New Perspectives for Recommendations in Location Based Social Networks

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http://delab.csd.auth.gr
Structure

- Social Networks (SN)
- Recommender Systems (RS)
- Location Based Social Networks (LBSN)
- New Perspectives
  - Time
  - Privacy
  - Explainability
Social Networks are everywhere
Domains

- **Entertainment** – movies, music, IPTV
- **Content personalized** – newspapers, web pages, documents, e-learning applications
- **E-commerce** – books, cameras, PCs
- **Services** – travels
Structure

• Social Networks (SN)
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Recommender Systems (RS)

Recommender Systems have to provide accurate and justifiable recommendations.

why?

- They gain the user’s trust and their credibility.
- They improve customer attraction/retention.
LBSNs

entities and their correlations

Map Locations

User graph

Group graph

Group-User-Location-Activity graph

KDD

Recsys

LBSN

User-Group graph

Bipartite graph

User-Location graph

Location-activity graph

Map Locations

Group-User-Location-Activity graph

Tripartite graph

Quadripartite graph

Unipartite graph

Activity graph

User-Group-Location-Activity

User-Group-Location
Categorizing 14 real-world LBSNs based on their features

- Platform used
- Personalization
- System features
- Recommendation types
- Explanation
Systems in numbers (1/3)

- **Web**: 9
- **Platform**: 10
- **Mobile/Tablet**: 12
- **Personalization**: 8
- **Generic**: 10
- **Personalized**: 12
Systems in numbers (2/3)

Recommendation Types

Location: 14
Friend: 3
Activity: 6
Event: 6
Non-Local: 5
Local: 10
Systems in numbers (2/3)

Explanations

User

Activity  Location

6  4  7
Convergence

Platform

Personalization

Generic

Personalized

Web

Mobile

Location

User

Activity

Explanations

Recommendation Types

Location

Friend

Activity

Event

Cross system connectivity

Wish list

To do list

Duplicate correction

Map visualization

System Features

Foursquare
# Systems Comparison

<table>
<thead>
<tr>
<th>Systems</th>
<th>Platform</th>
<th>Personalization</th>
<th>System features</th>
<th>Recommendation types</th>
<th>Explanation</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Web</td>
<td>Mobile/tablet</td>
<td>Generic</td>
<td>Cross-system connectivity</td>
<td>Wish list</td>
<td>To do list</td>
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<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8 raved¹³</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<td>11 geosocialrec¹⁶</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>✓</td>
<td>✓</td>
<td>-</td>
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</tr>
<tr>
<td>13 Facebook Places¹⁸</td>
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<td>✓</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14 Sindbad¹⁹</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

| Systems supporting the feature | 9 | 12 | 10 | 8 | 10 | 2 | 1 | 2 | 14 | 8 | 14 | 3 | 6 | 5 | 1 | 7 | 6 | 4 | 1.75G |

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Missing Features in Systems

- Time
- Privacy
- Explainability
Structure

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Time
The problem

• Time is the most important factor to provide accurate Recommendations

Example:

Recommendation: I recommend you to go to the library which is nearby and 5 of your friends visited it in the past.
Motivation
Periodicity
Related Work

L. Xiang et al. (KDD 2010)

- Framework that models user **long-term** and **short-term** preferences over time.
- Their model is built on a **Session-based Temporal Graph (STG)**, which incorporates user, location and session information.
Running example

John

L1

L2

L3

L4

Session 1

Session 2

Session 3

Maria
Extending Random Walk to IPF

• Injected Preference Fusion (IPF) algorithm
• long-term preferences
• short-term preferences

Algorithm 1: Pseudo code of IPF to make recommendation for active user $u$ at time $t$.

