Adaptive algorithms for efficient content management in social networks

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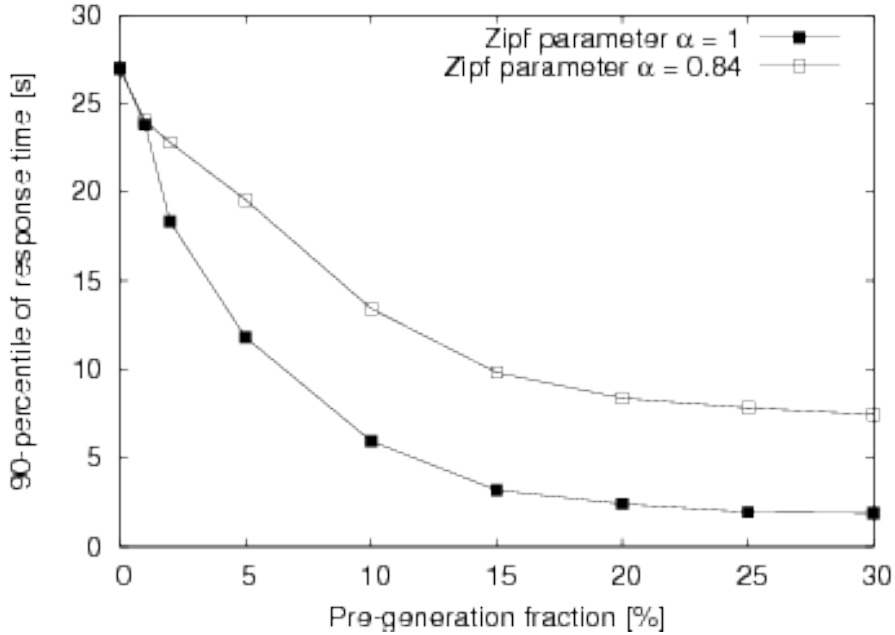
Future Web Scenarios

- **Community-based services**
  - Social networking: support for user interaction be the killer of future Web
  - Rich-media content
  - Presence of Mobile User access

- **Workload evolution in the next four years**
  - Computational demand will grow faster than CPU power (Moore's Law)

Motivations for content management

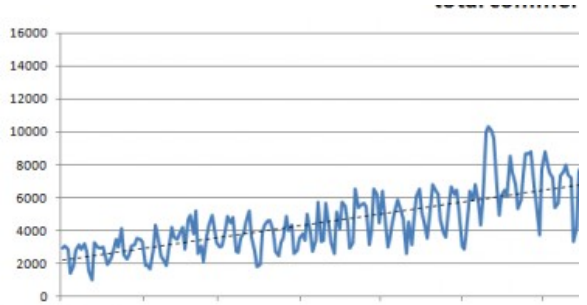
- **Content management**
  - Content replication
  - Caching
  - CDN delivery
  - Resource pre-generation



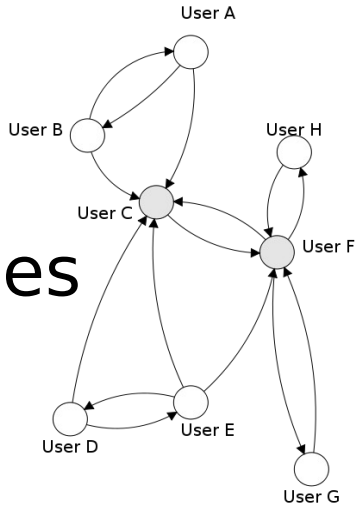
- **→ Need to identify the Hot set of popular resources**
  - Variability in workload characteristics
  - Rapid variations in access patterns
  - Workload dynamics related to social interactions
- **→ Need for algorithms providing early and fast detection of popular resources.**
- **→ Stable performance are not an optional**

Hot set identification

- **The algorithm must identify the most popular resources (Hot set)**
  - Hot set is evaluated periodically with interval Δt
  - Hot set resources will receive the highest number of accesses in the interval [t, t+Δt]
- **Predictive-based algorithm**
  - Evaluates past access patterns and uses a simple predictor to forecast future accesses



- **Social-based algorithm**
  - Evaluates number of incoming social links
  - High connection degree → popular resources
- **Combination of approaches**
  - → must merge heterogeneous information

