Peer-to-Peer search and recommendations of scientific literature

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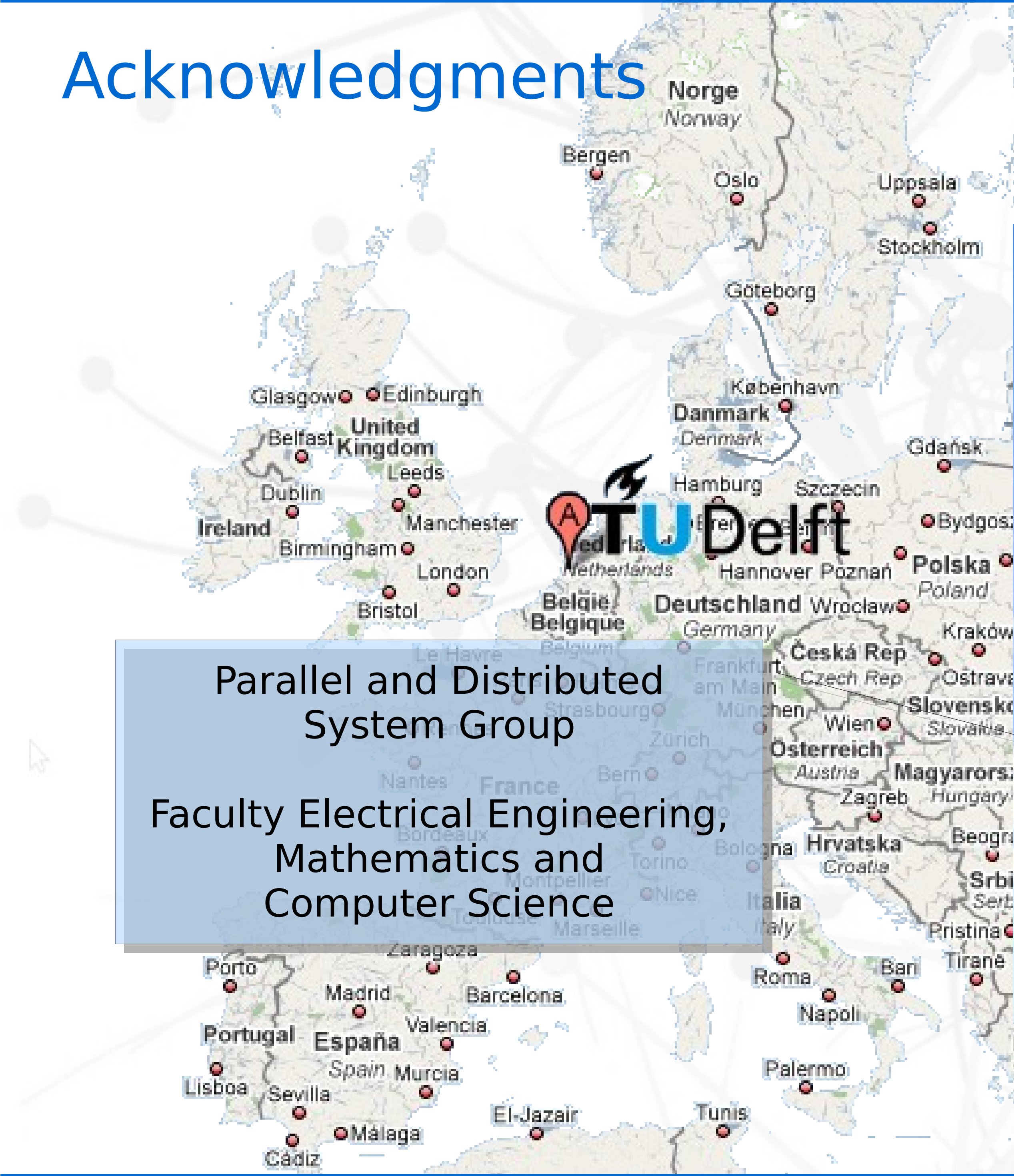
Acknowledgments



Parallel and Distributed System Group

Faculty Electrical Engineering, Mathematics and Computer Science

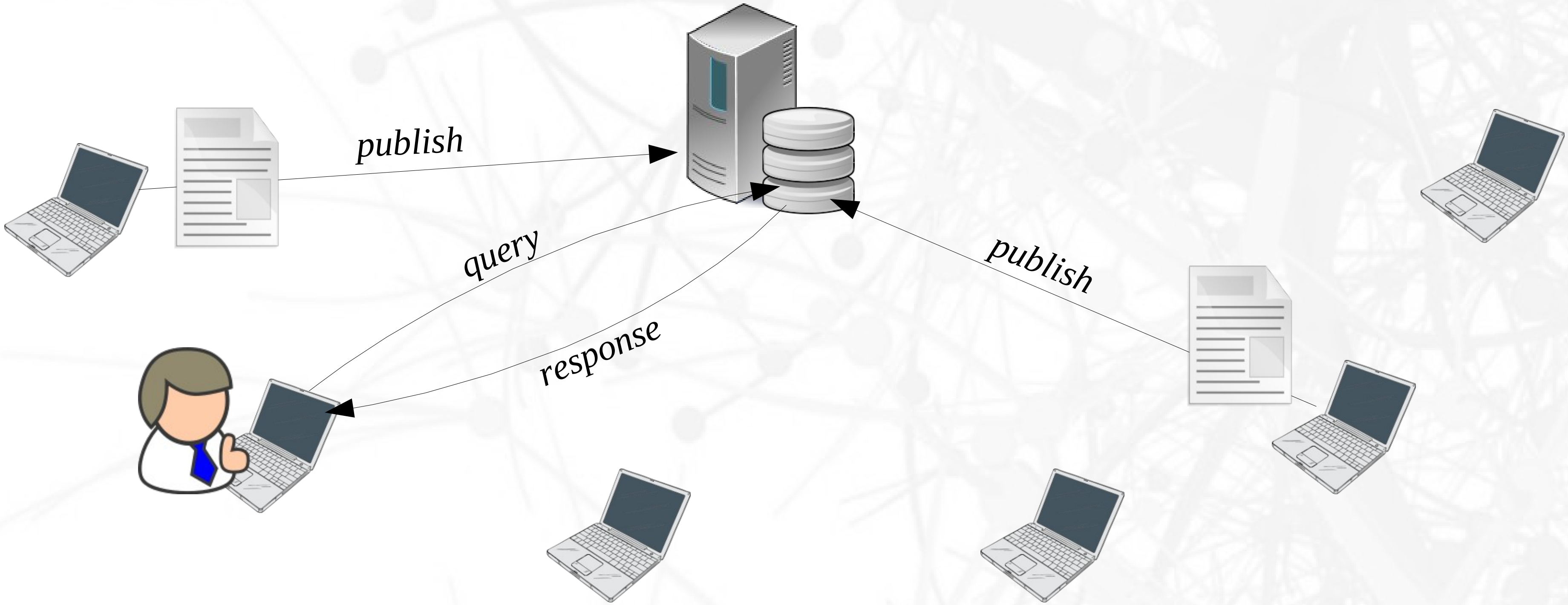
Overview

- Motivation for a fully-decentralized approach to content location
- Approach to proposed solution
  - Underlying idea: exploiting network topology to ease content location
- A fully-decentralized search and recommender system
  - Aggregation of users with similar information needs
  - Search and recommendation service built on top of a social network
- Demo

Motivation

Most of p2p file sharing systems rely on centralized information retrieval service

- Global knowledge of available contents ☺
- High cost (scalability, dependability, maintenance) ☹
- Prone to data exploitation 😐



Objective of this thesis

Goal

Crafting the foundations of a fully-decentralized search and recommender system for text-based documents

Settings

- Highly-populated, highly-dynamic p2p networks
- Contents are provided by peers
- Each node has a partial view of the network
  - Overlay network
- Keyword-based access to information retrieval