Data: STG $G$, user $u$, time $t$
Result: Recommendation for user $u$ at time $t$
Queue $Q$;
NodeSet $V$;
$Q$.append($v_u$);
$Q$.append($v_{ut}$);
distance[$v_u$] = distance[$v_{ut}$] = 0;
rank[$v_u$] = $\beta$;
rank[$v_{ut}$] = $1 - \beta$;
while $Q$ is not empty do
    Node $v$ = $Q$.top();
    if $V$.contains($v$) then
        continue;
    if distance[$v$] > 3 then
        break;
    $V$.insert($v$);
    foreach $v' \in out(v)$ do
        if !$V$.contains($v'$) then
            distance[$v'$] = distance[$v$] + 1;
            $Q$.append($v'$);
        if distance[$v$] < distance[$v'$] then
            rank[$v'$] = rank[$v'$] + rank[$v$] \cdot $\psi(v, v')$;
    rank.sort();
return top-N unknown items;
S.S. Ho et al. (MobiGIS 2012)

- They extract spatio-temporal information for future events from news articles.
- They analyze sentimentally each news article to identify the **positive** or **negative** perception of the article.
- Their system recommends suitable events for a user to attend or avoid.
Method

Input: News Article
- Recognition:
  - Toponyms
  - Temporal Patterns
  - Title and URL

Matching/Resolution:
- Spatiotemporal Disambiguation, De-duplication, and Pairing
- Key Phrase Extraction
- Event Sentiment Analysis

Output:
Event {temporal information, spatial information, sentiment, key phrase, title, URL}
Running example
Exploited spatio-temporal characteristics of POIs by using a unified framework, which consists of the

• **spatial** and
• **temporal** dimensions
They claim that locations, which are in distance from the current user's location, are not probable to be visited.
Spatial dimension (2/2)

Given a user $u$, and the history of his check-ins $L_u$ in locations, they calculate the conditional probability $P( l \mid L_u )$ as the ranking score for each candidate location $l$ and propose the top ranked locations by using the Bayes rule.

$$C_{u,l}^{(s)} = P(l) \prod_{l' \in L_u} P(l' \mid l)$$
Temporal dimension

- They split time in multiple slots. Then, they fill these slots with check-in values that users made at each specific hour of the day.
- Moreover, they use a **User-Time-POI (UTP) cube** to present check-in records.

\[
\hat{C}^{(t)}_{u,t,l} = \frac{\sum_v w^{(t)}_{v,t} \cdot C_{v,t,l}}{\sum_v w^{(t)}_{v,t}}
\]
Spatio-Temporal Fusion

- They use linear interpolation to compute the final recommendation score for each location \( l \), by normalizing the two scores.
- Finally, they use the tuning parameter \( \alpha \) to compute the final probability that a user \( u \) will check-in a location \( l \) at a specific time \( t \)

\[
C_{u,t,l} = \alpha \cdot C_{u,t,l}^{(t)} + (1 - \alpha) \cdot C_{u,t,l}^{(s)}
\]
Structure

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  • Privacy
  • Explainability
Privacy
Systems Privacy Policy

- Users let the social network services to concern about their privacy policy by using only the default system’s configuration.
Privacy policy

• User’s privacy in LBSNs is even more important than OSNs since user’s location can be revealed

• The nature of LBSNs imposes strong privacy barriers

• Nowadays, user geo-location can be inferred even for people who keep their GPS signal private
Users' privacy vulnerability example
Related Work


D. Freni et al. (CIKM 2010)

- Their method allows users to define regions along with time periods that should and should not be published
- Wyse (Watch Your Social stEp) technique provide a safe way to publish a location

**Wyse**
- checks user's profile for a restriction on a location
- retrieves the preferences of user friends
- retrieves relevant locations, and publishes other locations (if there are no restrictions preventing the target location)
System Architecture
Running example
K.P.N. Puttaswamy et al.  
(HotMobile 2010)

• Argue that LBSNs should adapt an approach where the untrusted third-party servers are given encrypted data, and the application functionality will be moved to the client devices.

• The location coordinates should be encrypted, when shared, and could be decrypted only by the users that the data is intended for.
Main idea

- Users should exchange cryptographic keys in an off-line social network with their friends storing these keys in their smart phones.
- If a user wants to exchange location information with a friend, this should be done through encryption keys between their devices.

| Friendship Proof | (Content = <PubKey_A, PubKey_B, SKey_A, timestamp>)  
|                  | Then, FProof_{A\rightarrow B} = <Content,PrivKey_A(Hash(Content))> |
| Transaction Proof | Content = <Sess_A(PubKey_A, timestamp, msg)>.
|                  | Then, TProof_A = <Content,PrivKey_A(Hash(Content))> |
W. Wei et al. (INFOCOM 2012)