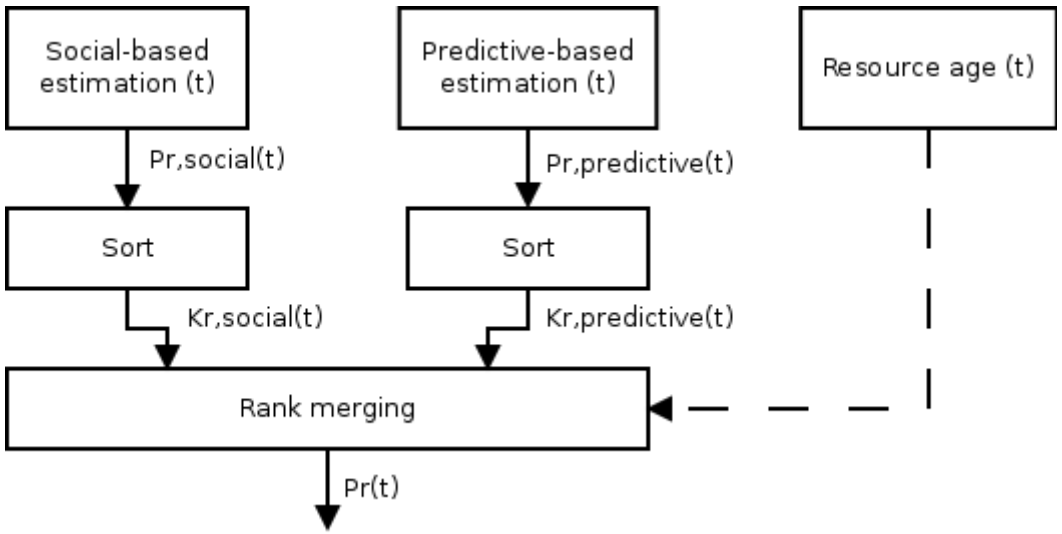


Proposed algorithms

- **Proposal: novel algorithms that merge access pattern prediction and social information**
  - Rank-age
  - Linear-adaptive
  - Rank-adaptive
- **Use of adaptive techniques that takes into account workload characteristics**
- **Comparison with existing solutions**
  - social- and predictive-based

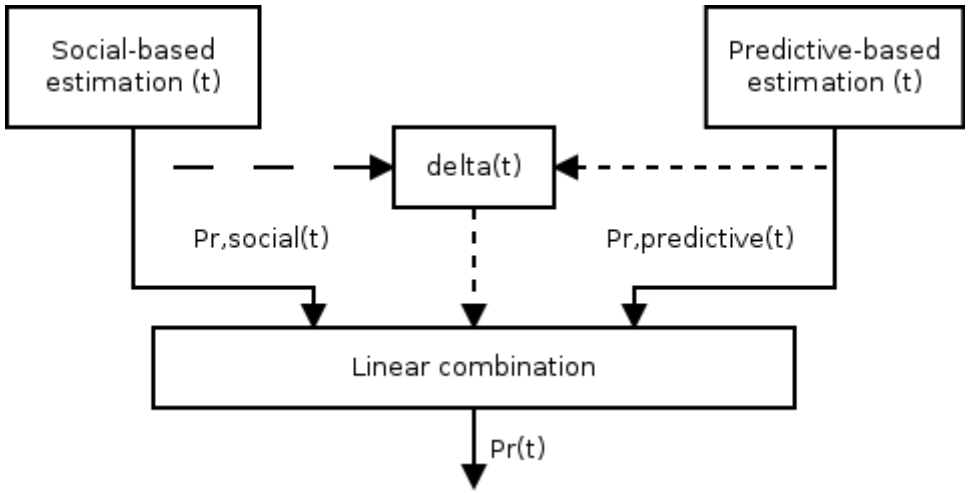
Rank-Age algorithm

- **Social- and predictive-based information have different probability distribution**
  → Use of rank merging
- **Weighting different information:**
  - Predictive information are more reliable for older resources
  - Social-based information may be used otherwise
- **Resource age is used to determine the weight in rank-merging**