Key concern

- Global knowledge of available contents requires high costs ☹

Organizing network topology around data

Semantic proximity of information should be mapped into an overlay network topology in order to ease content location

Underlying idea

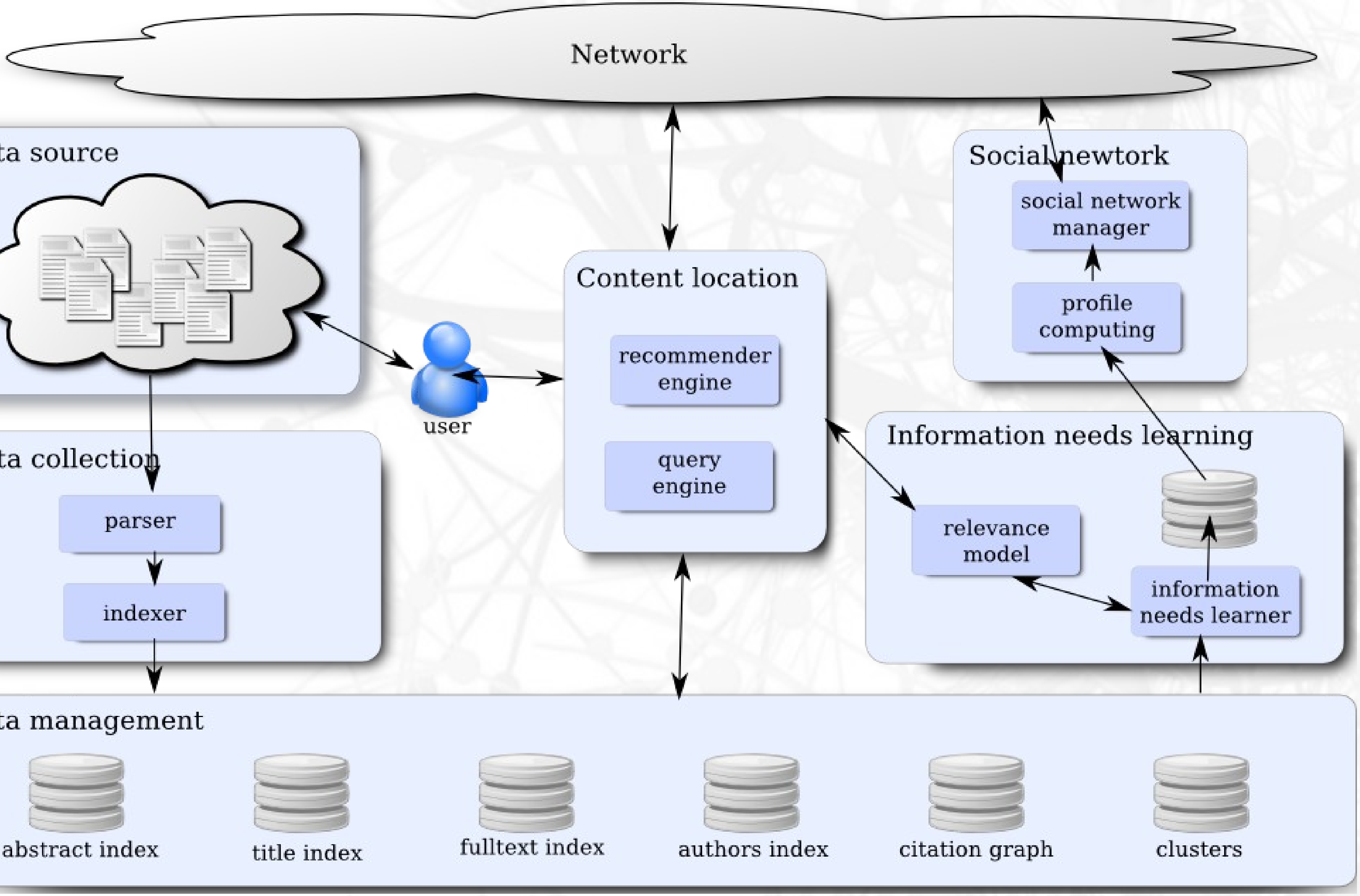
Agents of a population self-organize into a connection topology which reflects similarities between users information needs.

Each user is supported by an agent which learns his information needs

Key concerns

- How to capture user information needs?
  - They are dynamically changing
- How to manage network topology in a decentralized fashion?
  - Low-intrusion principle
  - Fast adaption to dynamics

Agent architecture



Collecting data

Research papers which have been read by user are locally collected

- The agent builds a local database

Which data model should be used?

- a fine-grained model allows better definition of the relevance model ☺
- difficult of extracting structured information from visual layout documents ☹
  - machine learning algorithm as state-of-the-art

✎ proof-of-concepts:

We designed a system which extracts title, abstract, fulltext, citations from pdf scholarly papers

- hybrid approach: rule based parser + machine learning algorithm 😐
  - fast prototyping ☺
  - difficult to adapt to new data ☹

Vector Space Model

An algebraic model for representing text

- A vocabulary of t words is treated as the basis of a $\mathbb{R}^t$ vector space
- Combination of words (i.e. text) is turned into a vector

Semantics of text can be estimated by relying on statistical model of language

Tf-Idf weighting scheme $w_{ij} = \mathrm{tf}_{ij} \cdot \mathrm{idf}_i$

- Term frequency
  - local weight which depends on number of occurrences
- Inverse document frequency
  - global weight: discriminative power within a collection

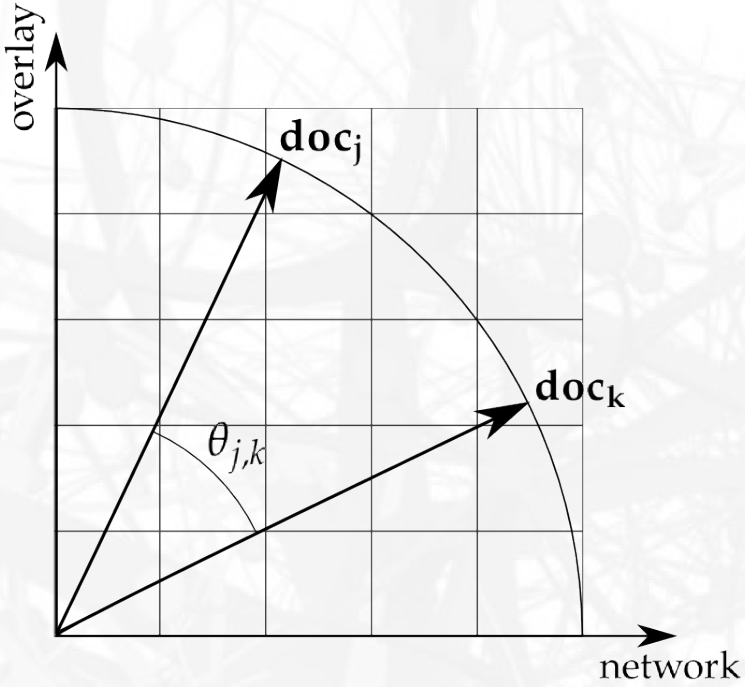
$$\mathbf{A} = \begin{array}{l} \\ \text{content} \\ \text{network} \\ \text{overlay} \\ \text{peer-to-peer} \\ \text{semantic} \end{array} \begin{array}{c} \begin{array}{cccccc} \text{doc}_1 & \text{doc}_2 & \text{doc}_3 & \text{doc}_4 & \text{doc}_5 & \text{doc}_6 \end{array} \\ \left(\begin{array}{cccccc} 0 & 0.807 & 0 & 0 & 0.938 & 0 \\ 0.653 & 0 & 0.610 & 0.863 & 0 & 0 \\ 0.653 & 0.509 & 0.610 & 0 & 0 & 0 \\ 0 & 0 & 0.357 & 0.505 & 0.346 & 0.707 \\ 0.382 & 0.298 & 0.357 & 0 & 0 & 0.707 \end{array} \right) \end{array}$$

Computing similarities

Similarity between documents

Computed as Euclidean distance between corresponding normalized vectors

- Cosine similarity



Criticism

- Document semantics relies on a lexicon based model
  - Inability to deal with natural language ambiguity
  - Latent Semantic Indexing offers a better model of document semantics by performing linear algebraic operations on the Vector Space Model

Learning user information needs

How to learn user information needs?

