Online Centrality in Temporally Evolving Networks

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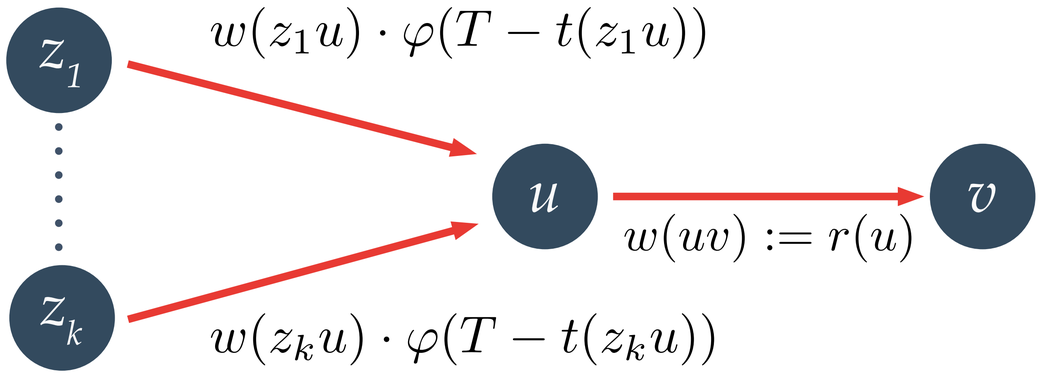
OBJECTIVE

- We introduce a centrality measure updateable by the edge stream in a dynamic network
- It incorporates the elapsed time of edge activations

ONLINE CENTRALITY

- $D = (V,A)$: dynamic directed graph, e.g.: mention network
- Edges can be activated multiple times, cannot be deleted
- $A(T)$: set of edges activated before time T, $A(0)=\emptyset$.
- $w(uv)$: weight over edge uv
- $t(uv)$: last edge activation time of edge uv
- $\varphi(x)$: time decay function, vanishes in infinity
- $r(v)$: the Online Centrality score of node v

UPDATE RULE



- Edge uv activated at time T, we update: (1) r, (2) w and t

$$r(u) := \alpha + \sum_{zu \in A(T)} w(zu) \cdot \varphi(T - t(zu))$$

$$w(uv) := r(u)$$

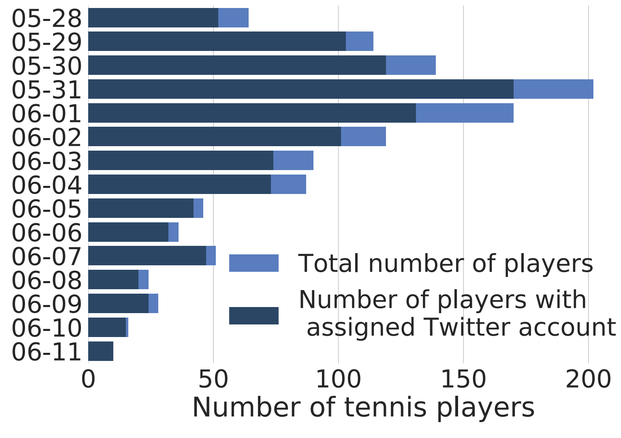
$$t(uv) := T$$

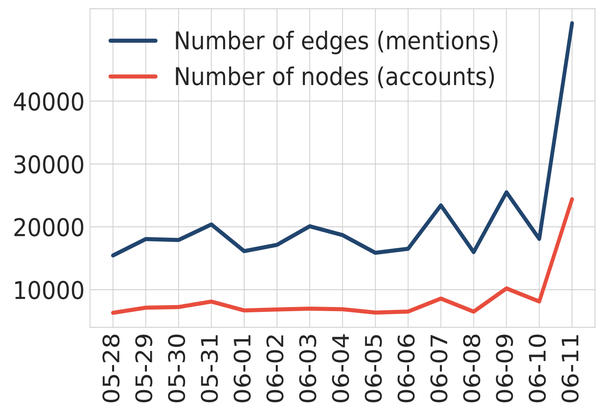
TIME DECAY

- Decay intensity is controlled by parameter n
- Δt is measured in seconds
- Exponential decay: $\varphi(\Delta t) := b^{\frac{\Delta t}{n}}, (0 < b < 1)$
- Rayleigh decay: $\varphi(\Delta t) := \frac{1}{\sigma^2} \cdot \frac{\Delta t}{n} \cdot e^{-\frac{1}{2\sigma^2} \cdot (\frac{\Delta t}{n})^2}$

