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Visibility in Information Spaces and in Geographic Environments

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Preface

The users of mobile social media navigate in information spaces and, at the same time, they move in geographic environments. Both activities follow a similar type of information economy in which decisions by individuals or groups require a highly selective filtering to avoid information overload. In this context, the concept of visibility refers to the fact that in social processes some actors, topics or places are more salient than others. Formal notions of visibility include the centrality measures from social network analysis or the different web page ranking methods from computer science. Recently, comparable approaches have been proposed to analyze activities in geographic environments: the Place Rank measure, for instance, describes the social visibility of urban places based on the temporal sequence of tourist visit patterns.

This volume collects articles that were presented at the KI-2011 Workshop on Visibility in Information Spaces and in Geographic Environments which was held on October 4, 2011 as part of the program of the annual German conference on Artificial Intelligence in Berlin. Researchers with a background in Artificial Intelligence, Information Retrieval, Geographic Information Science, and Cognitive Science attended the workshop. They shared an interest in learning more about how the different forms of visibility in digital and physical spaces relate to one another. As the contributions show, the research results also have practical implications: they can be used to improve spatial search engines, geo-recommender systems or location-based social networks.

Seifert and Saendig describe an approach for determining and visualizing geographic regions that are of interest for shoppers in an urban environment. Regions of interest constitute a typical example of a concept which emerges from spatial behavior and which can be used for filtering information in a mobile application scenario. The authors propose to compute regions of interest from a set of points of interest by a clustering algorithm based on the euclidean minimum spanning tree connecting the points.

Schlieder and Kremer investigate the visibility of touristic sites in an urban environment as they are experienced by visitors. They present data from an empirical study of cultural tourists using volunteered-employed photography, GPS-tracking and interviews to learn about the visitor's spatio-temporal decision behavior. One of their results is that the rank ordering of sites according to photographic attention and the rank ordering according to visit time reflect complementary aspects of touristic popularity.

Schmid, Grossmann, Wachter, Raab, Carbon, and Faerber address visibility from the perspective of cognitive processing, more specifically esthetical judgments. The authors ask whether visibility affects prototype generation. Data from experiments on the perception of business logos shows which variations of spatial features and relations affect esthetic judgments.

Andreas Henrich studies the visibility of terms and phrases in the context of geographic information retrieval. He discusses different techniques for geographically grounding terms that appear on web pages. Examples include vernacular place names but also names for everyday objects that show regional variation like dialectal terms for bread.

Re-reading the articles convinced me that a fundamental advance on the issue of spatial information filtering will only be made by combining the approaches that have been developed for information spaces with those that apply to geographic environments. It became also clear, however, that there are still many challenging problems to solve: for computer science but also for neighboring disciplines such as Geographic Information Science and Cognitive Science. The workshop contributions should be seen as an initial step towards a unified research perspective on informational and physical visibility.

Bamberg, November 26, 2011 *Christoph Schlieder*

Clustering and Regionalization for Mobile Applications

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Abstract. This paper describes preliminary results that involve clustering of Points of Interest into regions. It illustrates the first ideas towards connection of regions of interest and public transportation networks that are displayed on mobile smart phones. The aim of this work is to communicate the first ideas towards rendering schematic mobile maps that provide an overview about the structure of an urban environment to support people at every day activities.

Key words: spatial cognition, regions, mobile applications, clustering, navigation, route-planning, public transportation networks

1 Motivation

Mobile devices like smart phones are getting more and more involved in our every day activities. Finding the best subway connections, nearest shops, restaurants, or events are tasks that are already supported by various mobile applications. Meanwhile, we become addicted to our smart phones that seam to be conquering our perception and diminishing our navigation skills. Our goal is to help people navigate in an urban environment using public transportation systems without providing turn-by-turn instructions. We want to draw their attention away from the mobile devices back into environment by providing overview information about the activities that can be accomplished in a city in combination with the topology of the public transportation system. We want to facilitate the understanding of the structure of a city and find a solution for communicating this structure using a small-scaled device such as smart phone.

In this contribution, we will address people who frequently use public transportation and know their city quite well. For example, people, who use the underground transportation network to get from home to the office. Since obviously, there is no need for assistance for such a routine task, our scenario involves uncommon situations such as searching for specific goods, or events on the way to the office or back home. The initial motivation was the searching for appropriate shops to buy baby accessories, milk, and some groceries that became an endeavor due to the lack of connections between public transportation systems and the corresponding shops. A nice overview of the environment in the vicinity of underground stations of a particular line would have been very helpful in this situation.

