Objective

To find and state key open algorithmic problems for future web technologies

Outline

1. Intro: Criteria and Questionnaire
2. Problem 1: Large-Scale Filtering
3. Problem 2: Large-Scale Matching
4. Problem 3: Tag Propagation
5. Problem 4: Structure Discovery

INTRO

What are my personal criteria for choosing open problems?

What kind of questions should I answer about proposed problems?

Criteria

- Ultimate relation to technology challenge
- Familiarity with the corresponding applied field
- Interplay of several basic fields
- Freshness (hence, badly formalized)

I do not use:
- Difficulty
- Popularity and age of the problem
- Famous author

Questionnaire

- Technology challenge?
- Sample formalization?
- Basic fields involved?
- Research workflow?
- Your constructive feedback?
- References? Similar Ideas? [To be done]

Disclaimer

My style is
- At first, think independently (e.g. pose new problems)
- Only after that look into literature

Hence, the following problems might be already known and heavily studied!

PROBLEM 1

Large-Scale Filtering

What are the fastest algorithms for personal news aggregation?
1.1. Challenge

Personal news aggregation:
Every user has a preference profile:
  specified information sources, keywords, tags (topics), popularity, references to the preferences of others

Every news item has its own description:
text, votes and recommendations, tags, author reputation, comments

Filtering problem:
To find, say, ten most appropriate news items for every user

1.2. Formalization

Every profile is a normalized red vector (point on sphere) in \( n \)-dimensional space
As well, every news description is a normalized blue vector in the same space
We use cosine measure (scalar product) for similarity
Computational problem: after preprocessing all blue points, for every incoming red point compute quickly ten closest blue points

Data structures for storing all profiles and all news?

1.3. Fields Involved

- Text classification, kNN algorithms
- Computational Geometry
- Data Structures
- Compression (sparse sets)
- Linear Algebra (singular decomposition trick)
- What else?

1.4. Workflow

1. Find fast algorithms for all-to-all filtering problem
2. Suggest data structures for storing profiles and news
3. Study filtering in dynamic settings: with profiles and descriptions quickly evolving in time
4. Describe spam prevention mechanisms for large filtering systems

1.5. Constructive Feedback

Do you know related results?
What is the most important theoretical question in this problem?
How to make my formalization better?

PROBLEM 2
Large-Scale Matching
What is the most effective algorithm for distributing sponsored links among all websites?

2.1. Challenge

Effective sponsored links (ads) distribution:
Every ad has a target description
Every website has an audience description

Business objective:
Maximize ratio clicks/displays

2.2. Formalization

Every website’s audience profile is a normalized red vector in \( n \)-dimensional space
As well, every ad target is a normalized blue vector in the same space
We use cosine measure for similarity
Computational problem: compute matching between ads and websites that satisfy some constraints and minimize the sum of distances (ad - website)
2.3. Fields Involved

- Computational Geometry
- Linear Algebra (singular decomposition trick)
- Data Structures
- Compression (sparse sets)
- Game theory
- Optimization
- What else?

2.4. Workflow

- State ads distribution as an optimization problem
- Find algorithms that can approximately solve this problem faster than \((\#\text{websites}) \times (\#\text{ads})\)
- Introduce feedback to the model: after every click on any ad we receive some additional knowledge about the world and can use it for improvement of our matching

2.5. Constructive Feedback

Do you know related results?
What is the most important theoretical question in this problem?
How to make my formalization better?

PROBLEM 3
Tag Propagation
How to extend partial categorization of websites to the whole web?

3.1. Challenge

Web categorization:
People use millions of keywords (tags)
There are billions of webpages
We have very sparse training collection of pairs (website, tag)

Goal:
Get a fast algorithm that can characterize any given website

Applications:
Ads targeting
Search results annotations
Automatic web directories

3.3. Fields Involved

- Data Structures
- Compression (sparse sets)
- Numerical Analysis (speed of convergence)
- What else?

3.2. Formalization

- We have the graph of hyperlinks
- Fix a tag. For every initially labelled website let \(T_0(i) = 1\), for others \(T_0(i) = 0\)
- Then we use recursive equation and take a limit:
  \[
  T_k(i) = T_{k-1}(i) + \alpha \sum_j \text{links to } i \ T_{k-1}(j)
  \]
- Computational problem: use some preprocessing for initial tag distribution and then for every given website compute quickly ten tags with the highest rank

3.4. Workflow

- Define formulas for tag "propagation"
- Construct a fast algorithm for computing, say, ten most relevant tags of arbitrary website
3.5. Constructive Feedback

Do you know related results?
What is the most important theoretical question in this problem?
How to make my formalization better?

4.1. Challenge

We can collect many huge data sets:
call graphs, shopping histories, search histories social networks, RSS subscription graph
HOW TO BENEFIT FROM THEM?

Example: hierarchy discovery
We have some folksonomy
How to compute “optimal” tags hierarchy?

Applications:
Visualization and better navigation
Solving synonymy problem

4.2. Formalization

- Every tag is characterized by corresponding set of websites
- We want to compute the optimal AND-OR tree of tags
- Optimal means minimal correctness violation
- Correctness: sons of OR vertex should be disjoint, parent set contains children sets, etc...

4.3. Fields Involved

- Computational Biology (phylogeny algorithms)
- Approximate algorithms
- What else?

4.4. Workflow

1. Fix a format of tag description and define an optimality criteria for hierarchy of tags
2. Construct a fast algorithm for computing optimal hierarchy
3. Study interplay with algorithms for constructing phylogeny tree

4.5. Constructive Feedback

Do you know related results?
What is the most important theoretical question in this problem?
How to make my formalization better?

Voting

We discuss four problems. Which one do you like the most?
- Large-Scale Filtering
- Large-Scale Matching
- Tag Propagation
- Structure Discovery
Main points

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Today we learn:

- Technology challenges: personal aggregation, effective ads, usage of huge data collection
- Key algorithmic challenge: large-scale algorithms that are faster than naive (usually quadratic) approaches
- Next steps: (1) survey, (2) formalizations, (3) public discussion

Thanks! Questions?