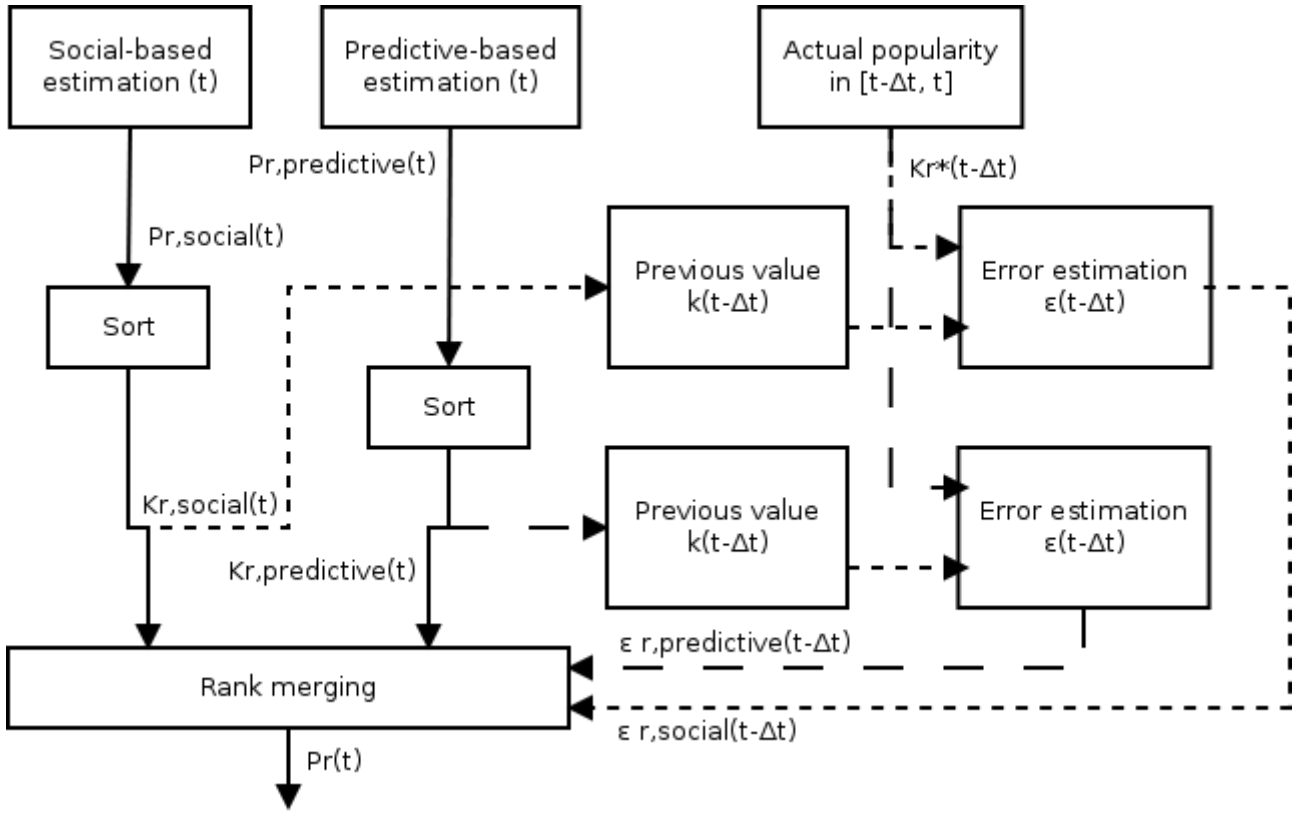
Linear-Adaptive algorithm

- **Social-based and predictive based information have different probability distribution**
  → use of adaptive technique to estimate the weight of each information
  → need to normalize different values
- **The weighting function takes into account *median* and *quartile* information about social information and predicted accesses for the whole working set**



Rank-adaptive algorithm

- **Use of rank merging → handles different probability distribution**
- **Use of a feedback on the popularity estimation errors in previous interval to compute the weight used in rank merging**