- MobiShare → Privacy management system

System shares the user's location among trusted social relations, and excludes it from untrusted strangers

- Stores users' identity information to an untrusted third-party social network server
- Stores encrypted the users' location to an untrusted third-party location server
Encrypted location is visible to his friends but not to strangers
Friends vs. Strangers

Fig. 2. Querying friends’ locations

Fig. 3. Querying strangers’ locations
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Explainability
Explanations in General Words

• What is explainability?
  • A system should justify its recommendations

• How does it help Users?
  • Explanations are the mirror of each LBSN, because they reflect in a transparent way the logic behind a recommendation.
Example of “Nearest Neighbor” style of Recommendation

“Customers who bought item X also bought items Y, Z, etc”

Customers who bought this item also bought:
- *Data Mining: Concept and Techniques (The Morgan Kaufmann Series in Data Management Systems)* by Jiawei Han
- *Introduction to Machine Learning (Adaptive Computation and Machine Learning)* by Ethem Alpaydin
- *Data Mining: Introductory and Advanced Topics* by Margaret H. Dunham
- *Data Mining with SQL Server 2005* by ZhaoHui Tang

- Explore similar items: Books (49)
Example of an “influence” style of recommendation

“Item Y is recommended because you rated item X”

1. **Pattern Classification (2nd Edition)**
   by Richard O. Duda (Oct, 2000)
   Average Customer Review: ★★★★★ (26)
   In Stock

   **List Price:** $140.00
   **Price:** $116.00
   55 used & new from $60.00

   □ I own it   □ Not interested   ★★★★★ Rate it

   Recommended because you purchased **Survey of Text Mining I** and more (Fix this)
### Explanation Dimensions (1/2)

<table>
<thead>
<tr>
<th>Photo</th>
<th>First Name</th>
<th>Last Name</th>
<th>Email address</th>
<th>Explanation</th>
<th>Add as a friend</th>
</tr>
</thead>
</table>
| ![Nikos](image1.png) | Nikos | Papas | papas@csd.auth.gr | Number of common friends: 4  
Names of common friends: 
Nick John  
Petro North  
Maria Downs  
Paul Manos | ![Add](image2.png) |
| ![Petros](image3.png) | Petros | Johns | john@csd.auth.gr | Number of common friends: 3  
Names of common friends: 
Petro North  
Maria Downs  
Kostas Papas | ![Add](image2.png) |
| ![Maria](image4.png) | Maria | Down | down@csd.auth.gr | Number of common friends: 2  
Names of common friends: 
Petro North  
Kostas Papas | ![Add](image2.png) |
| ![Pavlos](image5.png) | Pavlos | Doe | doe@csd.auth.gr | Number of common friends: 2  
Names of common friends: 
Maria Downs  
Nick John | ![Add](image2.png) |

**1-D explanation type**
Explanation Dimensions (2/2)

We recommend the following locations for Mr. Kefalas.

<table>
<thead>
<tr>
<th>Point of interest</th>
<th>POI Address</th>
<th>Total check-ins</th>
<th>Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thessaloniki’s White Tower</td>
<td>Leoforos Nikis 24</td>
<td>14</td>
<td>4.931</td>
</tr>
<tr>
<td>Aristotle University</td>
<td>University Campus</td>
<td>12</td>
<td>4.479</td>
</tr>
<tr>
<td>Historic Center</td>
<td>Benizalou 55</td>
<td>9</td>
<td>4.453</td>
</tr>
<tr>
<td>Tsimiski’s market</td>
<td>Tsimiski 48</td>
<td>6</td>
<td>3.702</td>
</tr>
</tbody>
</table>

2-D explanation type
Explanation Dimensions

• By supporting many dimensions, RS justify the reasons behind a recommendation in a proper way:
  • User Dimension
  • Activity Dimension
  • Location Dimension
  • Time Dimension
4D Explanation styles
Related Work


S. Thirumuruganathan et al.  
(VLDB 2012)

• MapRat
  • helps users to significantly improve their decisions by providing them meaningful explanations and visualizing them in a map

• Steps
  • **Similarity Mining** (identify groups of reviewers with same ratings on items)
  • **Diversity Mining** (identify groups of reviewers with non-similar ratings on items)
MapRat