2 Searching for POIs

Our target environment is the city of Berlin that has a huge public transportation network which involves buses, trams, underground, subway and railway lines. Historically, Berlin was divided into East and West Berlin. Although, the German reunification took place more then 20 years ago, the feeling of two separated parts is still existing. The city topography is characterized by the lakes, rivers, canals that cross the city, and the partially open space between the two parts. This space becomes year for year covered with modern buildings.

Commonly used geographic mobile maps such as Google maps[1] and Openstreet maps[2] contain additionally to the mentioned topography also information about various points of interest (POIs). Points of interest encompass sightseeing attractions, shops, cafes, bars, atms, public facilities like: schools, hospitals and many more other locations.

At the current moment, the most widely used location based applications are google places[3] and Qype[4] that supply points of interest with user-generated recommendations. These applications provide two different possibilities to view the search queries. The first view depicts points of interest as markers on a mobile map in order to communicate their geographic positions. The users can click the markers on the interactive map to get further information about the POI. Yet, too many markers may overlap with each other which contributes to hitting a wrong POI. The second view shows a list of POIs which is usually sorted by the distance according to the current GPS position of the mobile device. This view is more convenient since it allows for inspecting information about each POI. Yet, in this case, we are loosing the spatial information.

Public transportation apps such as "Oeffi"[5] or the official DB Navigator[6] are limited to the routing in railway, underground, or subway networks. There is no additional information about POIs in the vicinity of the stations available.

We are looking for a solution, that first, aggregates POIs into regions and second, shows the topology of the public transportation network in order to provide an overview about the spatial relations between such regions of interest and the public transportation network. We believe that such regions of interest will facilitate the interaction with a small-scale device such as smart phone. Representing spatial information on a higher level of granularity corresponds to

[1] http://maps.google.com
[2] http://www.openstreetmap.org/
[3] http://www.google.com/places/
[4] http://www.qype.com/
[5] http://oeffi.schildbach.de/
[6] http://www.bahn.de/p/view/buchung/mobil/mobile-apps.shtml

human's spatial planning strategies [2] and allows for better understanding of the structure of the urban environment.

3 Communicating the structure of the urban environment

Klippel [1] introduced the concepts of *structure* and *function* in wayfinding and navigation tasks. With structure he refers to the object level, while function refers to the actions. Structure denotes the physically present features of an environment, like streets or buildings, and their static configuration. Function, on the other hand, captures the relation of the structural elements to the actions performed in the environment. Techniques based on these concepts allow for constructing "focus", "route aware maps" or more generally speaking *schematic maps* proposed by [3], [4]. The main idea behind this technique is visualizing and highlighting only those structural elements that are necessary to perform the task. In doing so, the schematic "focus" and "you are here maps" show only streets and junctions with decision points that are necessary to find a way from A to B without getting lost.

In our scenario, people are searching for no particular, but rather for a category of POIs of interest, for example shops. The structural elements for taking actions are underground stations (or bus stops, depending on the transportation mode), streets, and the POI locations. Studies conducted by Hayes-Roth and Hayes-Roth [2] showed that people plan everyday activities (they called them errands) at different levels of abstraction. When solving the errand sequencing task, people arranged nearby errands into clusters or regions in order to facilitate the mental processing of spatial information.

Since in the city of Berlin, especially in the city center, we can find many shops, we also decided to aggregate them into regions in order to create a higher level of abstraction. As a result, people get an overview about the nearby underground stations and corresponding regions of interest.

The up to date techniques to aggregate the POIs is to highlight the POI density on a heat map[7] or combine multiple POI markers into one large marker [8]. Yet, heat maps hide the underlying structure of the streets and the larger markers don't provide information about the shape of the regions.

Partitioning of a spatial environment into geographic regions: ... help people organize their understandings of the world in an efficient manner, they also help various activities in space occur more efficiently!" (see [5])

Along with the administrative districts, Berlin harbors various smaller regions, so called "Kieze". These regions encompass relatively small areas with shops, restaurants and cafes that possess their own extraordinary subculture but no official or administrative notion.

Our goal is to detect such regions using clustering techniques and visualize them on mobile maps together with the public transportation network.