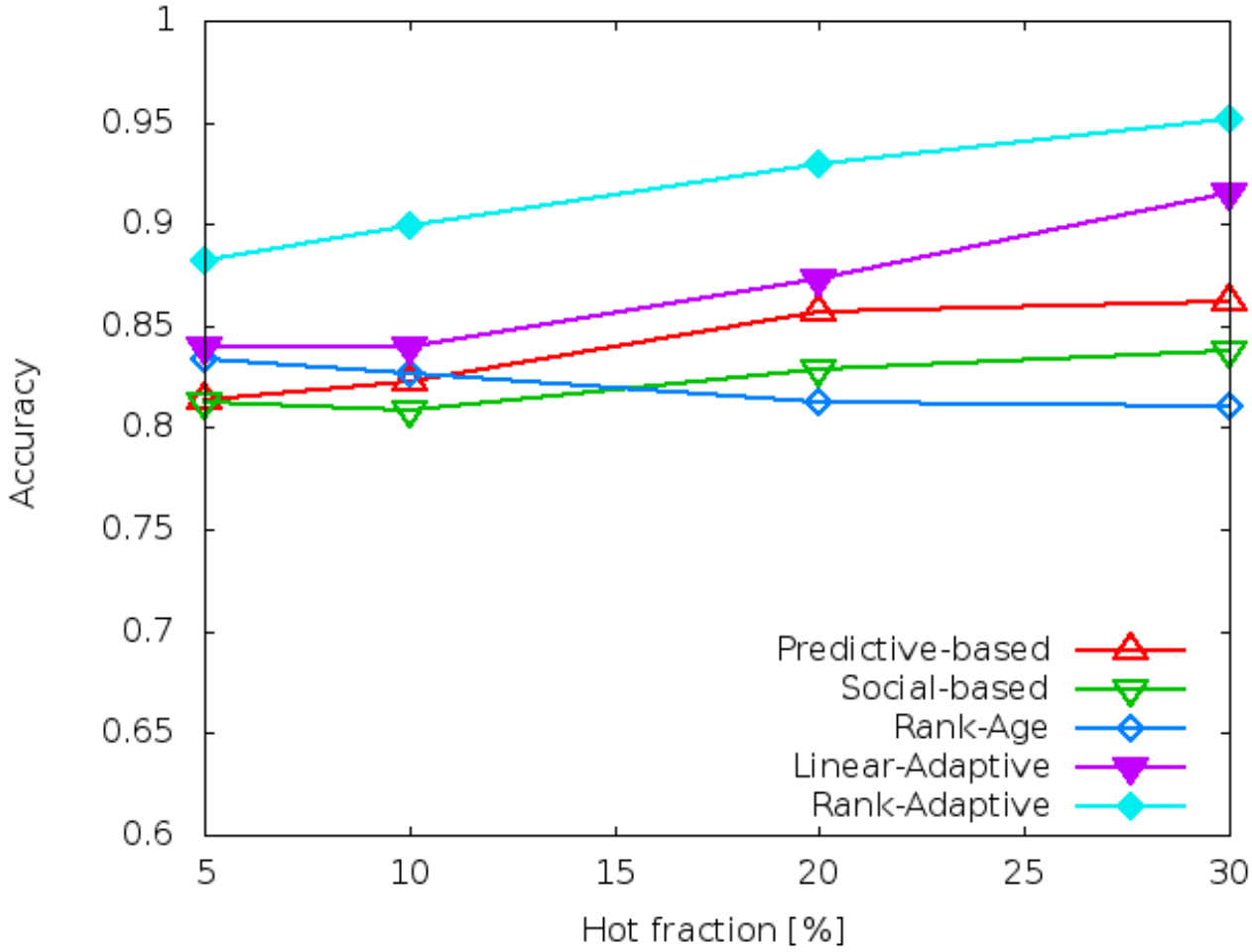
Experimental setup

- **Simulation based on Omnet++ framework**
  - User population up to 20000 units
  - Average of 100 requests/sec
  - 12 hours of simulated time
  - Δt=20minutes
  - Main metric: accuracy=|HS(t) ∩ HS*(t)|/|HS*(t)|

Parameter	Range	Default
Hot fraction [%]	5%-30%	20%
Upload percentage [%]	1%-20%	5%
User/resource popularity correlation	0.6-0.8	0.7