The agent should learn user information needs by relying on a model which takes into account a number of objective measurements of user interaction with the system:

- Semantics of documents which have been read
- Time spent while reading documents
- Tracking of issued queries
- ...

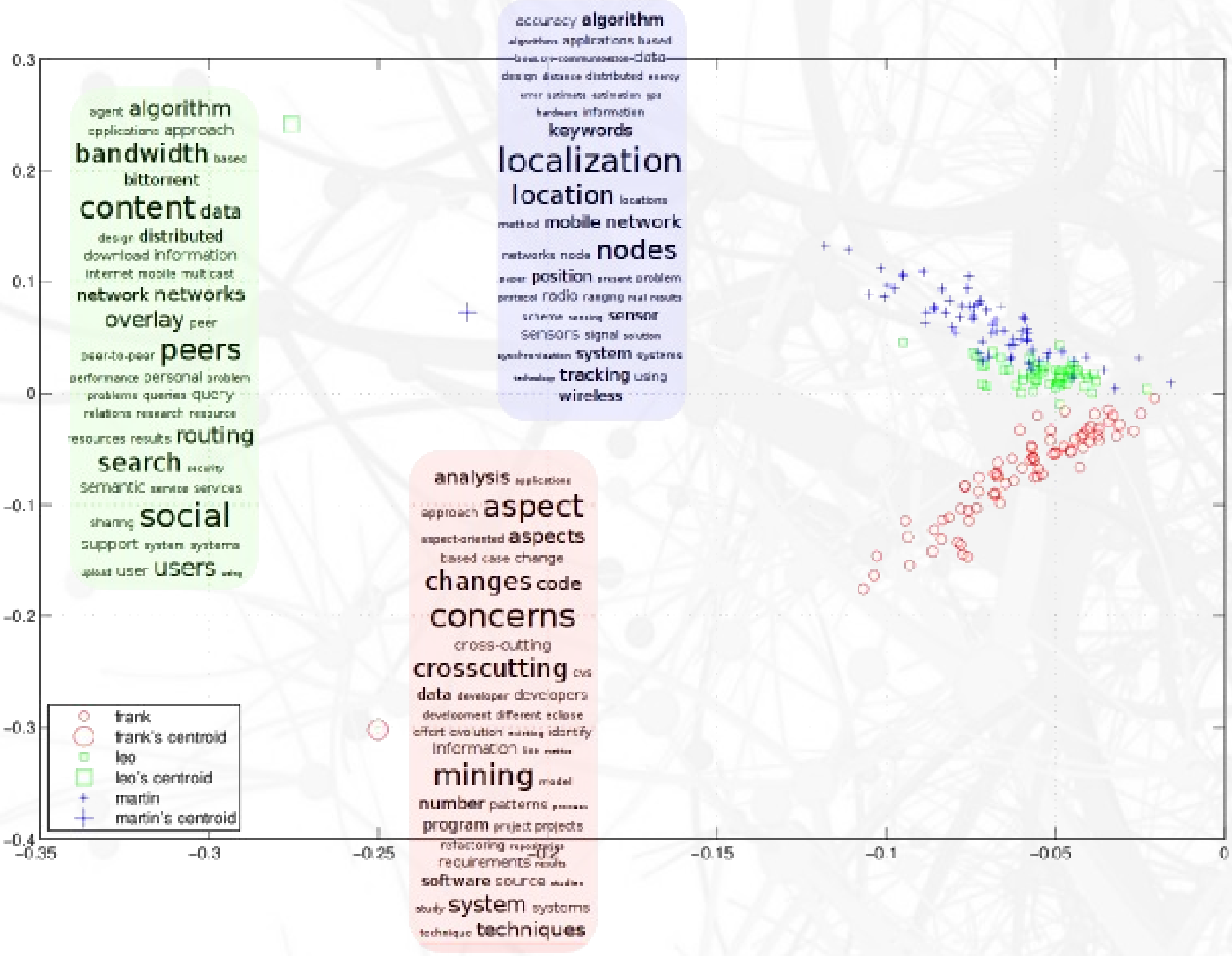
Model should be shaped by relying on a machine learning approach

proof-of-concepts:

We rely just on user's collected documents

- User information needs are estimated with the centroid of document vectors computed according to vector space model

Locality of interests principle



Topology construction problem

Each agent has:

- a profile
- a ranking function which defines an order over nodes profile
- a partial view of size c of the network

Topology management as a membership service middleware

The goal is to build the views of each node such that each view contains the first c elements according to the order defined by the ranking function

How to manage topology in highly-dynamic, highly-populated network with the minimum intrusion and without the need of a global view?

Gossip protocol: probabilistic multicast scheme

- Model to spread information among a large number of processes with dynamic collection topology
- Robust and scalable even in presence of high rate failures ☺

Aggregating users with similar interests

✎ User profile

In order to keep light the protocol we rely upon an approximation of user documents centroid

- we retain just the most 30-weighted terms according to td-idf

✎ Ranking function

Users information needs similarity is computed by cosine similarity between corresponding approximated documents centroids

- Documents centroids must refer to the same basis
  - Terms are spread together with their weights

Social network of researchers

- Agents aggregates users with similar information needs
- Friendships emerge around data

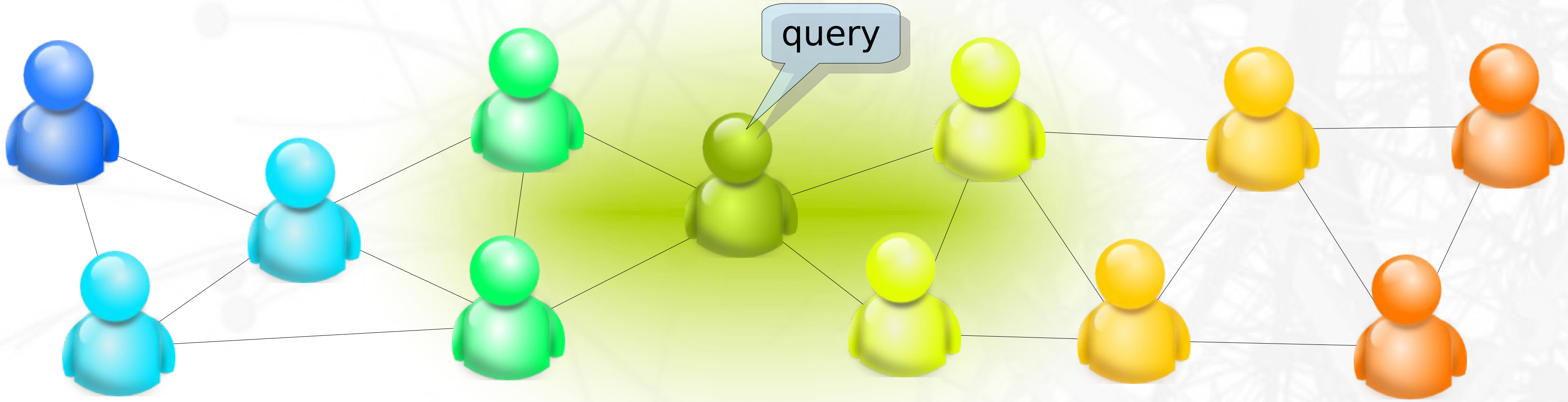
Searching on top of a social network

Network topology facilitates content location

✎ Querying the system

User queries are routed by exploiting the network topology

- Relevant information is expected to be located in the user neighborhood
  - We limit the search radius to the first connection level
- Effectiveness of the model resides in the ability of estimating user information needs and in his locality of interests



