rules

Strategies S1
- Consequences

Strategies S2
- Consequences

Best Strategies S3
- Rational Consequences

Best Strategies S4
- Rational Consequences

The Semantics of P
- Consequences
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Prototype System

- The current working version of our prototype system provides a default function to generate HTML forms for open predicates
- External functions are allowed to implement complex algorithms and customized user interface
- Modules to work with AMT is under development
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Related Work(1/3)

Recent Work: Qurk, sCOOP/hQuery, CrowdDB

• Common or Similar Points
  – Declarative approach
  – Concepts similar to open predicates/attributes
    (hPred, CNULL,...)
• Points Unique to CyLog
  – Introduce rational data sources
  – Data games as a means to obtain appropriate values
Related Work (2/3)

Collective Knowledge base [Richardson, Domingos 2003]

- Common or Similar Points
  - Rules and facts can be added by humans
  - Feedback to contributors
- Points Unique to CyLog
  - Designed for data-centric applications in the presence of human data resources
  - Open predicates/attributes, data games

Related Work (3/3)

Turkalytics [Heymann, Garcia-Molina, 2011]
- An analytics tool for Human Computation

Can be used to tune and optimize CyLog programs when executed with the Amazon Mechanical Turk.
Open Problems

- Optimization issues
- Advanced mechanisms for player selection
- Development of various types of data-games
- Design theory
- Definitive rationality

Some of the above are addressed in the related work

The Current Status

- Updating and extending the syntax of CyLog
  - The basic idea is the same
  - Nest Structure for the concise description
  - Support of Status values for complex games
- Developing a software platform open to public
Summary

- CyLog: Datalog-like *declarative* language
- Introduces the concept of *rational data source* as a new type of Web data source
- *Open predicates/attributes* to interact with people
- *Data games* for obtaining appropriate values

The FusionCOMP Project:
http://www.kc.tsukuba.ac.jp/~mori/isbuilder/