Performance evaluation

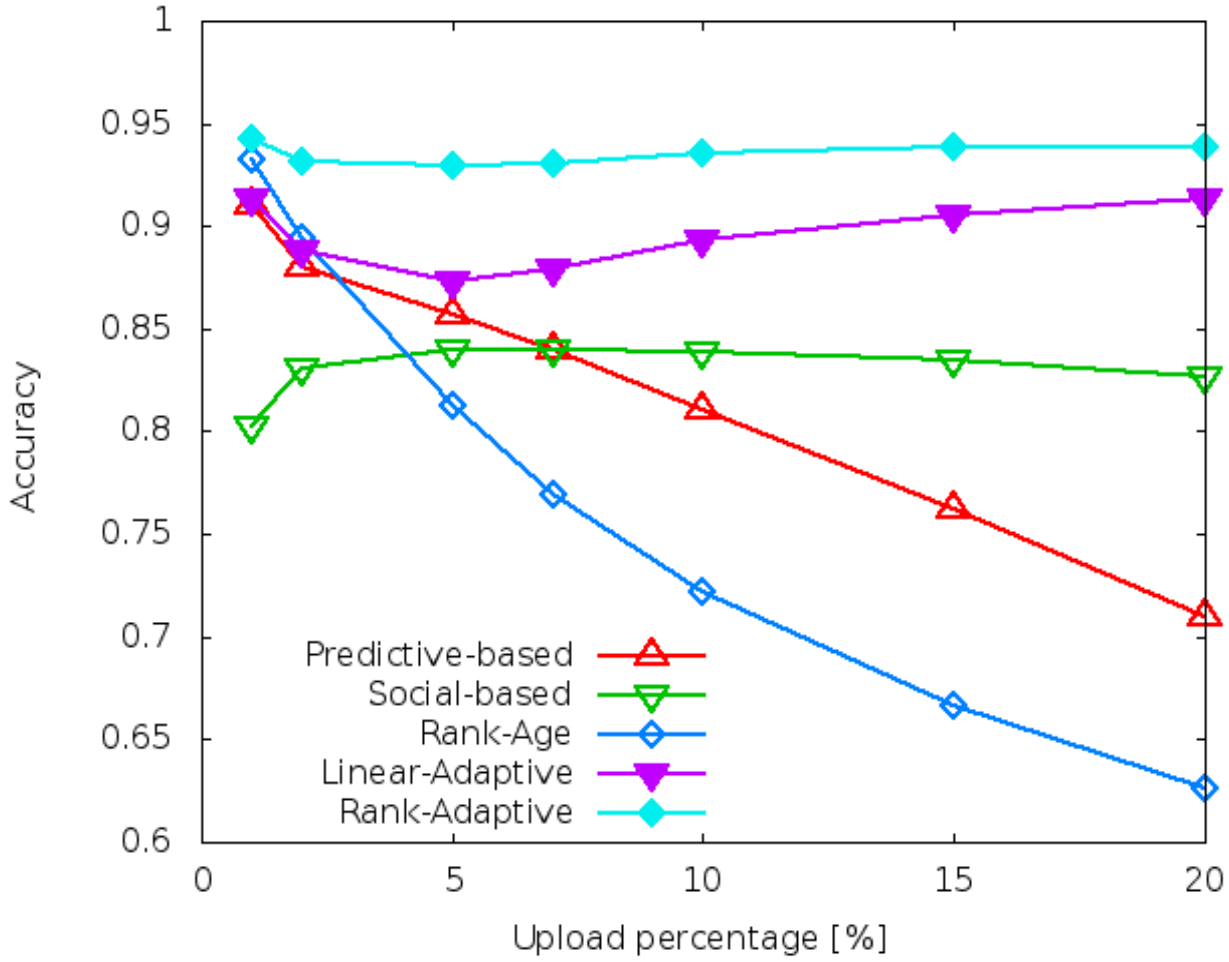
- Predictive and social-aware algorithms can be improved
- Adaptive algorithms outperforms other solutions
- Rank-age algorithm provides poor performance because it tends to prefer younger resources even when they are not popular