[7] http://opengeodata.org/osm-heatmaps-in-the-browser-w-openlayers
[8] http://www.click2map.com

4 Our approach: clustering of POIs

Common clustering criteria aim at finding homogeneous and well-separated clusters. A homogeneous cluster includes points that are close to each other. Two clusters are well-separated if there are no points in one cluster that are close to any point in the second cluster. The most well-known criteria reported by [6] are a) maximizing partitioning split, 2) minimizing partition diameter, and 3) minimizing within-cluster sums of squares.

We consider the criterion of maximizing partitioning split as most appropriate to our problem, since it is based on the construction of a minimal spanning tree which is embodied in the structure of the urban environment. Furthermore, calculating a minimal spanning tree can be done in a polynomial time (see [7]). We considered the low runtime complexity of Kruskal's algorithm essential for a huge number of POIs and potential users. To obtain clusters, several larges edges of the resulting tree have to be removed.

After determining the clusters of POIs, we connect the most distant points of a cluster using the Jarvis March also called "gift wrapping" algorithm in order to draw a convex hull (see [8]). This allows us to visualize approximate boundaries of the resulting regions.

We used the POI data from the open source project Open street map[9] which contains 24.009 captured POIs in Berlin.

Our mobile application is based on the Android operation system. We employed the mapsforge[10] tile server for rendering the interactive maps on mobile smart phones. To enhance the performance of the clustering procedure, we implemented a web-service which runs on a remote server. The mobile application calls the web service that accesses the data base with POIs and performs the data clustering.

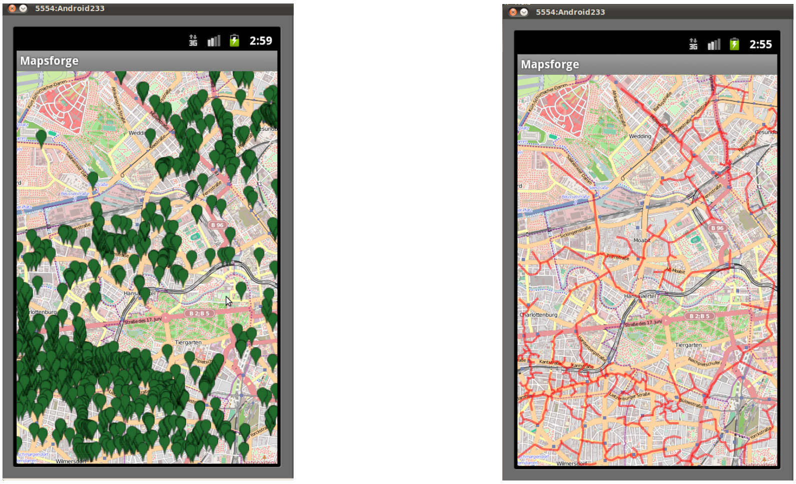
The following figure Fig.1(a) illustrates the distribution of approximately 2000 POIs in Tiergarten and Alt-Moabit for the search query "shop". One can see, too many overlapping markers make the underlying structure of the region invisible. Fig.1(b) shows the minimal spanning tree that connects the returned POIs.

Fig. 2(a), shows the POIs returned from the search query "shop", minimal spanning tree, the resulting regions, and the topology of the underground network (red line).

In Fig. 2(b) inverts the regions with POIs showing only the streets, i.e., structural elements inside of the clusters. It also illustrates the minimal spanning tree, the resulting regions, and the topology of the underground network (red line).

At the current prove of concept stage, we used the POI coordinates, latitude and longitude, to determine the distance between the found POIs. To obtain a minimal spanning tree, we generate a graph that contains POIs and distances between them, represented as weighted edges. During the graph construction,

