A Platform for Matching Context in Real Time

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- Context
- Formal Model
- Graph Matching
- Platform
- Experiments
- Conclusions

A Platform for Matching Context in Real Time

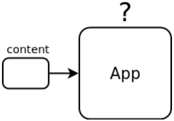
overview

Problem Context

This research is framed by the AmIciTy initiative, with the purpose of creating a software infrastructure for Ambient Intelligence (AmI) applications, that handles context at its constructive level.

[http://aimas.cs.pub.ro/amicity]

application receives message →



Questions asked:

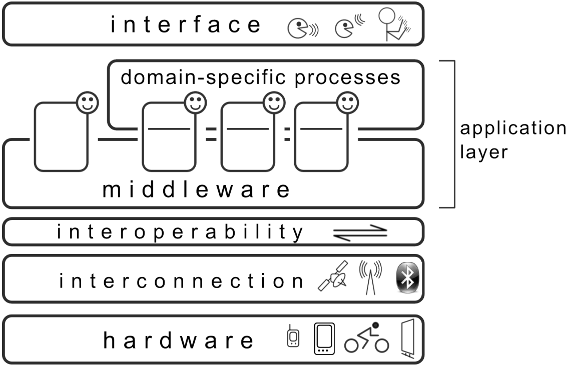
- How to represent message content as context information?
- Is content relevant to the activity of the application?
- How to integrate received content with current knowledge?
- What information should be sent to other applications / users?

How to integrate these processes in an[y] application?

Problem Context

Solution: a multi-agent system that handles context information accross the AmI ecosystem and provides it to applications → works as a context-ware middleware.

[Olaru et al., 2013]



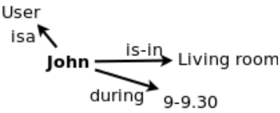
· What representation to use and how to work with it?

Formal Model

- We represent the information about the current situation as a Context Graph (directed graph with labeled nodes and optionally labeled edges), [Olaru et al., 2011]
- known situations as Context Patterns (graphs with some unlabeled nodes),
- and we use context matching (matching a pattern against a graph) to [Olaru et al., 2013]
  - detect whether new information is relevant
  - detect if we are in a known situation and potentially decide upon action to take
  - detect interests of other agents

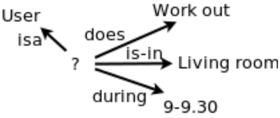
Formal Model

Current situation, as detected by smart bracelet:



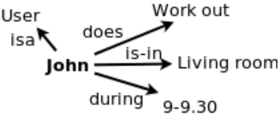
John is in the living room, during the interval $9 - 9^{30}$ (activity is unknown)

Known situation:



users work out in the living room during $9 - 9^{30}$

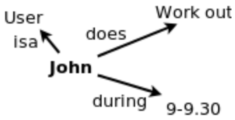
Inference:



John is probably working out

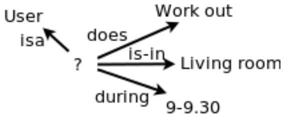
Formal Model

Current situation, as detected by smart bracelet:



John is working out, during the interval $9 - 9^{30}$ (location is unknown)

Known situation:



users work out in the living room during $9 - 9^{30}$

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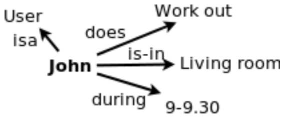


John is probably in the living room

Graph Matching Algorithms

· The problem of graph matching (MCS isomorphism) is NP-complete.

· Algorithms for graph matching normally work on unlabeled, sometimes undirected graphs.

Some examples include:

- Larossa – using CSP solving for exact matching [Larrosa and Valiente, 2002]
- Bron & Kerbosch – using maximal cliques in the modular product of the two graphs [Bron and Kerbosch, 1973]
- Koch – similar, but using the modular product of edge sets [Koch, 2001]

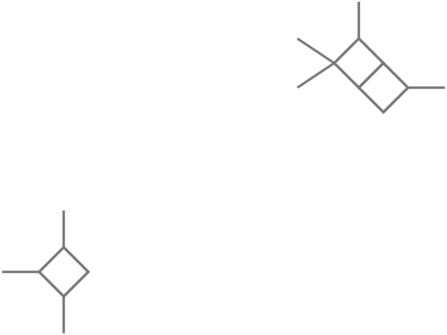
Graph Matching Algorithms

· We have developed the QuickMatcher algorithm in 2013, targeting specifically the problem of context matching. [Olaru, 2013]

- it starts from single-edge matches between the graphs and grows them to reach a maximal match.
- a match has a frontier, immediate merger candidates, and outer merger candidates.
- candidates need only be searched for once; when merging two matches, candidates can be computed through set operations.