→ Need to evaluate performance stability

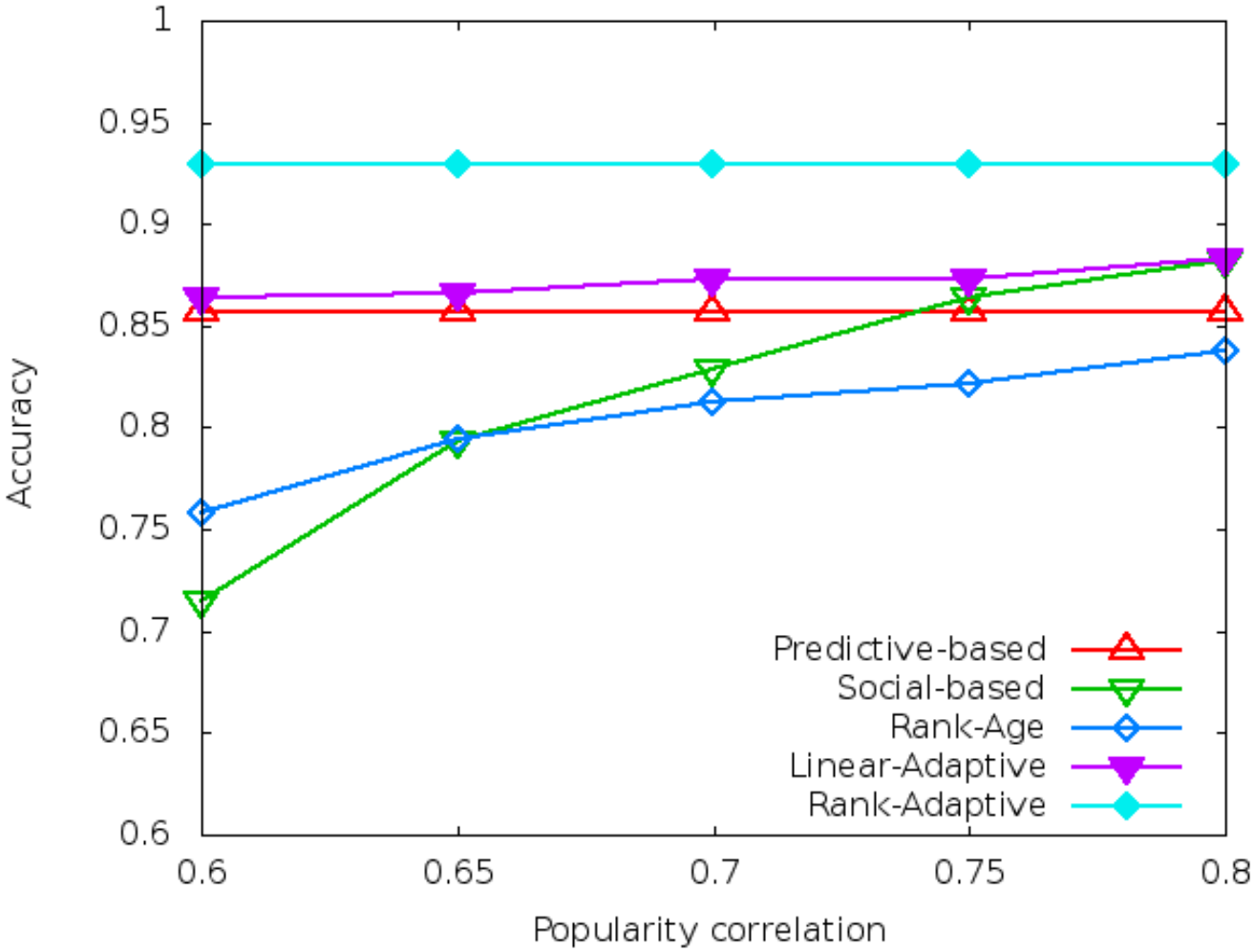
Sensitivity to workload dynamics

- Prediction is highly sensitive to upload percentage
- Social-aware algorithm is not sensitive to workload dynamics
- Rank-age algorithm provides poor performance when many young resources are present
- Adaptive algorithms provide stable performance



Sensitivity to social parameters

- Prediction is not affected by social phenomena
- Social-aware is highly sensitive to the correlation between user and resource popularity
- Rank-age relies on social-aware algorithm and shares its drawback
- Adaptive algorithms provide very stable performance



Conclusions

- **Content management will be fundamental for future social network applications**
  - Need to identify the Hot set
  - Must cope with novel challenges (social interaction, short resource lifespan, ...)
  - Need for high accuracy and stable performance
  - Can rely on heterogeneous information, but we must combine them
- **Proposal of different algorithms that combine heterogeneous information**
  - Adaptive techniques allow to exploit the benefits of predictive and social-aware information
  - Non-adaptive approach result in poor and highly variable performance

