CONTEXT-AWARE PROCESSING OF CONTINUOUS LOCATION-DEPENDENT QUERIES IN INDOOR ENVIRONMENTS

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Talk Outline

1. Research Context
   - Location- and context-aware services and queries in indoor environments
   - Research challenges

2. Methodology & Results
   - Preliminary recommendations
   - A hierarchical and context-dependent indoor data model
   - Continuous query processing architecture
   - Query language for navigation-related queries in indoor environments
   - Continuous processing of location-dependent queries

3. Discussion
   - Implementation Experience
   - Achievements and Status of Research Activities
   - Research perspectives
RESEARCH CONTEXT
- Location- and context-aware services and queries in indoor environments
- Research challenges

METHODOLOGY & RESULTS
- Preliminary recommendations
- A hierarchical and context-dependent indoor data model
- Continuous query processing architecture
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DISCUSSION
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- Research perspectives
CONTEXT CLASSIFICATION

Modelling the notion of context returns to the following questions: *Who is the user? Where is he/she? What resources are nearby? What is his/her purpose?*
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Context-aware indoor navigation services exploit context dimensions in order to

- anticipate user’s needs
- customize the user’s experience

Many components that contribute to the design of a context-aware system should be reflected by the spatial model underneath.
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  ★ anticipate user’s needs
  ★ customize the user’s experience

Many components that contribute to the design of a context-aware system should be reflected by the spatial model underneath

Location-dependent queries (LDQ) comprise requests triggered by the user to “pull” some location-dependent information about objects of interest
  ★ Position queries
  ★ Navigation queries
  ★ Range queries
  ★ K nearest neighbour (kNN) queries
Developing a context-dependent indoor data model that

★ represents the features that populate the environment along with their dynamic properties

★ supports a large spectrum of services and queries (at different levels of abstraction)
RESEARCH CHALLENGES

- Developing a context-dependent indoor data model that
  - represents the features that populate the environment along with their dynamic properties
  - supports a large spectrum of services and queries (at different levels of abstraction)

- Designing a continuous query processing architecture for LDQs in indoor environments
- Introducing a query language to improve expressiveness of navigation-related queries
- Developing algorithms to process continuous navigation, range, and nearest neighbour queries in indoor environments
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Preliminary recommendations

Service-oriented requirements

- Localisation: either geometric or symbolic format, should support hybrid positioning techniques
- Context-aware Adaptive navigation: multi-criteria path selection
- Location-aware communication: quality and format of exchanged data
- Activity-oriented interaction
PRELIMINARY RECOMMENDATIONS

SERVICE-ORIENTED REQUIREMENTS

- Localisation: either geometric or symbolic format, should support hybrid positioning techniques
- Context-aware Adaptive navigation: multi-criteria path selection
- Location-aware communication: quality and format of exchanged data
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EFFICIENCY-RELATED REQUIREMENTS

- Modelling effort: the cost and complexity of building the model
- Flexibility: may a simple unmixed spatial model deal with a very diverse intelligent navigation tasks efficiently?
- Performance and scalability: real time constraints
**Spatial Component**

The spatial component $S = \bigcup_{i=1}^{\mid S \mid} S_i$ is made of a set of layers hierarchically organised and representing the indoor space, and thus defining the multi-granular spatial structure of the model.

**Feature Component**

The feature component $F = \bigcup (P, OOI)$ encompasses the features (i.e., persons and objects of interest) located in the environment.

**Action Component**

The action component $A$ represents actions that are either predefined and triggered automatically by the system in form of informative, context-aware messages, or generated by a given feature acting in the environment.
CONTINUOUS QUERY PROCESSING ARCHITECTURE

SQL-like query

Phase 1: User

Phase 2: System interface

Phase 3: Generating an SQL-like query

Phase 4: Parsing the query

Phase 5: Rewriting and analysing the query

Phase 6: Is route computation required?

Yes

Phase 7: Generating standard queries

Route manager

- Refine candidate routes based on updated edge weights
- Maintain the set of relevant routes up-to-date

Distribution manager

Graph & context data

Cancel?

No

Yes

stop
CONTINUOUS QUERY PROCESSING ARCHITECTURE

ROUTE MANAGER

In charge of determining the best candidate routes for navigation-related queries based on context data (e.g., information about user profiles, descriptions of objects of interest, etc.)

QUERY EXECUTION ENGINE

1. Update simple queries with locations of relevant objects and with the new set of relevant routes, if needed,
2. Execute standard queries,
3. Join the results to standard queries,
4. Present the answer to the user

DISTRIBUTION MANAGER

- Keeping track of the relevant servers needed to execute a given continuous query
- Computing the answer in a distributed environment
QUERY LANGUAGE FOR NAVIGATION-RELATED QUERIES IN INDOOR ENVIRONMENTS

General query structure
Query → (Standard-query | Navigation-query)

Navigation-query → select (Attr-Projections | '*') from All-routes-expression (',Class-names)* (with Stop-vertices) ? (where Conds) ? (optimization-criteria) ?