Recommendation as collaborative filtering

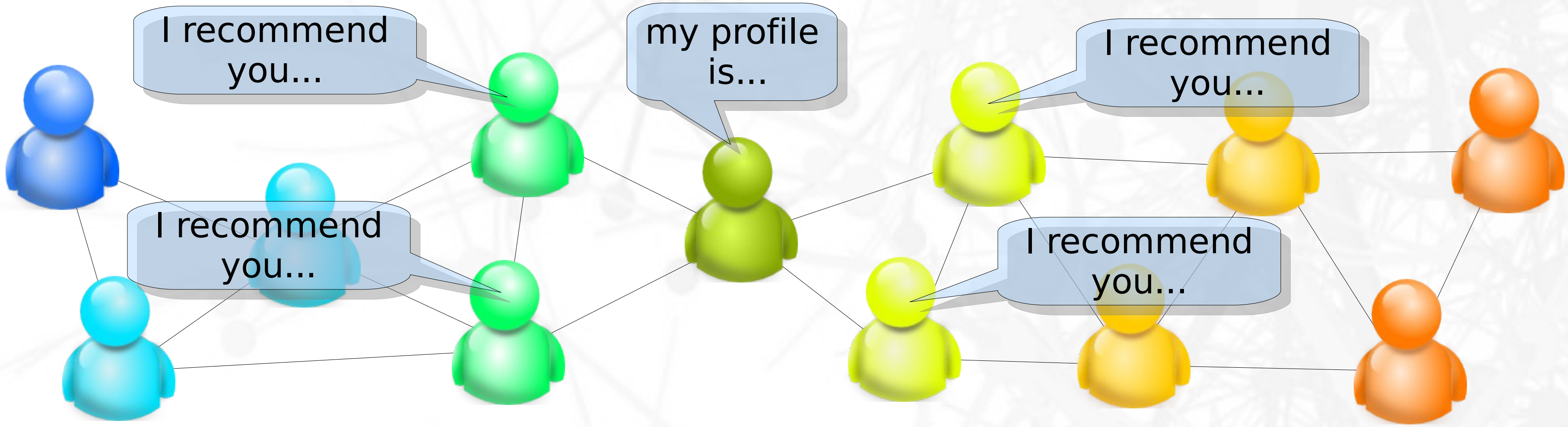
Collaborative filtering

Agents adapt available information to each user information needs

✎ Recommendation model

User's neighborhood recommends their contents which are most similar to user information needs

- We rely on a linear combination of cosine similarity and link analysis



Conclusions

Centralized information retrieval systems requires sizeable capital investments and are prone to data exploitation

Contribution

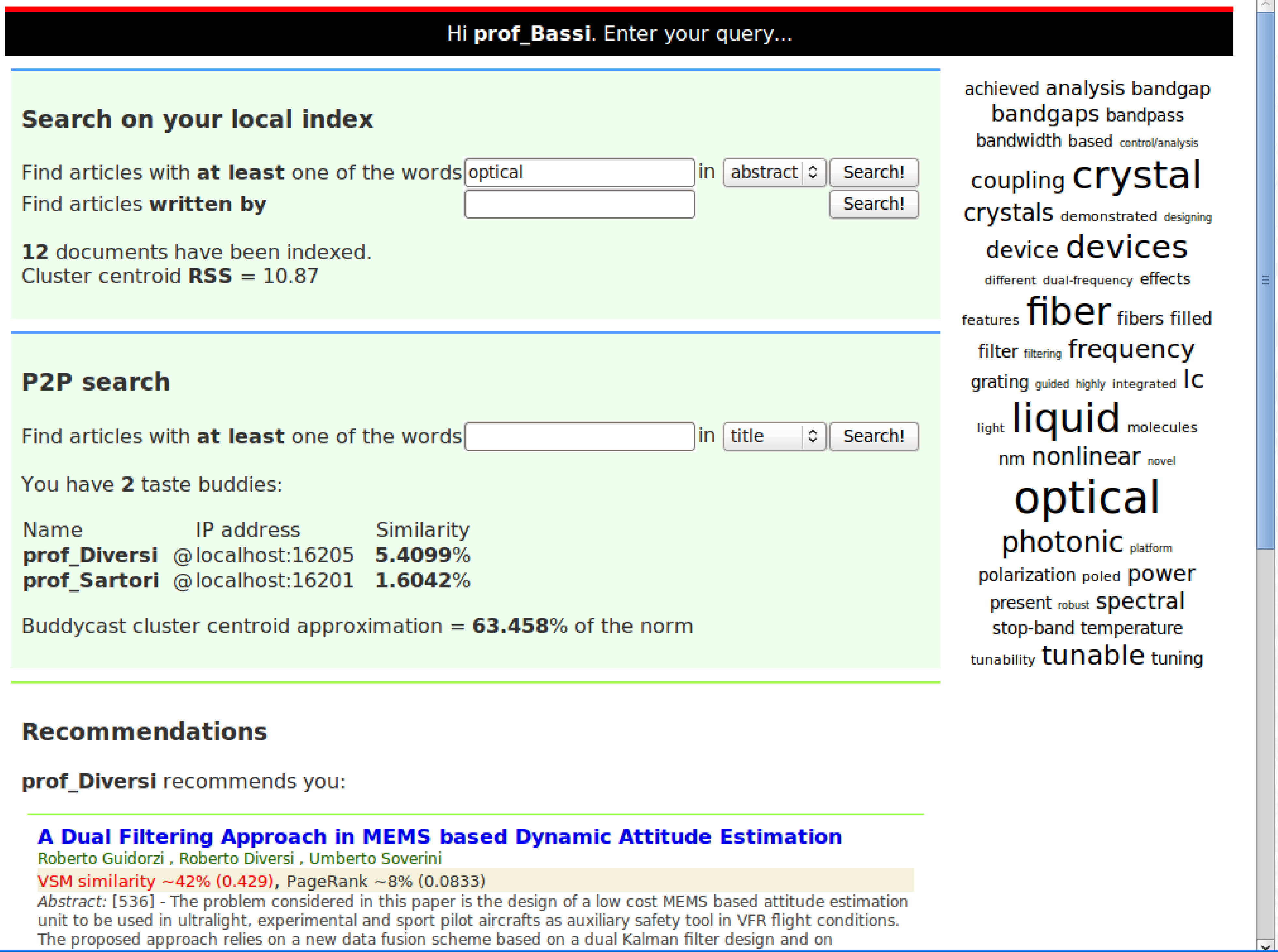
We designed a proof-of-concept prototype of a fully-decentralized search and recommender system for scientific literature

- Search and recommendation as a service developed on top of a proactively managed social network
  - Aggregation of users with similar interests
- user interests are automatically learned by tracking his reading habits

Future work should improve:

- relevance model
- user information needs estimation
- agent profile and ranking function in order to achieve desirable clustering of information

Demo and Question time



Hi **prof_Bassi**. Enter your query...