ROLAND-GARROS DATASET

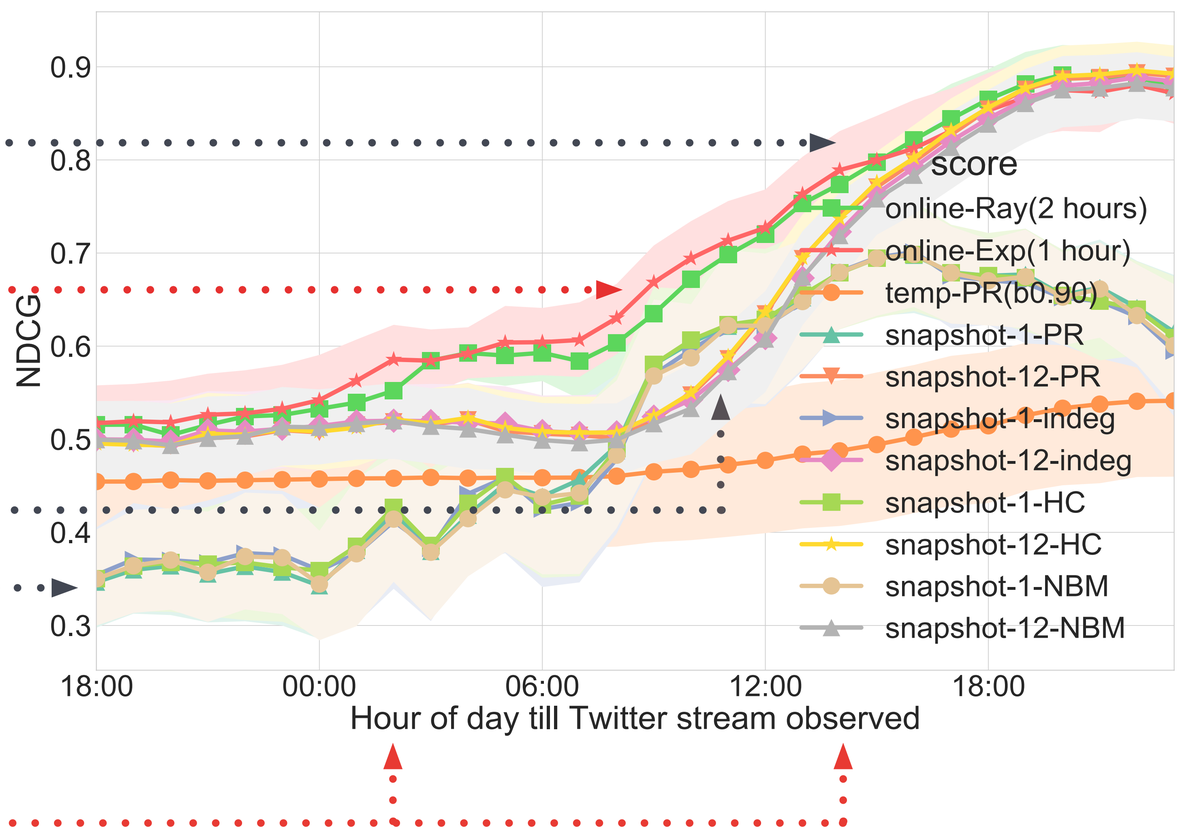
- We collected tweets from May 23 to June 16 using keywords: *@rolandgarros, #rolandgarros2017, #frenchopen, #rg17*
- 444,328 tweets, 351,692 mentions
- Mention network: nodes are accounts, edges are mentions
- Assign tennis players to Twitter accounts (412 account found)
- Filter for relevant players: Men's, Women's, Legends Under 45
- Tournament days from 2017 May 28 to June 11 (15 days)





MEASUREMENT

- Central node prediction in the temporally evolving mention network of Roland-Garros 2017
- **Goal:** predict list of players who play on a given day
- **Evaluation** by $\mathrm{NDCG} = \frac{1}{\mathrm{IDCG}} \sum_{i=1}^{\infty} \frac{\mathrm{rel}(i)}{\log_2(i+1)}$,
  - ranking is based on network centrality
  - rel(i) = 1 if node i is related to a player who participated on the given day and *0* otherwise
- **Baselines:** Temporal PageRank [Rozenshtein et al.] **(temp-PR)** and static centrality measures; PageRank **(PR)**, Indegree **(indeg)**, Negative-Beta measure **(NBM)**, Harmonic centrality **(HC)**; calculated in 1 or 12 hour time windows
- NDCG averages of 15 days, with confidence intervals shown



By the end of the day most of the models can predict daily tennis players accurately

Online Centrality with both Exponential (*online-Exp*) and Rayleigh time decay (*online-Ray*) outperforms baselines for all snapshots

Snapshot-12 methods are slow at detection, Snapshot-1 methods give less increase and decline too early

Our methods are best at early detection, from 2AM to 2PM, before the actual games.

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All datasets and results are available on GitHub
https://github.com/ferencberes/online-centrality