MapRat: Meaningful Interpretation, Exploration and Geo-Visualization of Collaborative Ratings

- **Movie Name**: Toy Story
- **Time Interval**:
  - Jan-Jun 2000
  - Jul-Dec 2000
  - Jan-Jun 2001
  - Jul-Dec 2001
  - Jan-Jun 2002
  - Jul-Dec 2002
  - Jan-Jun 2003
  - Jul-Dec 2003
- **Settings**:
  - Number of Groups: 3
  - Ratings Coverage: 30
- **Final Query**:
  - Movie Name = Toy Story, Time Interval = January 2001 to December 2001

[Button] Explain Ratings!
Graphical interface results
Results in Charts
An internet-based application that recommends:

(1) friends,
(2) locations,
(3) activities.

- Friends are recommended based on the FriendLink algorithm and the geographical distances between user “check-ins”, which are used as link weights.
- New Users/locations/activities are also inserted into a 3-order tensor, which is then used to provide location and activity recommendations.

http://delab.csd.auth.gr/geosocial2
Recommendation Engine

Friendship Profile
- From user id
- To User id

Check-in Profile
- User id
- Location id
- Activity id
- Rating id
- Time

User Profile
- User id
- User Name

Activity Profile
- Activity id
- Activity Name

Time Profile
- Time id
- Time Stamp

Location Profile
- Location id
- Location Name
- Location Position

Rating Profile
- Rating id
- Rating Name

Geo-Social algorithm
- Dynamically analyzed 3-order tensor (user, location, activity)

Database Profiles

Friend Recommendations
Location Recommendations
Activity Recommendations
Check-in System

Web Site

Mobile users
## Friend Recommendation

### Geo-social

We recommend the following users as possible 2-hop friends!

<table>
<thead>
<tr>
<th>Name</th>
<th>Last Name</th>
<th>E-mail</th>
<th>Add as a friend</th>
<th>Picture</th>
<th>Number of common friends</th>
<th>Names of common friends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maria</td>
<td>Kontaki</td>
<td><a href="mailto:kontaki@csd.auth.gr">kontaki@csd.auth.gr</a></td>
<td>Add</td>
<td><img src="image" alt="Maria" /></td>
<td>3</td>
<td>Dimitris Katsaras, Yannis Manolopoulos, Efi Tsamoura</td>
</tr>
<tr>
<td>Nikos</td>
<td>Dinokas</td>
<td><a href="mailto:dinokas@csd.auth.gr">dinokas@csd.auth.gr</a></td>
<td>Add</td>
<td><img src="image" alt="Nikos" /></td>
<td>2</td>
<td>Yannis Manolopoulos, Efi Tsamoura</td>
</tr>
<tr>
<td>Panagiotis</td>
<td>Symeonidis</td>
<td><a href="mailto:symeon@csd.auth.gr">symeon@csd.auth.gr</a></td>
<td>Add</td>
<td><img src="image" alt="Panagiotis" /></td>
<td>1</td>
<td>Dimitris Katsaras</td>
</tr>
</tbody>
</table>

We recommend the following users as possible 3-hop friends!

<table>
<thead>
<tr>
<th>Name</th>
<th>Last Name</th>
<th>E-mail</th>
<th>Add as a friend</th>
<th>Picture</th>
<th>Number of pairs of users</th>
<th>Paths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasos</td>
<td>Gounaris</td>
<td><a href="mailto:tasos@csd.auth.gr">tasos@csd.auth.gr</a></td>
<td>Add</td>
<td><img src="image" alt="Tasos" /></td>
<td>1</td>
<td>Yannis Manolopoulos -- Nikos Dinokas -- Tasos Gounaris</td>
</tr>
</tbody>
</table>
Location recommendation

Please choose an activity you would like to perform:

- study

Select:

We recommend the following location(s) for the selected activity:

<table>
<thead>
<tr>
<th>Place</th>
<th>Times visited by your friends and similar users</th>
<th>Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auth Library</td>
<td>1</td>
<td>1/3</td>
</tr>
<tr>
<td>Starbucks</td>
<td>1</td>
<td>3/3</td>
</tr>
</tbody>
</table>
**Location recommendation**

**EXPLANATION STYLE A:**

We recommend the following POI’s (Point of Interest) based on total Check-ins!