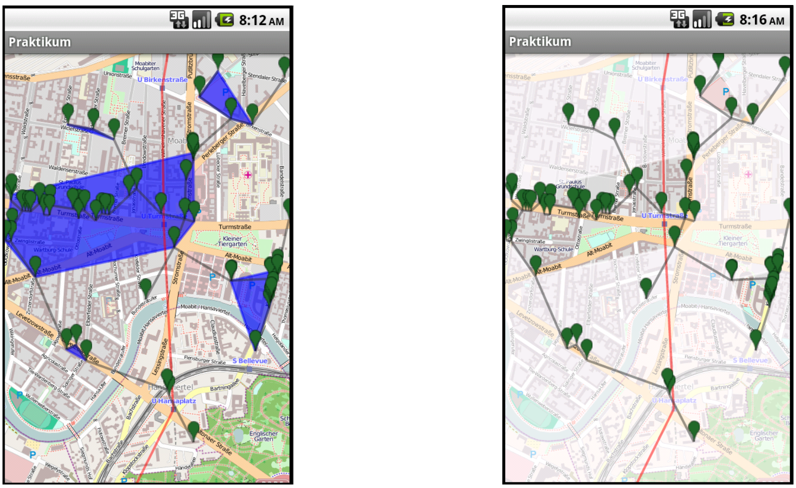
[9] www.openstreetmap.org
[10] www.mapsforge.org



(a) Points of Interest: too many overlapping markers make the underlying structure of the region invisible

(b) Minimal spanning tree

Fig. 1. Search query “shop”



(a) Clusters resulting from removing 10% of the larges edges, the minimal spanning tree, and the underground network (red line)

(b) Highlighting the content of the regions, the minimal spanning tree, and the underground network (red line)

Fig. 2. Search query “shop”

we iterate over every POI and insert an edge with the corresponding distance. We reduced the number of edges by constraining the distance between the POIS for the better runtime performance and the moderate size of the resulting graph. As a distance constraint, we defined a threshold of 2000 meters. We assumed that each POI in Berlin is definitely less then 2000 meters far away from the next one. Therefore, using the distance threshold should take no influence on the resulting minimal spanning tree.

The constructed minimal spanning tree connects all POIs of the user's search query. To obtain clusters, a certain amount of the largest edges has to be removed from the tree. To make this amount dynamic, we removed, for the present, ten percent of the edges.

5 Outlook and future work

In this paper, we presented an approach to visualization of regions of interest in combination with the topology of the public transportation system. Representing this information at different levels of abstraction should help people find appropriate points of interest and facilitate planning of every day activities, and enhance using public transportation networks in big cities like Berlin. Our preliminary results encompass clustering of POIs by constructing a minimal spanning tree and removing the ten percent of the larges edges. After that we connect the most distant POIs of the cluster by applying an algorithm for building a convex hull. The results are encouraging. Our next steps include developing better heuristics to remove the largest edges, since the ten percent criterion may lead to removing too many edges that share almost the same length. This leads to regions that are according to human perceptual sense too near to each other. We are also now working on k-means clustering approaches which allow for generation of centroid-based clusters. It would be interesting to compare these two approaches regarding the human perception of the regions, or experiment with the positions of centroids. We want to pursue all these interesting issues in the future.

Another important issue is the rendering of the schematic maps. We want to elaborate on further schematizing of the structural elements displayed on the mobile maps. For this purpose, the mapsforge project is developing specific stylesheets that can be used to define which elements and the areas should be rendered and how they should be visualized, for example specific fonts and colors. Since this feature is still under development, we are looking forward to be able to test this new technique in the near future.

Finally, the interaction with the schematic maps is a very interesting open research question that occupies at the current moment many scientific minds.

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Visiting the Same Place but Seeing Different Things: Place Models of Touristic Behavior

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Abstract. GPS tracks and geo-referenced photographs permit to closely monitor the spatial decisions of tourists exploring an urban environment. Different methods for identifying places of high touristic popularity from such data have been proposed, some based on the time tourists spend at a place, others based on their photographing activity. Little is known about how these two ways of defining touristic popularity relate. The article describes a data set and a method for defining the extent of places of touristic interest. Within that methodological framework the two approaches are compared.

1 Producing and Consuming Places

Human geographers have studied tourism, and more specifically, the tourist gaze, to understand the social processes involved in producing places of touristic interest. It turns out that we rarely visit places without a preconception of the sights we expect to see (Urry, 1995; Cresswell, 2004; Larsen & Urry, 2011). While most of this geographic analysis is based on qualitative research, computer scientists have followed quanti-tative approaches. They analyzed tourist activity by observing photographs taken with digital cameras in conjunction with GPS trajectories (e. g. Girardin et al., 2009). Different quantitative place models have been proposed which describe the popularity of sites within a tourist destination on the basis of photographic popularity. Unfortunately, little is known about how photographic popularity relates to popularity based on visit times. The starting point for our research was to clarify that issue in order to gain insight into the spatial and the temporal mechanisms of touristic place consumption. Our paper reports about ongoing work and makes the following contributions:

– We describe a data set of GPS tracks and geo-referenced photographs that documents the spatial behavior of tourists in an urban environment. Based on the data, we identify problems with aggregation methods for defining places of interest and show how to solve them using a network-based place model.

