



MoViSys – A Visualization System for Geo-Referenced Information on Mobile Devices

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Outline

- Motivation
- Objectives
- Visualization issues
- Query specification interface
- MoViSys prototype

Motivation

- Increasing use of mobile devices and improvements in its capabilities
- Several limitations, like screen size or interaction methods



Visualization applications for mobile devices have to adopt

- efficient mechanisms to select the relevant information
- appropriate interactive interfaces that integrate context information and user preferences

Objectives

Develop a visualization system for geo-referenced data organized in categories with multiples attributes that includes

- Filtering mechanisms to control the number of data elements displayed
- Selection of the adequate symbol
- Adaptive interface for user query specification

Visualization Issues

The visualization of query results is done using icons superimposed on a map to represent the data elements that satisfy the query

To obtain intelligible images we need to

- Limit the number of icons displayed
- Select appropriate symbols to convey the information

Visualization Issues

The number of icons displayed is reduced combining

- Filtering mechanisms based on degree of interest functions to omit less relevant data elements
- Aggregation of elements to group results geographically close

Degree of Interest Function

- The concept of degree of interest function was introduced by Furnas, 1986
- Other authors, like Reichenbacher, Keim et al., defined functions with the same goal



Quantify the importance of a given data element

Degree of Interest Function

- The Degree of Interest Function of a given point of interest (POI)

$$DoI(p_j) = \frac{\sum_{i=1}^k UI(a_i, p_{ji})}{k} \in [0,1]$$

Where

a_i specific values of $i=1, 2,..k$ different attributes selected by the user

p_{ji} value of the attribute i at the given POI

Degree of Interest Function

- For each selected attribute,
an user's interest function is calculated for the given POI:

$$UI(a_i, p_{ji}) = 1 - Dist(a_i, p_{ji}) \times w_i, \quad w_i \in [0,1]$$

where

a_i is a target value for the attribute

p_{ji} the value of the attribute i for POI p_j

w_i weight factor of the attribute i

- The interest decreases as distance increases
- The weight factor specifies how important the attribute is in a query

Degree of Interest Function

Distance function

- For an attribute of nominal type

$$Dist(a_i, p_{ji}) = \begin{cases} 0, & \text{if } a_i = p_{ji} \\ 1, & \text{if } a_i \neq p_{ji} \end{cases}$$

- For an attribute of numerical type

$$Dist(a_i, p_{ji}) = \left| \frac{a_i - p_{ji}}{\max_i - \min_i} \right|$$

- For a geographical location

$$Dist(a_i, p_{ji}) = \sqrt{\left(\frac{x_a - x_{p_i}}{\max_x - \min_x} \right)^2 + \left(\frac{y_a - y_{p_i}}{\max_y - \min_y} \right)^2}$$

Extended Degree of Interest Function

- To allow different weights for different categories

$$DoI(p_j) = \frac{\sum_{i=1}^k UI(a_i, p_{ji})}{k} \times w_{cat} \in [0,1]$$

where

w_{cat} is the weight selected for the category of the given POI

Extended Degree of Interest Function

To allow the selection of **multiple values** or a **range of values** for an **attribute**

- nominal type
$$Dist(a_i, p_{ji}) = \begin{cases} 0, & \text{if } a_{i1} = p_{ji} \vee a_{i2} = p_{ji} \vee \dots \vee a_{il} = p_{ji} \\ 1, & \text{if } a_{i1} \neq p_{ji} \wedge a_{i2} \neq p_{ji} \wedge \dots \wedge a_{il} \neq p_{ji} \end{cases}$$
- numerical type
$$Dist(a_i, p_{ji}) = \min \left\{ \left| \frac{a_{i1} - p_{ji}}{\max_i - \min_i} \right|, \left| \frac{a_{i2} - p_{ji}}{\max_i - \min_i} \right|, \dots, \left| \frac{a_{il} - p_{ji}}{\max_i - \min_i} \right| \right\}$$
- numerical type with a range of values
$$Dist(a_i, p_{ji}) = \begin{cases} 0, & \text{if } a_{i1} \leq p_{ji} \leq a_{i2} \\ \left| \frac{a_{i1} - p_{ji}}{\max_i - \min_i} \right|, & \text{if } p_{ji} < a_{i1} \\ \left| \frac{a_{i2} - p_{ji}}{\max_i - \min_i} \right|, & \text{if } p_{ji} > a_{i2} \end{cases}$$