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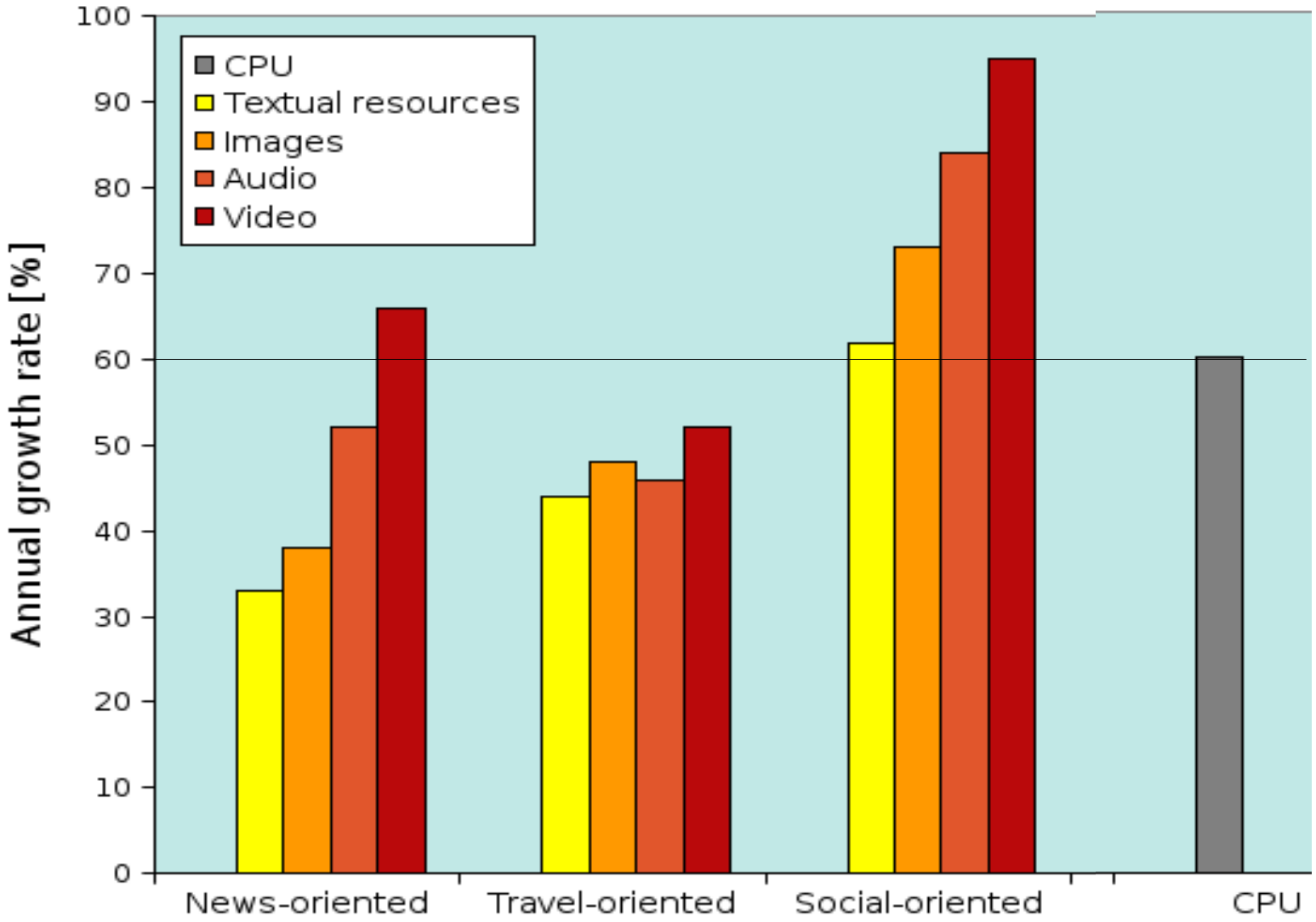
Expected growth of computational demands



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Predictive-Social algorithms