Search on your local index

Find articles with **at least** one of the words optical in abstract

Find articles **written by**

12 documents have been indexed.
Cluster centroid **RSS** = 10.87

P2P search

Find articles with **at least** one of the words in title

You have **2** taste buddies:

Name	IP address	Similarity
prof_Diversi	@localhost:16205	**5.4099**%
prof_Sartori	@localhost:16201	**1.6042**%

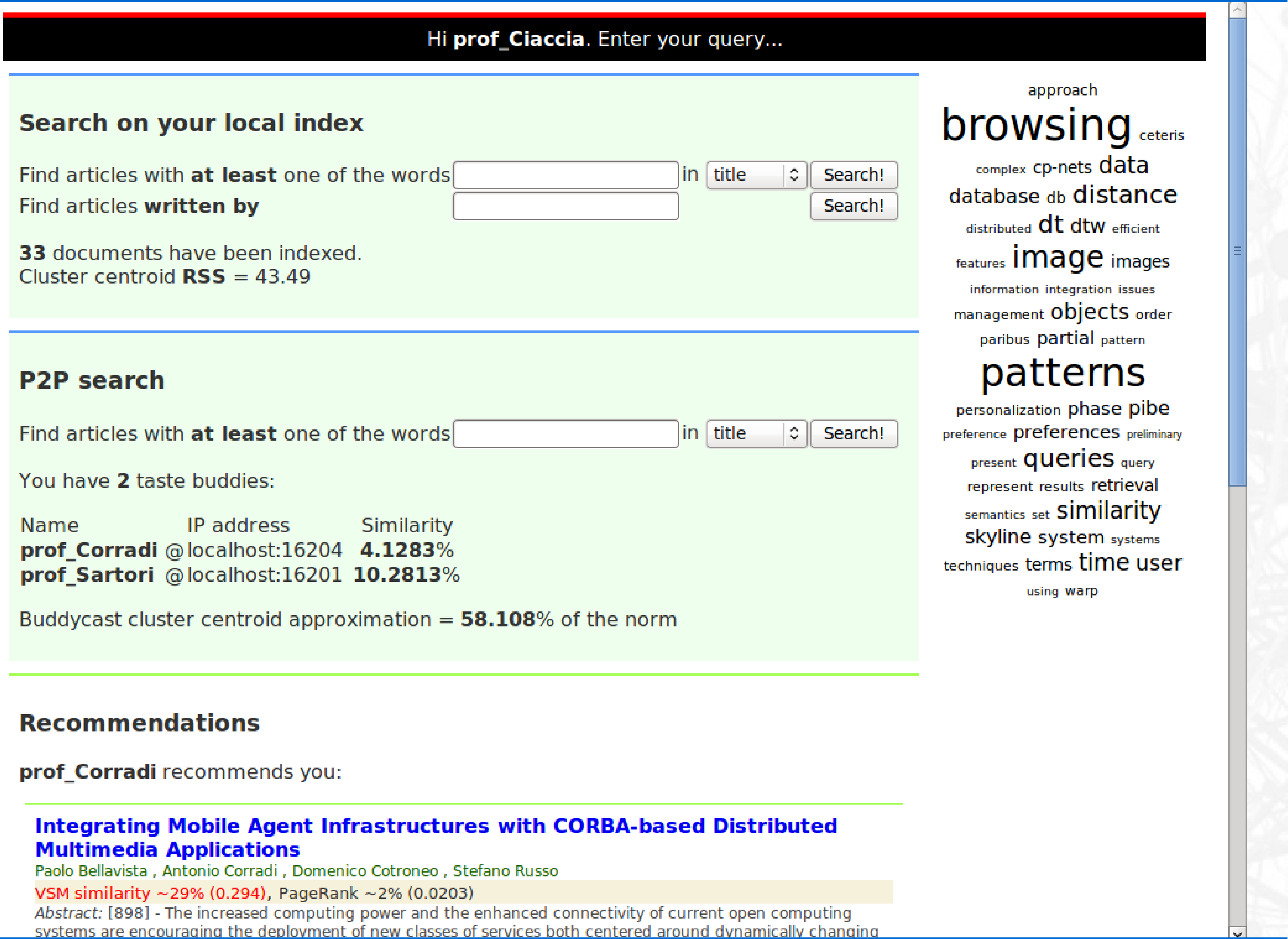
Buddycast cluster centroid approximation = **63.458**% of the norm

Recommendations

prof_Diversi recommends you:

A Dual Filtering Approach in MEMS based Dynamic Attitude Estimation
Roberto Guidorzi , Roberto Diversi , Umberto Soverini
VSM similarity ~42% (0.429), PageRank ~8% (0.0833)
Abstract: [536] - The problem considered in this paper is the design of a low cost MEMS based attitude estimation unit to be used in ultralight, experimental and sport pilot aircrafts as auxiliary safety tool in VFR flight conditions. The proposed approach relies on a new data fusion scheme based on a dual Kalman filter design and on

achieved analysis bandgap
bandgaps bandpass
bandwidth based control/analysis
coupling crystal
crystals demonstrated designing
device devices
different dual-frequency effects
features fiber fibers filled
filter filtering frequency
grating guided highly integrated lc
light liquid molecules
nm nonlinear novel
optical
photonic platform
polarization poled power
present robust spectral
stop-band temperature
tunability tunable tuning



Hi **prof_Ciaccia**. Enter your query...

Search on your local index

Find articles with **at least** one of the words in title Search!

Find articles **written by** Search!

33 documents have been indexed.
Cluster centroid **RSS** = 43.49

P2P search

Find articles with **at least** one of the words in title Search!

You have **2** taste buddies:

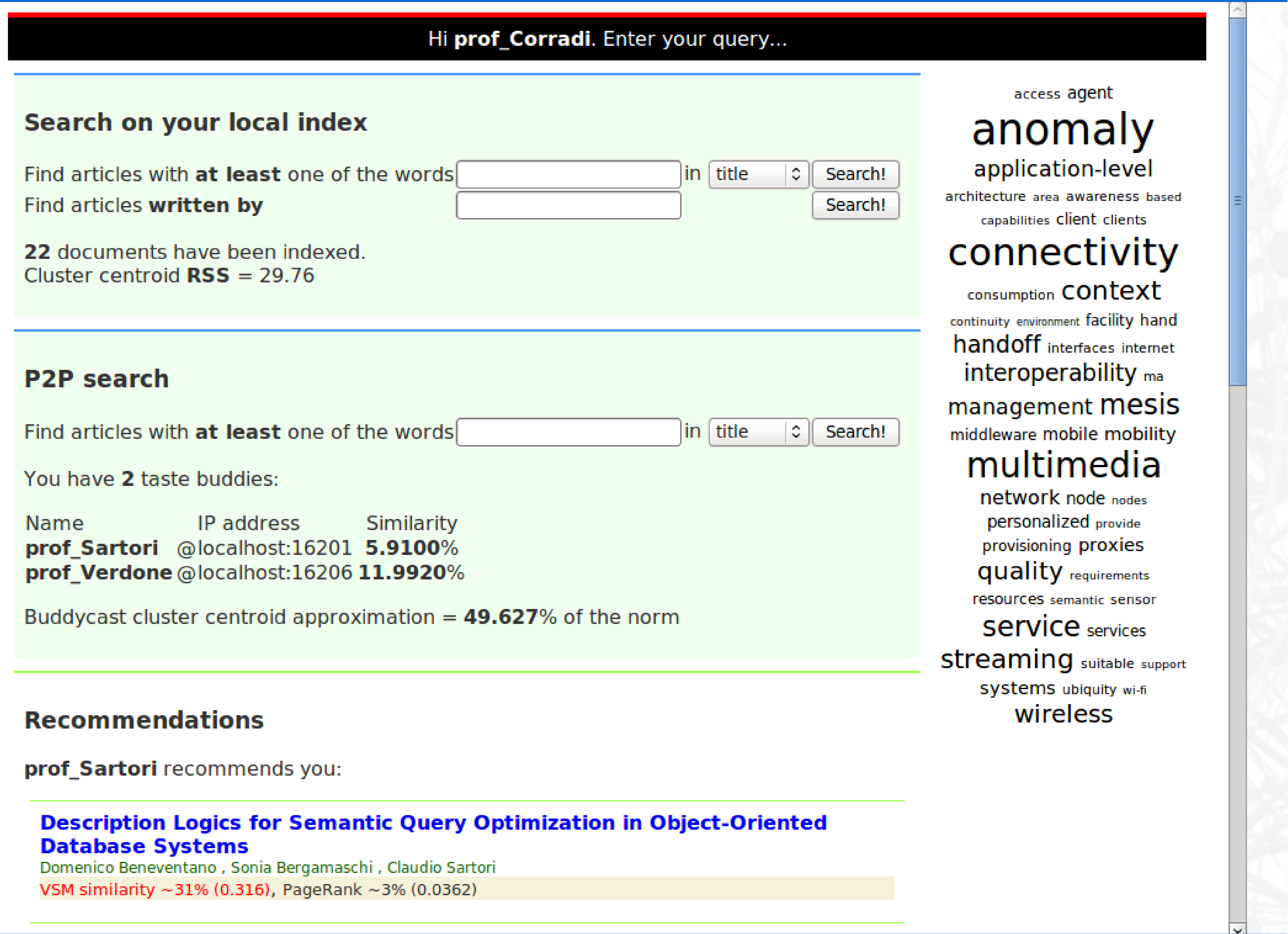
Name	IP address	Similarity
prof_Corradi	@localhost:16204	**4.1283**%
prof_Sartori	@localhost:16201	**10.2813**%