Filtering with the Degree of Interest Function

- DoI function quantifies the relevance of each POI
- If a predefined number of icons are allowed only the POI with higher degree of interest are displayed



Less relevant POI are omitted

Aggregation

- Even if we limit the number of icons displayed, they can overlap each other
- We use an aggregation symbol to replace overlapping icons
- A regular grid is used to decide whether to aggregate icons and which icons should be combined

Aggregation

- A regular grid is superimposed on the visualization area
- If the number of results in a certain cell exceeds a default number an aggregation is made
- To avoid visual discontinuity in pan operations the grid is associated with the visible area in user's coordinates

Aggregation

Grid superimposed on the map



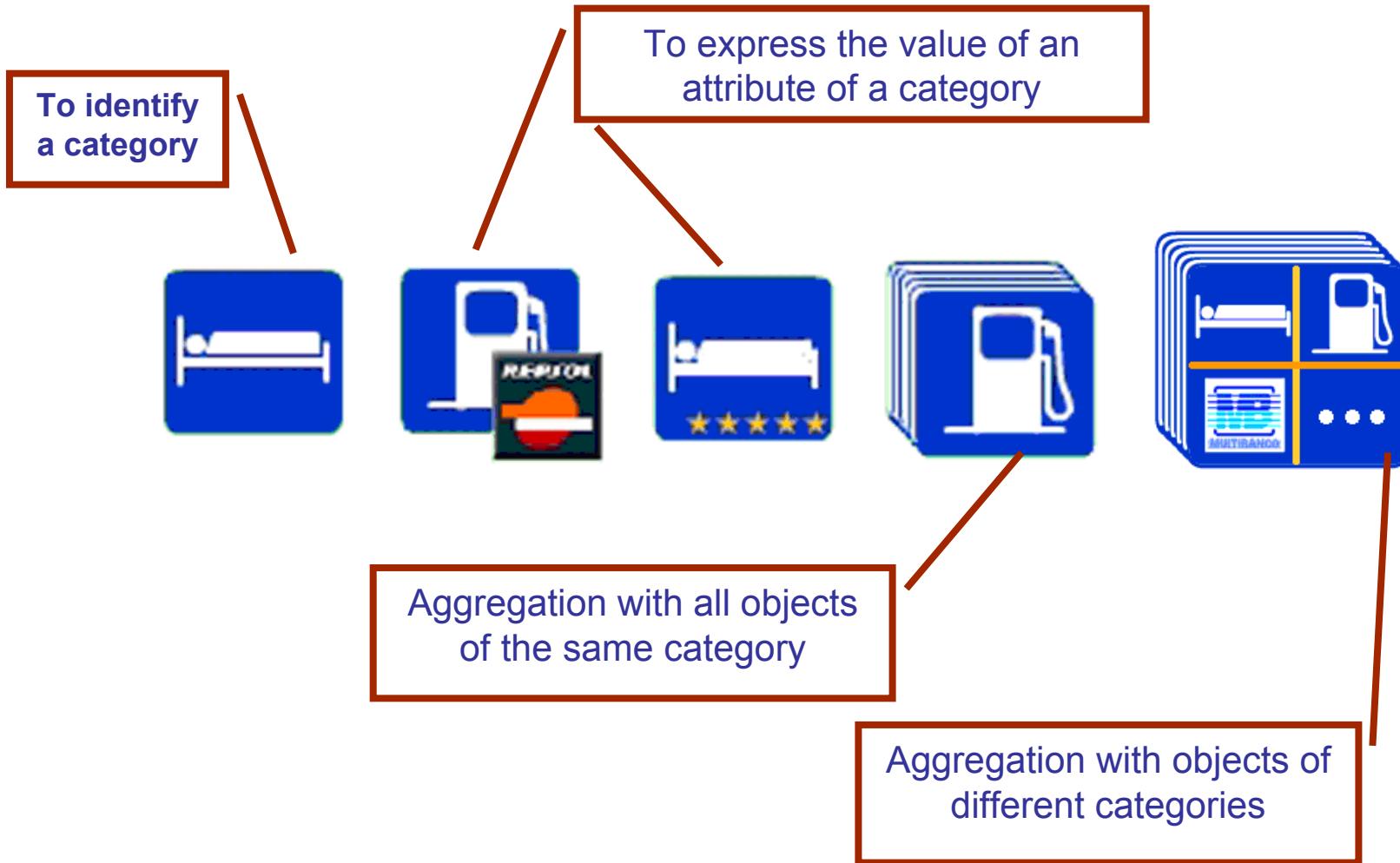
Aggregations based on the number of elements in each cell of the grid