<table>
<thead>
<tr>
<th>Point Of Interest</th>
<th>POI Address</th>
<th>Explanation Style A: Total Check-Ins</th>
<th>Average Rating from style A</th>
<th>Go To</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRISTOL</td>
<td>George Papandreou 24</td>
<td>7</td>
<td>4.2857</td>
<td>Move!</td>
</tr>
<tr>
<td>BERLIN</td>
<td>Krysostoumou Smyrnis 10</td>
<td>6</td>
<td>3.5000</td>
<td>Move!</td>
</tr>
<tr>
<td>ART HOUSE</td>
<td>Vogatsikou 4</td>
<td>6</td>
<td>3.0000</td>
<td>Move!</td>
</tr>
</tbody>
</table>

**EXPLANATION STYLE B:**

We recommend the following activities based on the Check-Ins made by your friends!

<table>
<thead>
<tr>
<th>Point Of Interest</th>
<th>POI Address</th>
<th>Explanation Style B: Check-Ins made by your friends</th>
<th>Average Rating from style B</th>
<th>Go To</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRISTOL</td>
<td>George Papandreou 24--Poseidonio</td>
<td>3</td>
<td>4.0000</td>
<td>Move!</td>
</tr>
<tr>
<td>BERLIN</td>
<td>Krysostoumou Smyrnis 10--City Center</td>
<td>2</td>
<td>4.5000</td>
<td>Move!</td>
</tr>
<tr>
<td>ART HOUSE</td>
<td>Vogatsikou 4--City Center</td>
<td>2</td>
<td>3.5000</td>
<td>Move!</td>
</tr>
</tbody>
</table>
Activity recommendation

We recommend the following activities for the selected location:

<table>
<thead>
<tr>
<th>Place</th>
<th>Activity</th>
<th>Times visited by your friends and similar users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trendy Bar</td>
<td>clubbing</td>
<td>1</td>
</tr>
<tr>
<td>Picadilly</td>
<td>clubbing</td>
<td>1</td>
</tr>
</tbody>
</table>
# Activity recommendation

## EXPLANATION STYLE A:

We recommend the following activities based on total Check-ins!

<table>
<thead>
<tr>
<th>Activity</th>
<th>Point Of Interest</th>
<th>POI Address</th>
<th>Explanation Style A: Total Check-Ins</th>
<th>Average Rating from style A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight-seeing</td>
<td>White Tower</td>
<td>Nikis Avenue--Paralia Thessalonikis</td>
<td>14</td>
<td>4.3571</td>
</tr>
<tr>
<td>Education</td>
<td>Aristotle University of Thessaloniki</td>
<td>Egnatia &amp; Kondriktonos--Aristotle Campus</td>
<td>13</td>
<td>4.2308</td>
</tr>
<tr>
<td>Sight-seeing</td>
<td>Aristotelous Square</td>
<td>Aristotelous Square--City Center</td>
<td>11</td>
<td>4.1818</td>
</tr>
</tbody>
</table>

## EXPLANATION STYLE B:

We recommend the following activities based on the Check-Ins made by your friends!

<table>
<thead>
<tr>
<th>Activity</th>
<th>Point Of Interest</th>
<th>POI Address</th>
<th>Explanation Style B: Check-Ins made by your friends</th>
<th>Average Rating from style B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar</td>
<td>Sta Kastra</td>
<td>Επιταχυνήσι 118-126, Θεσσαλονίκη 546 34, Ελλάδα--</td>
<td>3</td>
<td>4.0000</td>
</tr>
<tr>
<td>Sight-seeing</td>
<td>White Tower</td>
<td>Nikis Avenue--Paralia Thessalonikis</td>
<td>3</td>
<td>3.3333</td>
</tr>
<tr>
<td>Sight-seeing</td>
<td>Aristotelous Square</td>
<td>Aristotelous Square--City Center</td>
<td>2</td>
<td>5.0000</td>
</tr>
</tbody>
</table>
New perspectives for Recommendations in Location Based Social Networks

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Luxembourg, 29 October 2013

http://delab.csd.auth.gr