Buddycast cluster centroid approximation = **58.108**% of the norm

Recommendations

prof_Corradi recommends you:

Integrating Mobile Agent Infrastructures with CORBA-based Distributed Multimedia Applications
Paolo Bellavista , Antonio Corradi , Domenico Cotroneo , Stefano Russo
VSM similarity ~29% (0.294), PageRank ~2% (0.0203)
Abstract: [898] - The increased computing power and the enhanced connectivity of current open computing systems are encouraging the deployment of new classes of services both centered around dynamically changing



Hi **prof_Corradi**. Enter your query...

Search on your local index

Find articles with **at least** one of the words [ ] in title [Search!]

Find articles **written by** [ ] [Search!]

22 documents have been indexed.
Cluster centroid **RSS** = 29.76

P2P search

Find articles with **at least** one of the words [ ] in title [Search!]

You have **2** taste buddies:

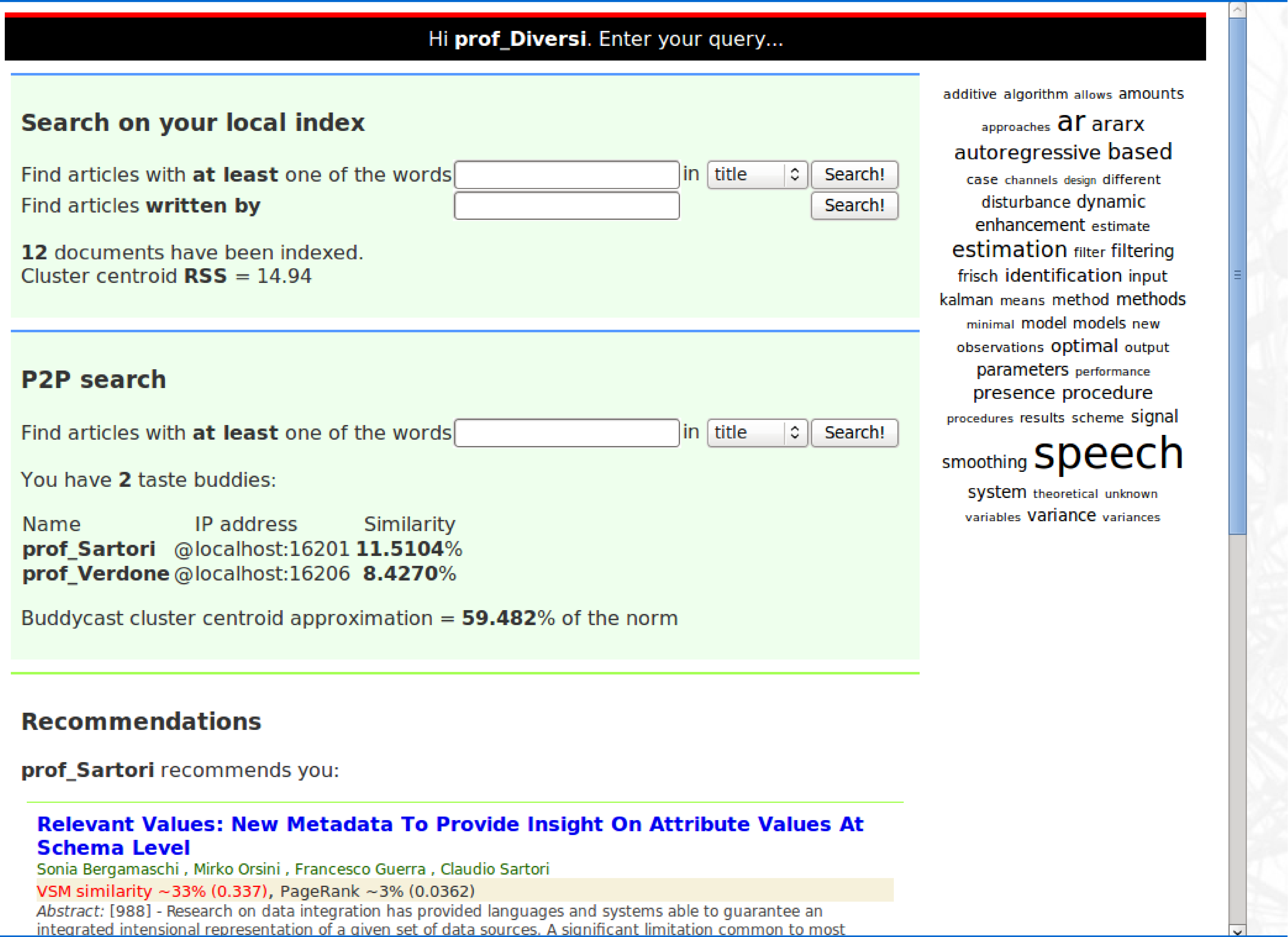
Name	IP address	Similarity
prof_Sartori	@localhost:16201	**5.9100**%
prof_Verdone	@localhost:16206	**11.9920**%

Buddycast cluster centroid approximation = **49.627**% of the norm

Recommendations

prof_Sartori recommends you:

Description Logics for Semantic Query Optimization in Object-Oriented Database Systems
Domenico Beneventano , Sonia Bergamaschi , Claudio Sartori
VSM similarity ~31% (0.316), PageRank ~3% (0.0362)



Hi **prof_Diversi**. Enter your query...

Search on your local index

Find articles with **at least** one of the words in title Search!

Find articles **written by** Search!

12 documents have been indexed.
Cluster centroid **RSS** = 14.94

P2P search

Find articles with **at least** one of the words in title Search!

You have **2** taste buddies:

Name	IP address	Similarity
prof_Sartori	@localhost:16201	**11.5104**%
prof_Verdone	@localhost:16206	**8.4270**%

Buddycast cluster centroid approximation = **59.482**% of the norm

Recommendations

prof_Sartori recommends you:

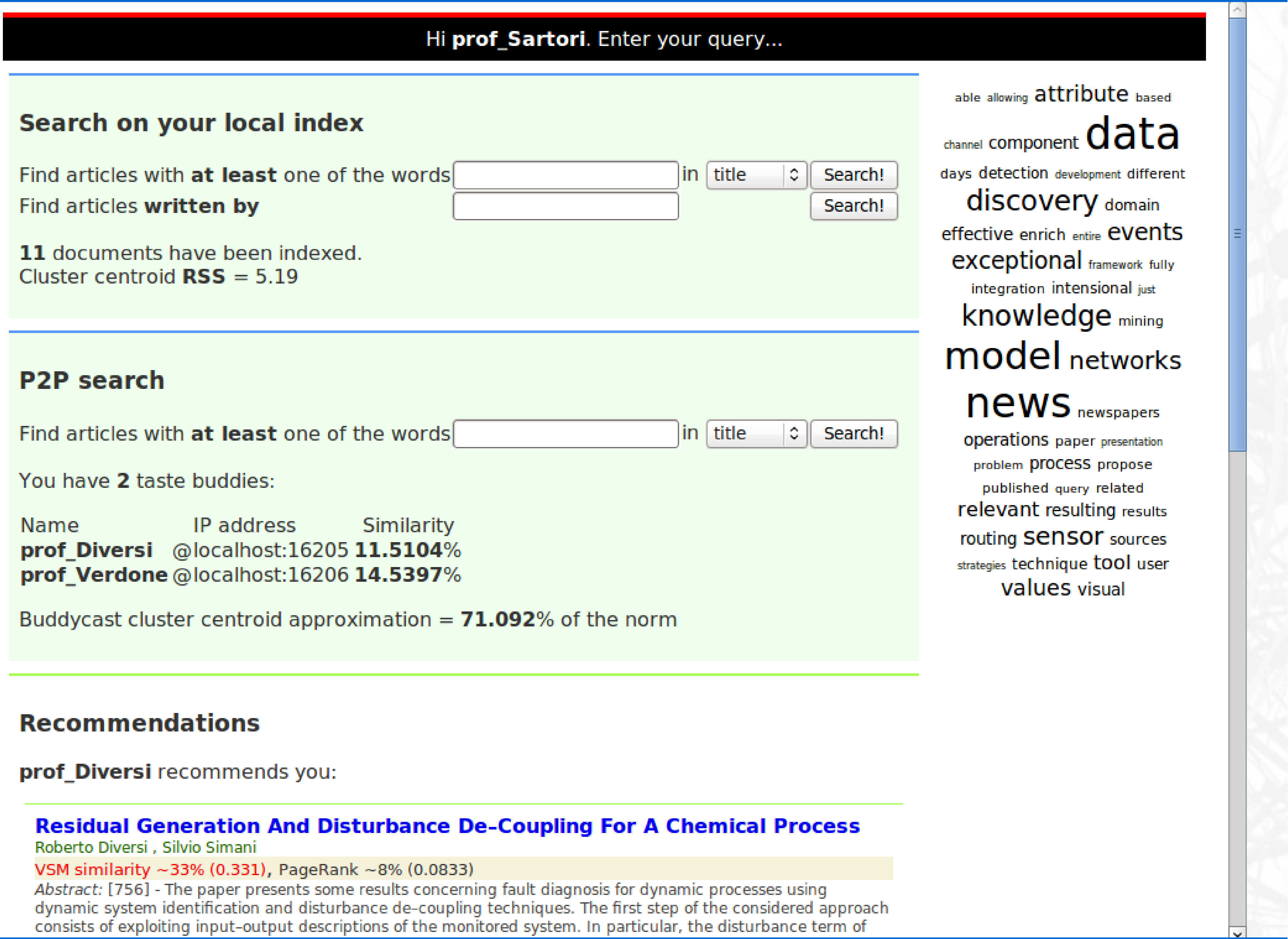
Relevant Values: New Metadata To Provide Insight On Attribute Values At Schema Level

Sonia Bergamaschi , Mirko Orsini , Francesco Guerra , Claudio Sartori

VSM similarity ~33% (0.337), PageRank ~3% (0.0362)

Abstract: [988] - Research on data integration has provided languages and systems able to guarantee an integrated intensional representation of a given set of data sources. A significant limitation common to most

additive algorithm allows amounts approaches ar ararx autoregressive based case channels design different disturbance dynamic enhancement estimate estimation filter filtering frisch identification input kalman means method methods minimal model models new observations optimal output parameters performance presence procedure procedures results scheme signal smoothing speech system theoretical unknown variables variance variances



Hi **prof_Sartori**. Enter your query...

Search on your local index

Find articles with **at least** one of the words ▭ in title ⇕ Search!

Find articles **written by** ▭ Search!

11 documents have been indexed.
Cluster centroid **RSS** = 5.19

P2P search

Find articles with **at least** one of the words ▭ in title ⇕ Search!

You have **2** taste buddies:

Name	IP address	Similarity
prof_Diversi	@localhost:16205	**11.5104**%
prof_Verdone	@localhost:16206	**14.5397**%

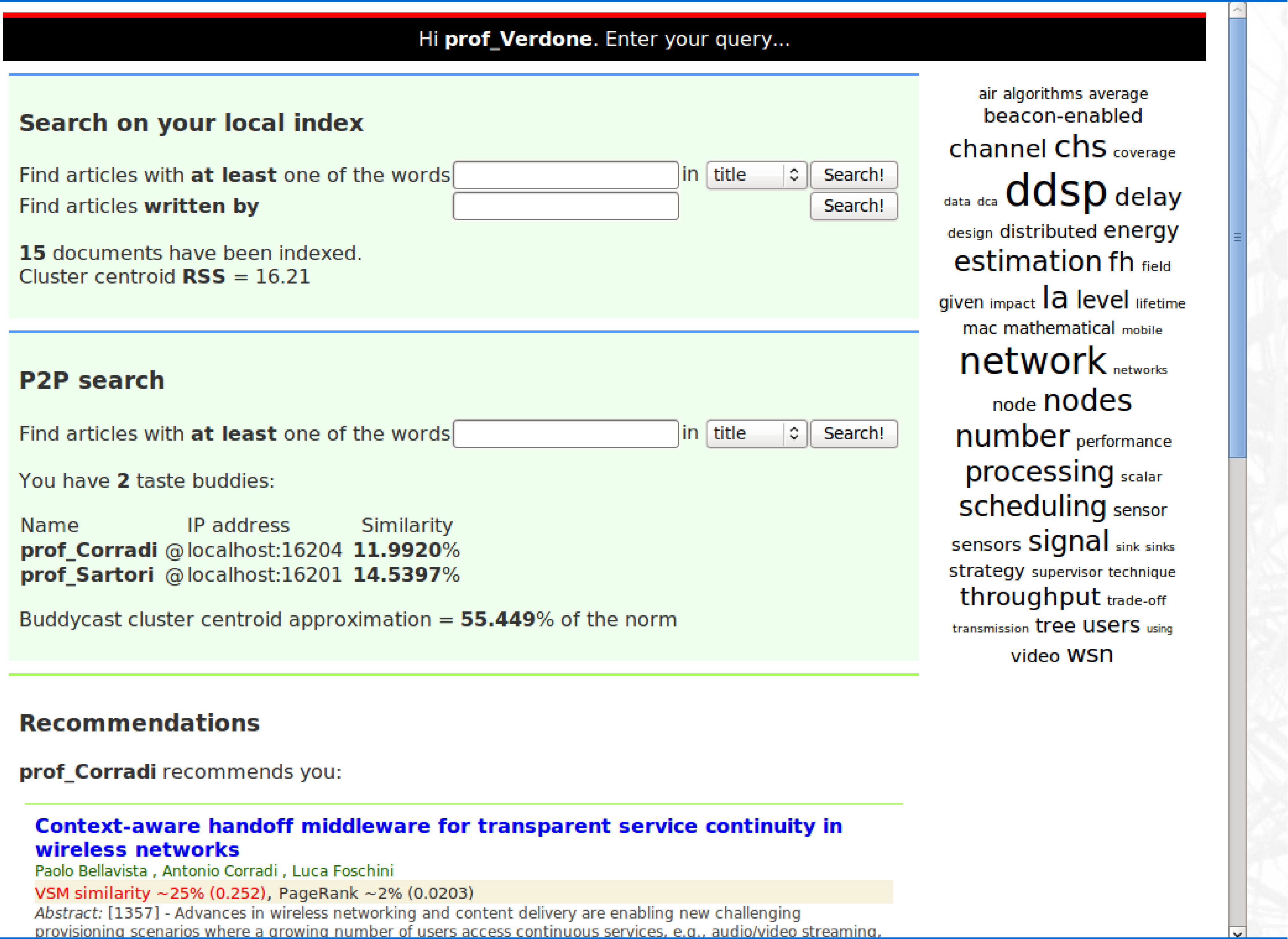
Buddycast cluster centroid approximation = **71.092**% of the norm

Recommendations

prof_Diversi recommends you:

Residual Generation And Disturbance De-Coupling For A Chemical Process
Roberto Diversi , Silvio Simani
VSM similarity ~33% (0.331), PageRank ~8% (0.0833)
Abstract: [756] - The paper presents some results concerning fault diagnosis for dynamic processes using dynamic system identification and disturbance de-coupling techniques. The first step of the considered approach consists of exploiting input-output descriptions of the monitored system. In particular, the disturbance term of

able allowing attribute based
channel component data
days detection development different
discovery domain
effective enrich entire events
exceptional framework fully
integration intensional just
knowledge mining
model networks
news newspapers
operations paper presentation
problem process propose
published query related
relevant resulting results
routing sensor sources
strategies technique tool user
values visual



Hi **prof_Verdone**. Enter your query...

