Manipulating Black-Box Networks for Centrality Promotion

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Graphs (Networks)

Q: Which node in the graph is the most important?

A: Centrality Measures
Graphs (Networks)

Q: Which node in the graph is the most important?

A: Centrality Measures

\[ \text{Degree} \quad d(v_9) = 4 \quad d(v_{10}) = 1 \]

\[ \text{Betweenness, Closeness, Eccentricity} \]
Problem Statement

Vital Nodes

*Nodes with high centrality values*

*Superior position (get high citations)*

Network Manipulation

Insert edges/nodes

Target node $t$ become vital

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1P. Crescenzi, et. al., Greedily improving our own closeness centrality in a network, TKDD, 2016.
Idea: greedily choose some nodes to connect

Limitations

Unknown graph structure (Black-Box Network)

Ranking is promoted (Ranking Promotion)

Graph $G$, centrality value $c(t)$

closeness: $c(v_4) = 1/23$

Update Graph $G'$, centrality value $c'(t)$

c'(v_4) = 1/21

$\text{rank}(v_4) = 9$: there are 8 nodes with values higher than $v_4$
Goal #1

Goals

- Black-Box Network
  - Insert nodes/edges around target node
- Ranking Promotion

Multi-Point

Double-Line
Goal #2

Goals

- **Black-Box Network**
  - Insert nodes/edges around target node

- **Ranking Promotion**
  - Non-trivial
  - How to choose a strategy for a centrality measure?

Do any of the strategies work for eccentricity promotion?

- **Multi-Point strategy:** no
- **Double-Line strategy:** yes

How to choose a strategy for a centrality measure?
Our Solution

Goals

Black-Box Network: Insert nodes/edges around target node

Ranking Promotion: Non-trivial How to choose a strategy for a centrality measure?

Idea

When inserting nodes into G (by some strategy)

Centrality measures: two groups

Value of target node can only be increased (or not changed), e.g., betweenness

choose a strategy to ensure target node:

Maximum Value Increase (Maximum Gain Principle)

Value of target node can only be decreased (or not changed), e.g., eccentricity

choose a strategy to ensure target node:

Minimum Value Decrease (Minimum Loss Principle)
### Maximum Gain Principle

**Goals**

- **Black-Box Network**: Insert nodes/edges around target node
- **Ranking Promotion**: Non-trivial
  - How to choose a strategy for a centrality measure?
  - Choose Multi-Point for betweenness promotion

**Maximum Gain Principle**

**Three Conditions**

- Target \( t \) has the maximum increase
- \( t \) overtakes some \( v \) (after inserting \( \sqrt{c(v) - c(t)} + 1 \) nodes)
- Node \( t \) has a value no smaller than inserted nodes \( w \)

**Ranking of \( t \) is improved by overtaking a vertex in \( G \)**

**Newly inserted \( W \) will not rank higher than \( t \)**
# Minimum Loss Principle

**Goals**

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<th>Insert nodes/edges around target node</th>
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<tr>
<td>Ranking Promotion</td>
<td>Non-trivial</td>
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<tr>
<td>Maximum Gain Principle</td>
<td>Choose Multi-Point for betweenness promotion</td>
</tr>
<tr>
<td>Minimum Loss Principle</td>
<td>Choose Double-Line for eccentricity promotion</td>
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</table>

**Three Conditions**

- Target $t$ has the *minimum loss*
- $t$ overtakes some $v$ (after inserting certain nodes)
- Node $t$ has a value no smaller than inserted nodes $w$
Experiments

Datasets

CA-HepPh (HEPP), 11204 nodes, 117619 edges

Maximum Gain Principle

Minimum Loss Principle

Multi-Point is effective for betweenness promotion

Double-Line is effective for eccentricity promotion

Target node improves the ranking by at least 3,000 on average (betweenness)

Target node improves the ranking by at least 2,000 on average (eccentricity)
Manipulating Black-Box Networks for Centrality Promotion

- Black-Box Networks
  - Assume that the graph structure is unknown
- Ranking Promotion
  - Maximum Gain or Minimum Loss Principles

Thanks