Simbology

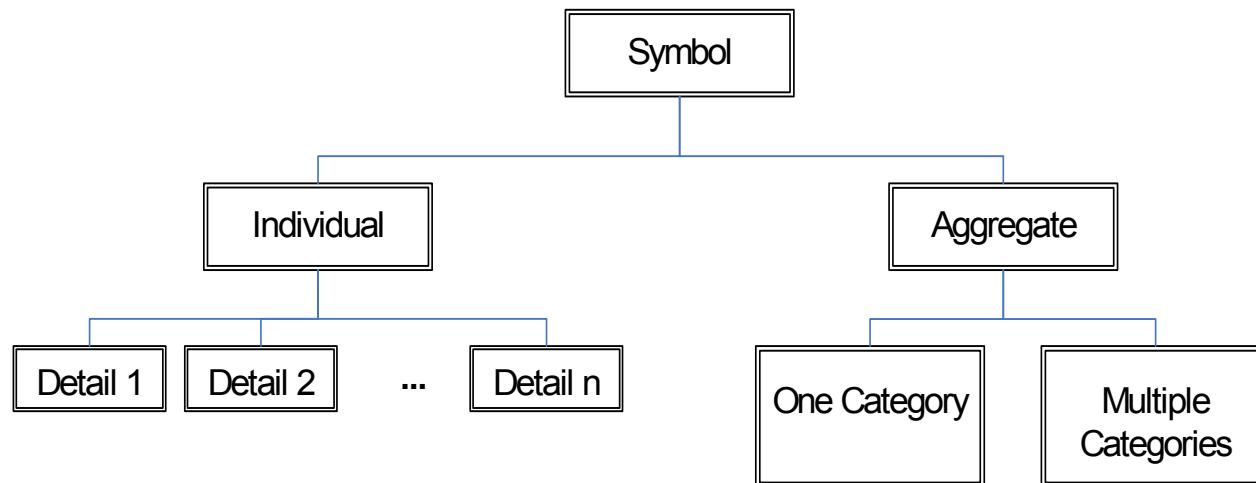
- Selecting the adequate symbol for each category leads to the generation of meaningful representations.
- We have considered different levels of detail expressing different meanings:
 - to identify a category
 - to express the value of an attribute of a category
 - to represent aggregations either with all objects of the same category or with objects of different categories.