Search on your local index

Find articles with **at least** one of the words in title Search!

Find articles **written by** Search!

15 documents have been indexed.
Cluster centroid **RSS** = 16.21

P2P search

Find articles with **at least** one of the words in title Search!

You have **2** taste buddies:

Name	IP address	Similarity
prof_Corradi	@localhost:16204	**11.9920**%
prof_Sartori	@localhost:16201	**14.5397**%

Buddycast cluster centroid approximation = **55.449**% of the norm

Recommendations

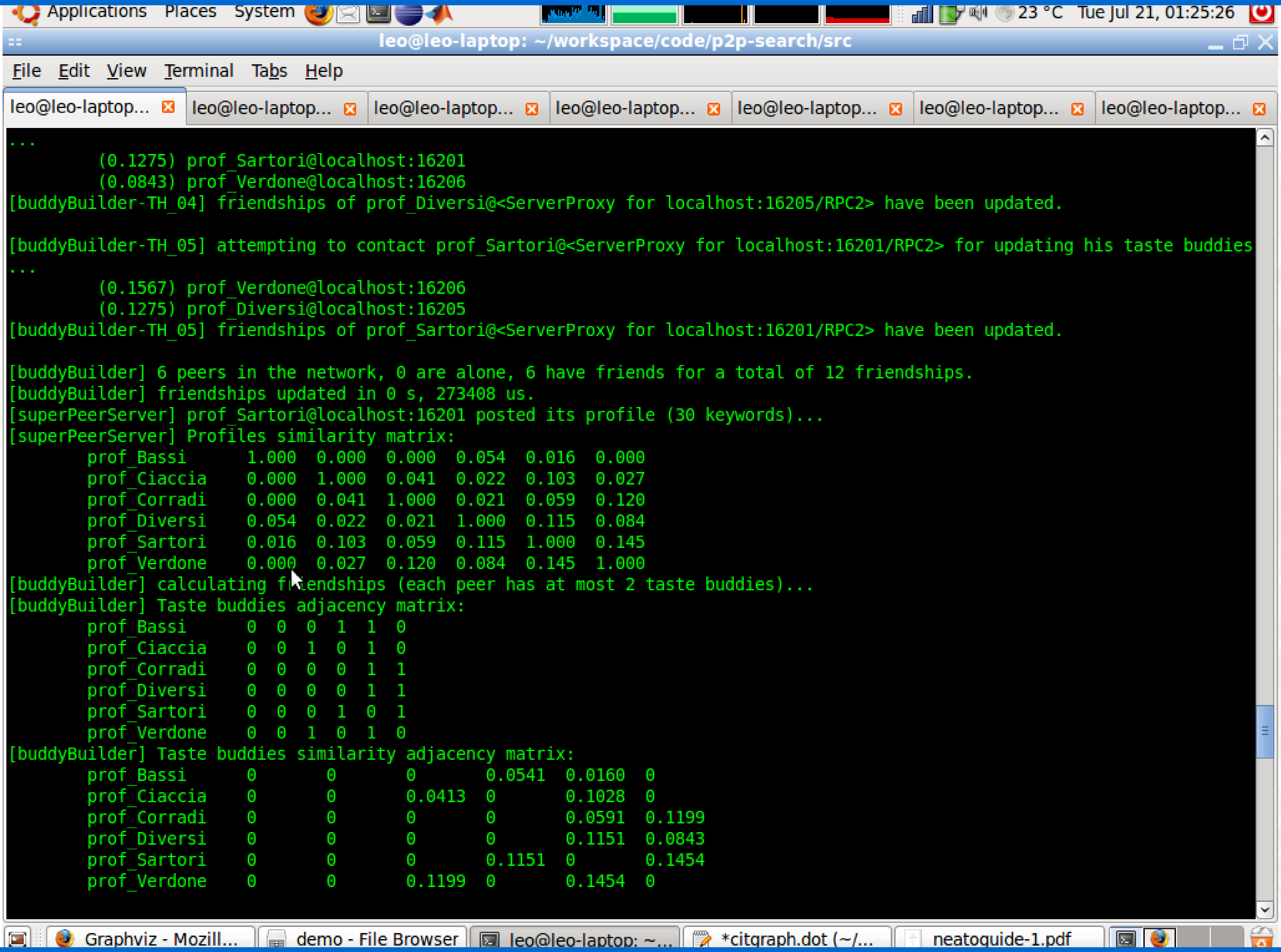
prof_Corradi recommends you:

Context-aware handoff middleware for transparent service continuity in wireless networks

Paolo Bellavista , Antonio Corradi , Luca Foschini

VSM similarity ~25% (0.252), PageRank ~2% (0.0203)

Abstract: [1357] - Advances in wireless networking and content delivery are enabling new challenging provisioning scenarios where a growing number of users access continuous services, e.g., audio/video streaming,



```
...
         (0.1275) prof_Sartori@localhost:16201
         (0.0843) prof_Verdone@localhost:16206
[buddyBuilder-TH_04] friendships of prof_Diversi@<ServerProxy for localhost:16205/RPC2> have been updated.

[buddyBuilder-TH_05] attempting to contact prof_Sartori@<ServerProxy for localhost:16201/RPC2> for updating his taste buddies
...
         (0.1567) prof_Verdone@localhost:16206
         (0.1275) prof_Diversi@localhost:16205
[buddyBuilder-TH_05] friendships of prof_Sartori@<ServerProxy for localhost:16201/RPC2> have been updated.

[buddyBuilder] 6 peers in the network, 0 are alone, 6 have friends for a total of 12 friendships.
[buddyBuilder] friendships updated in 0 s, 273408 us.
[superPeerServer] prof_Sartori@localhost:16201 posted its profile (30 keywords)...
[superPeerServer] Profiles similarity matrix:
        prof_Bassi      1.000  0.000  0.000  0.054  0.016  0.000
        prof_Ciaccia    0.000  1.000  0.041  0.022  0.103  0.027
        prof_Corradi    0.000  0.041  1.000  0.021  0.059  0.120
        prof_Diversi    0.054  0.022  0.021  1.000  0.115  0.084
        prof_Sartori    0.016  0.103  0.059  0.115  1.000  0.145
        prof_Verdone    0.000  0.027  0.120  0.084  0.145  1.000
[buddyBuilder] calculating friendships (each peer has at most 2 taste buddies)...
[buddyBuilder] Taste buddies adjacency matrix:
        prof_Bassi      0  0  0  1  1  0
        prof_Ciaccia    0  0  1  0  1  0
        prof_Corradi    0  0  0  0  1  1
        prof_Diversi    0  0  0  0  1  1
        prof_Sartori    0  0  0  1  0  1
        prof_Verdone    0  0  1  0  1  0
[buddyBuilder] Taste buddies similarity adjacency matrix:
        prof_Bassi      0       0       0       0.0541  0.0160  0
        prof_Ciaccia    0       0       0.0413  0       0.1028  0
        prof_Corradi    0       0       0       0       0.0591  0.1199
        prof_Diversi    0       0       0       0       0.1151  0.0843
        prof_Sartori    0       0       0       0.1151  0       0.1454
        prof_Verdone    0       0       0.1199  0       0.1454  0
```