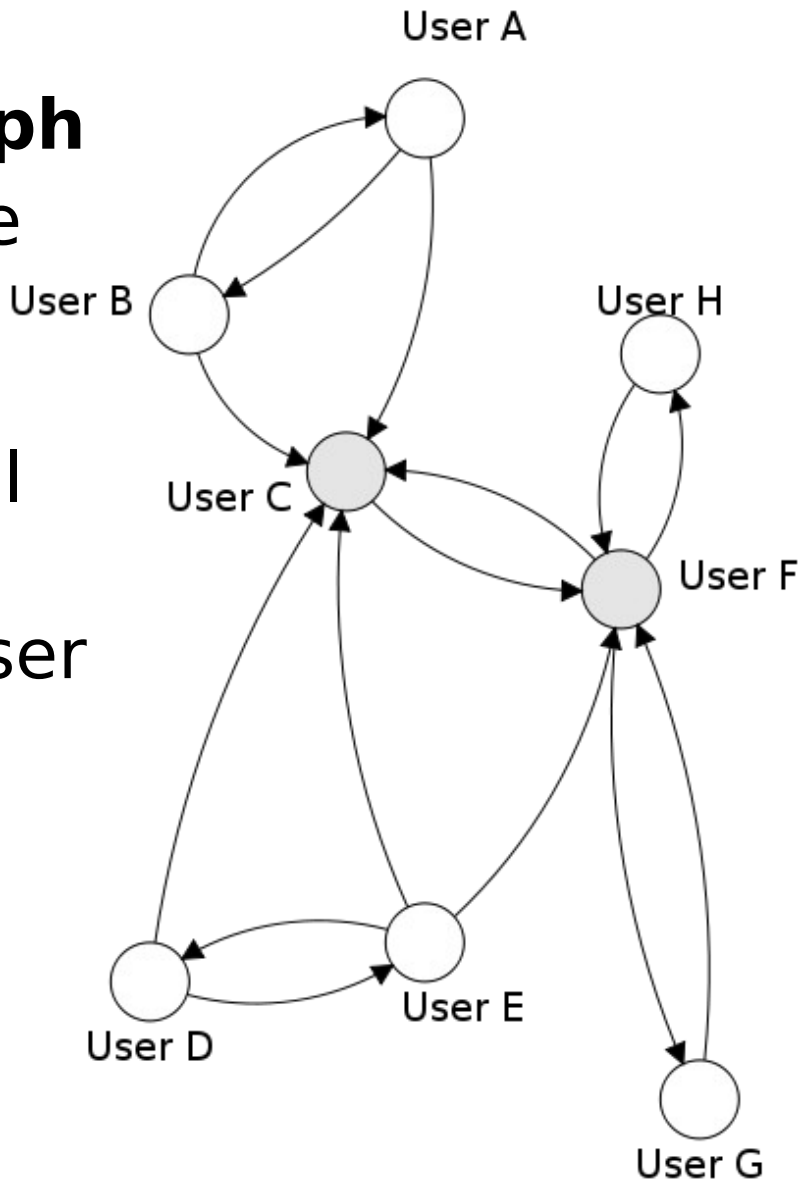
- **Merging social-aware and predictive information**
  - $p_r P(t)$ → predictive
  - $p_r S(t)$ → social
  - $\delta(t)$ → weight
- **That is:**
  - $p_r(t)=\delta(t)\ p_r P(t) + (1-\delta(t))\ p_r S(t)$
  - $\delta(t)=QWM(PS(t))/(QWM(PS(t)) + QWM(PP(t)))$

Predictive algorithms

- **History of past accesses to resource r represented as a time series:**
  - $D_r(t)=\{d_r(t), d_r(t-\Delta t), \ldots, d_r(t-(n-1)\Delta t)\}$
  - $d_r(t)$ is number of accesses to resource r in interval $[t-\Delta t, t]$, $d_r(t-\Delta t)$ refer to $[t-2\Delta t, t-\Delta t]$, ...
- **Use of an EWMA model for prediction:**
  - $d_r^*(t,t+\Delta t)=\gamma d_r^*(t,t+\Delta t)+(1-\gamma)d_r(t)$
  - $\gamma=2/n$, where n is the time series length
- **Other prediction models are possible**

Social-aware algorithms

- **Social network can be represented as a directed graph**
  - Reverse contact represent the popularity of a user within the social network
  - User navigation exploits social links
  - Strong correlation between user popularity and popularity of uploaded resources
  - → Popular users are likely to publish popular content



Predictive-Social algorithms

- **Most innovative class of algorithms**
  - Merges information from two sources:
  - Prediction
  - Social information
- **Need for a reliable way to merge two completely different sets of data**
  - Different value ranges
  - Different probability distributions
- **Use of a robust weighting function**
  - Two-sided quartile weighted median
  - Given distribution P(t):
  - $QWM(P(t))=(Q_{25}(P(t))+2Q_{50}(P(t))+Q_{75}(P(t)))/4$

Red

Green

Black