Simbology



Simbology

The symbols are organized in a hierarchy



Query Specification Interface

- The developed interface takes into account
 - Mobile devices limitations
 - Small displays
 - Inadequate mechanisms for input tasks
 - Categories and attributes data model
- The interface is automatically generated according to database contents

Query Specification Interface

- The MoViSys interface uses the concept of **dynamic queries for query specification and visualization of query results**
- Dynamic queries continuously update the data that is filtered from the database and visualized
- Query specification is performed by **direct manipulation of query devices** avoiding the use of a virtual keyboard

Query Specification Interface

- There are two distinct components in the interface
 - **Initial configuration interface**
 - **Definition of query parameters**, like the center of the geographic area of interest
 - **Specification of visualization parameters**, such as
 - the size of the icons
 - the maximum number of icons visualized on a map at the same time
 - the minimum level of zoom with aggregations
 - **Query specification interface**
 - Map area
 - Query specification area

Query Specification Interface



In the **map area** the user performs **pan**, **zoom** and **details on-demand** operations

To increase or decrease the size of the icons according to the user motion state

In the **query specification area** the **double tabbed interface** keeps categories and attributes always visible

tab line with the categories

tab line with the attributes of the selected category

query devices to select attribute values

Query Specification Interface

Four types of **query devices** are used for the definition of attribute query values:

Check boxes to select multiple options

A screenshot of a query specification interface. At the top right is a red 'X' button. Below it are three check boxes: 'Leisure' (unchecked), 'Repair shop' (unchecked), and 'Restaurants' (unchecked). To the right of these is a 'Search' button. In the center, there is a row of buttons: 'Brand' (selected), 'Extras' (selected), 'Types of Gasoline', 'Hour' with left and right arrows, and 'Service Station'. Below this is another row: 'Cinema', 'Hotel', 'Beach', and an empty input field.

Two Numeric Up and Down controls to select a range of values

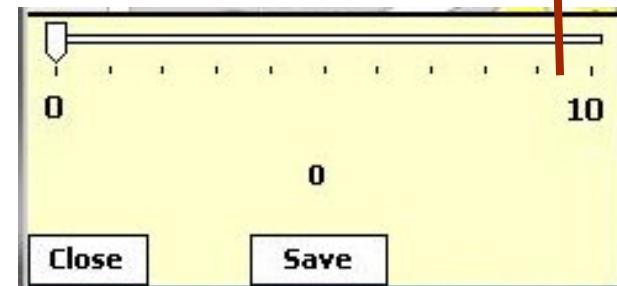
A screenshot of a query specification interface. At the top right are buttons for 'Weight' and 'Search'. Below them are two numeric input fields: 'Closing Hours' (set to 22) and 'Opening Hours' (set to 12), each with up and down arrow buttons. Below these are tabs: 'Distributor', 'Extras' (selected), 'Hours' (selected), and 'Nº of Rooms'. At the bottom are buttons for 'Service Station', 'Cinema', 'Hotel', 'Beach', and an empty input field.

Query Specification Interface

Radio buttons to select
only one option

The screenshot shows a user interface for querying service stations. At the top right are buttons for 'Weight' and 'Search'. Below them is a group of radio buttons for selecting gasoline types: 'N/A' (selected), 'Gasolina95', 'GPL', 'Diesel', 'Gasolina98', and 'Super'. Below this group are tabs for 'Brand', 'Extras', and 'Types of Gasoline' (selected). To the right of the tabs are buttons for 'Hour' with arrows, and below that are buttons for 'Service Station', 'Cinema', 'Hotel', and 'Beach'.