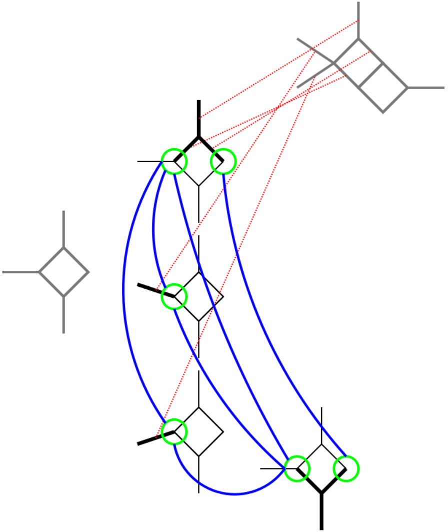
· The algorithm has outperformed classic matching algorithms, after they have been adapted to the context matching problem. [Dobrescu and Olaru, 2013]

Graph Matching Algorithms



graph & pattern

Graph Matching Algorithms



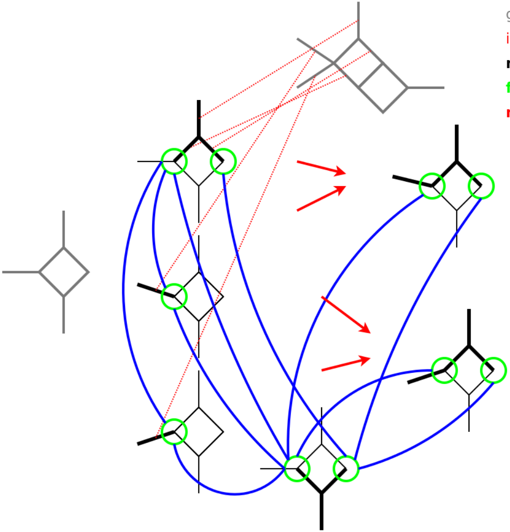
graph & pattern

isomorphism

matched part

frontier

Graph Matching Algorithms



graph & pattern

isomorphism

matched part

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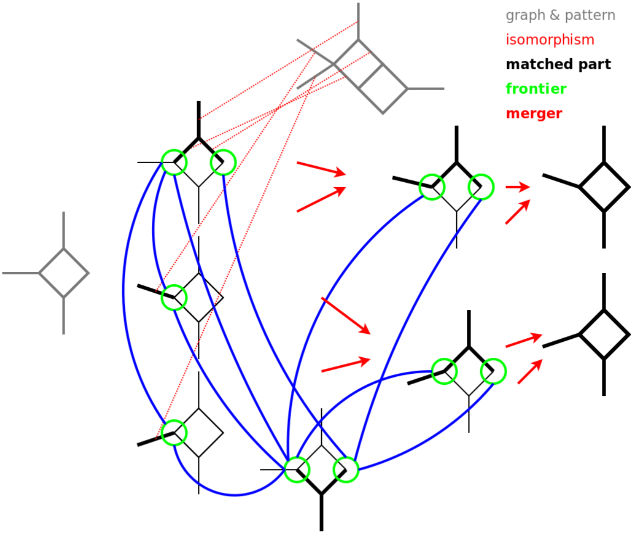
merger

Graph Matching Algorithms



graph & pattern

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CCM Platform

· the Continuous Context Matching Platform

Objective: create a platform for context matching that can be used by an agent that uses one context graph and multiple context patterns

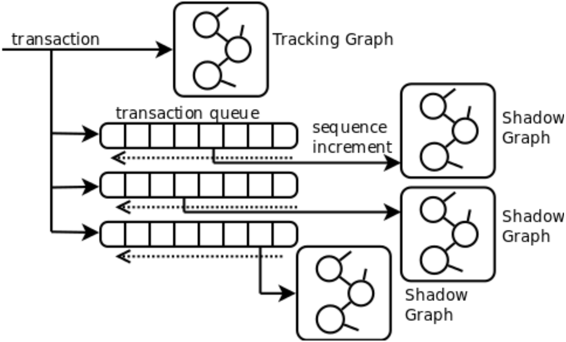
· The context graph changes incrementally, through the addition and removal of edges and nodes.