All-routes-expression → All-routes (Loc-Ref ', Loc-Target ')
Loc-Ref → Object-id ('.',coord') ? | gr ('Map-id ',Object-id ') | gr-map (' Map-id ',' Gr-id ')| Vertex-id
Loc-Target → Class-name | Object-id | Vertex-id '.'coord' | gr ('Map-id ','Class-name ')

Location-dependent conditions
LDQ-Cond → inside (' Args-Inside ') | nearest ('(Args-Nearest ')| ...
Args-Inside → Radius ' ; Loc-Ref ' ; Loc-Target
Args-Nearest → K ' ; Loc-Ref ' ; Loc-Target

Example of a navigation query: Find the shortest route from person ‘userID1’ to person ‘userID2’, showing the results at the room level:

SELECT gr('room-level', RO.id)
FROM Person AS P1, Person AS P2
All-routes(gr('micro', P1), gr('micro', P2)) AS RO
WHERE P1.id = 'userID1'
AND P2.id = 'userID2'
MINIMIZE length(RO)

Example of a range query: Retrieve all the communicating entities in the vicinity (at a distance smaller than 100 meters) of a user identified by ‘userID’ and with a communication range of at least 200 meters:

SELECT CO.id
FROM Object AS CO
WHERE inside(100 meters, gr('micro','userID'), CO)
AND CO.Communicate = true
AND CO.commRange >= 200
QUERY LANGUAGE FOR NAVIGATION-RELATED QUERIES IN INDOOR ENVIRONMENTS

LOCATION-DEPENDENT QUERIES

- **All-routes** *(Loc-Ref, Loc-Target)*: returns a set of tuples representing the valid routes between the current locations of the reference and target objects.

- Two kinds of location-dependent conditions can be expressed in the WHERE clause: *inside(Radius, Loc-Ref, Loc-Target)* and *nearest(K, Loc-Ref, Loc-Target)*

LOCATION GRANULES

- The *gr* operator allows to formulate queries using the location terminology required by the user (e.g., vertices at the fine-grained level, rooms, floors, buildings, etc.).

- It can be referenced in the SELECT clause, the FROM clause and/or the WHERE clause of a query, for visualisation and/or processing of constraints or routes.
CONTINUOUS PROCESSING OF LOCATION-DEPENDENT QUERIES

PROCESSING OF CONTINUOUS NAVIGATION QUERIES

**STEP 1 → STEP 3: HIERARCHICAL PATH SEARCH**

1. Find the optimal path within the initial granule until reaching the nearest exit.
2. Search at the abstract level for the optimal path from the exit of the initial granule to the granule containing the target object.
3. Find the optimal path within the last granule to the target object starting from the corresponding entrance of the granule.
CONTINUOUS PROCESSING OF LOCATION-DEPENDENT QUERIES

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STEP 4 : CONTINUOUS PROCESSING OF THE QUERY

4. Step 4 starts a continuous path search by taking into account updated locations of reference and target objects (considering moving targets)
   1. Transform an initial search tree rooted by the previous $v_{start}$ to an updated tree rooted by the current $v_{start}$
   2. The algorithm continues either by expanding new sub-trees from the leaves towards the target and/or by removing sub-trees that are no longer needed
CONTINUOUS PROCESSING OF LOCATION-DEPENDENT QUERIES

PROCESSING OF CONTINUOUS RANGE QUERIES

1ST ITERATION: HIERARCHICAL NETWORK EXPANSION

1. Perform a *hierarchical* network expansion in all directions around the reference object.

2. Keep all visited nodes along with pointers to their parent nodes as well as weights to the source node.
CONTINUOUS PROCESSING OF LOCATION-DEPENDENT QUERIES

PROCESSING OF CONTINUOUS RANGE QUERIES

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CONTINUOUS PROCESSING OF THE QUERY

3. Update the set of parent nodes when changing the root of the sub-tree (i.e., when the reference object moves)
4. Boundary nodes are checked to decide, for each of them, whether to further expand this node or to perform a reverse search towards the source to remove nodes that are not relevant any more
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IMPLEMENTATION EXPERIENCE

IMPLEMENTATION REQUIREMENTS

- An extensible DBMS that supports
  - developing network-based data models
  - new algebra (i.e., specific data types and operations)
  - implementing algorithms for LDQ processing over moving objects

- Continuous query processing architecture: could integrate a simulator of moving objects

A STAND-ALONE PLATFORM?

- Postgresql (Potential extensions: PgRouting, TelegraphCQ)
- Operators and location-dependent constraints are implemented as pl/pgsql functions applied on user-defined types
- A potential use of TelegraphCQ extension is expected for expressing continuous queries over spatial streams
CONTRIBUTIONS OF THE THESIS

- A hierarchical and context-dependent indoor data model
- A generic architecture to process continuous location-dependent queries in indoor environments
- A continuous indoor-based query language for location-dependent queries
- Hierarchical and incremental algorithms applied to both static and moving objects are proposed for continuous navigation and range queries
ACHIEVEMENTS AND STATUS OF RESEARCH ACTIVITIES

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COLLABORATIONS

- A fruitful collaboration with Dr. Ilarri from University of Zaragoza, Spain, within the context of the MOVE COST Action IC0903
- Participating in the PHC Pavle Savic 2012 : CG&GIS Lab from University of Nis - Naval Academy Research Institute (IRENAV)
**RESEARCH PERSPECTIVES**

**CURRENT AND FURTHER WORKS**

- Analysing the efficiency and scalability of the solutions proposed to deal with continuous location-dependent queries
- Developing a complete context model by integrating user activities as well as user-generated contents into query processing
- Generalising the hierarchical data model to higher levels of abstraction (floor and building levels)
Context-aware modelling of continuous location-dependent queries in indoor environments.
Journal of Ambient Intelligence and Smart Environments (JAISE, Impact factor: 1.5), accepted, pages 1–22, 2012.

Spatial models for indoor and context-aware navigation systems: A survey.

Un modèle de données pour les requêtes sensibles au contexte dans les environnements “indoor”.

A fine-grained context-dependent model for indoor spaces.
Thank you very much for your attention!
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