Range slider to select a
value in a range



MoViSys Prototype

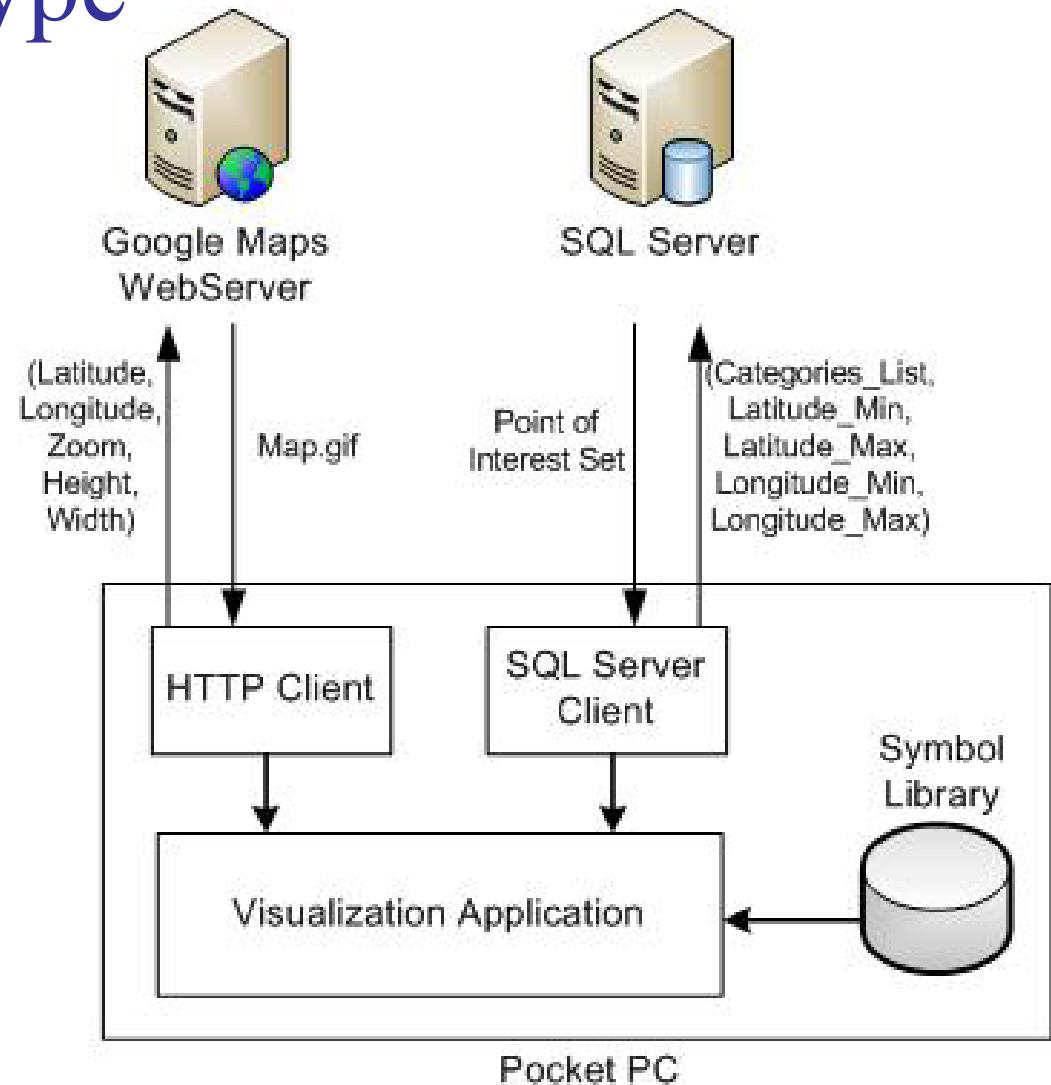
Our visualization system is being developed for a Pocket PC

- Windows Mobile 5.0 operating system
- .Net Compact Framework 2.0.
- SQL Server
- Google Maps WebServer
- Current user position can be obtained through an embedded GPS device

MoViSys Prototype

Given the current position

- Obtain map
- Obtain POI
- Calculate DoI value for each POI
- Icon selection
- Display image



Conclusions

MoViSys

- Visualization system for mobile devices
- Geo-referenced data organized in categories with multiple attributes
- Adaptive interface for query specification based on dynamic visual queries
- Filtering mechanisms to reduce the number of POI displayed
 - Degree of Interest Function
 - Aggregation

On-going and Future Work

✓ Usability tests

interface improvements to control DoI variation

enhancement of icons associated with more relevant POI

✓ Multi-lingual support

- Deal not only with icon overaping but also with icons and cartographical objects overaping
- Explore visualization techniques that include detail and context
- Improve the interface to allow more complex queries



Questions and Suggestions?

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