Challenges:

- don't miss changes while performing the matching
- keep information about the parts of the graph that don't change
- run in the background

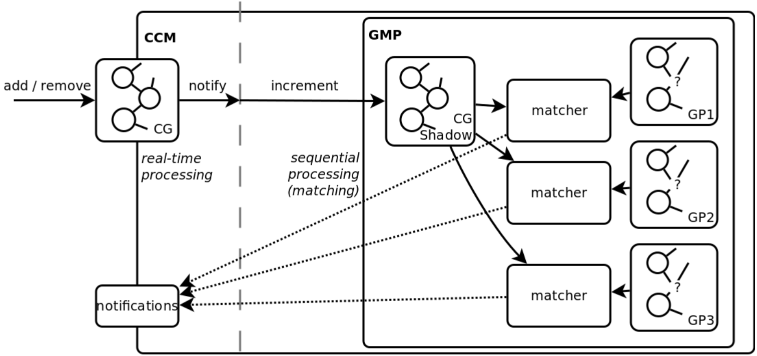
CCM Platform

- transactions as atomic sets of operations (add/remove node/edge)
- a TrackingGraph stores a queue of transactions applied to it
- ShadowGraphs are matched against the patterns, after each transaction is applied



CCM Platform

- the matching process runs in the background
- a shadow graph is used: after each transaction is applied, matching is incremented for each pattern
- notifications are produced when a match with certain parameters is found



CCM Platform

- partial matches are stored, complete with their data → no need to recreate them each time, since patterns modify rarely and the Context Graph is modified incrementally.
- when an edge is removed from the CG → matches containing it are removed.
- when an edge is added to the CG → the new single-edge match (if any) is checked against matches containing neighbor edges.

CCM Platform

· the Continuous Context Matching Platform uses a (tracking) graph and a set of patterns and allows the user to:

- receive a notification whenever a specific pattern is matched.

```
addMatchNotificationTarget(ContextPattern pattern, MatchNotificationReceiver receiver);
```

- receive a notification whenever a match with less than a specific number of missing edges (k threshold) is found.

```
addMatchNotificationTarget(int thresholdK, MatchNotificationReceiver receiver);
```

- start / stop the background matching process.

```
startContinuousMatching(); stopContinuousMatching();
```

- start a persistent background matching process on a specified graph (against the known set of patterns) and receive notifications whenever matches are found.

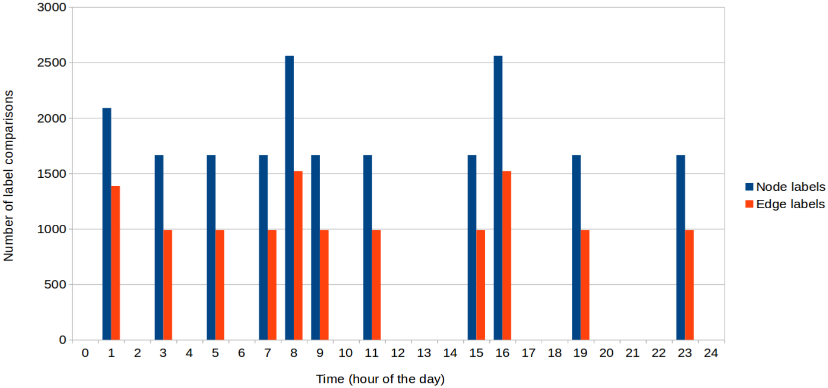
```
startMatchingAgainstAllPatterns(Graph graph, int k, MatchNotificationReceiver receiver);
```

- start a persistent background matching process of the context graph against a specific pattern.

```
startMatchingAgainstGraph(Graph pattern, int k, MatchNotificationReceiver receiver);
```

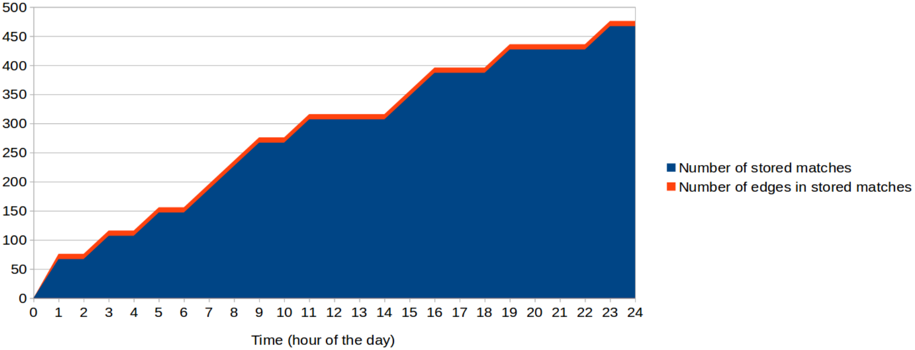
Experimental Results

- experimental setup: 24h-long synthetic scenarios



Label comparisons

Experimental Results



Matches stored in memory

- most matches are single-edge matches.
- in the future, a mechanism will be developed to select which single-edge matches to keep.

Conclusion and Future Work

Done

- built a context-matching platform for matching multiple context patterns against the same context graph.
- the platform can be added as a component that works in the background, tracking all changes and notifying the host applications about matches.

Future work

- optimize memory usage to store less single-edge matches.
- learn patterns of activity → use publicly available datasets.
- create large scenarios with a large number of agents, study performance.
- use the CCM Platform as a component in every agent in an AmI-oriented MAS.

Thank You!

Any Questions?

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