– We generalize the concept of visual popularity of a place introduced by Schlieder and Matyas (2009) to account for a process of touristic place consumption that is characterized by the time spent at the place rather than by the photographic sights taken of that place. The popularity rankings resulting from the original and the modified version are compared.

2 Related Work on Place Models

Recently, researchers from geographic information science became interested in place (Winter et al., 2009). Models of vague places are also of concern in the field of geographic information retrieval (Schockaert, 2011). A number of formal place models have been proposed, for instance, supervaluation semantics and qualitatively augmented fuzzy footprints. However, the connection between place models and user communities has been studied very little. Schlieder and Henrich (2011) have argued that there are scenarios where the classical membership problem (does the point X belong to the region R?) transforms into more complex problems: does user A believe X belongs to R? Do users A and B share similar beliefs about X belonging to R? The analysis of touristic data is a typical example for such a scenario.

Most relevant for our analysis are the place models that have been recently described in the context of computational analyses of touristic behavior by Girardin et al. (2008, 2009) who analyzed geo-referenced photographs and GPS tracks of tourists. Photo log data consists of a sparse stream of geo-referenced images, while a much denser stream of geographic positions represents the GPS track data. For the purpose of analyzing such data in terms of places, some spatial aggregation of the positions is needed. The simplest aggregation method uses a grid of fixed mesh size and considers all photographs taken within a grid cell to refer to the same place. Girardin et al. (2008) used this approach to generate density maps of photographic activity of tourists visiting Rome ("heatmaps").

Spatial clustering, on the other hand, uses a distance criterion for aggregating geographic positions. An example is the incremental clustering method which Schlieder and Matyas (2009) designed for the same purpose, the computation of density maps of photographic activity. Both approaches, however, lack a meaningful place concept. In a number of cases they aggregate pictures which show different objects while pictures of the same object may end up in different clusters.

3 Data and Methodological Issues

The data set consists of behavioral data from 17 tourists visiting the historical center of Bamberg, Germany, a UNESCO world heritage site. Contact with the participants was established in front of the tourist information office. Only tourists who said they planned to stay longer than 2 hours in the city were accepted as volunteer participants. They were handed a camera equipped with GPS and a magnetic compass, as well as a second GPS receiver with better positional accuracy for recording the track data. The tourist office served as the starting and ending point of the tour. No other constraints were imposed. The participants were told to explore the city in whatever way they liked and for how long as they pleased. The participants were only instructed to try to take at least one photograph every 10 minutes to avoid effects found in an exploratory study in which the photographing task was sometimes forgotten or squeezed into the very last minutes of the tour.

It took the 17 participants between 120 min and 420 min to complete their individually chosen tour. On average they spent 212 min on a tour. The length of the tours ranged between 2990 m and 10000 m with an average of 5440 m. The longer tours are those of tourists who spent more time on their visit. In other words, there were no surprising differences in locomotion speed which averaged at 1.59 km/h. The total number of photographs collected on a tour varied between a minimum of 15 images and a maximum of 234 images with an average of 58 images. An indicator of the photographic activity level is the number of photographs taken per hour which ranged between 3.46 and 33.43. Only the participant with the minimal photographic activity stayed under the 6 images per hour that the instruction requested. All others photographed more with an average of 15.6 images per hour.

4 Places of Touristic Interest

The tourist office of the city of Bamberg distributes a map that lists places of inter-ests, mostly historical buildings and green spaces, and displays them as point features on the map. We use the place names appearing on this map as a starting point for our analysis. Because the tourists move as pedestrians along the street network, the places cannot be described by simple polygon features. Inaccessible buildings and water bodies cause holes in the region. We argue that in such cases a network-based model is more appropriate. Fig. 1 (left) shows some of the points from which the Old Town Hall has been photographed. The Old Town Hall itself is situated on an island in the river Regnitz and connects to the city via bridges (dotted lines on the map).

Fig. 1. Determining a place of interest: Old Town Hall

The network-based place model is determined by the footprint of a touristic place of interest using the network hull (= convex subgraph) of the vantage points from which tourists have taken photographs. Basically, this amounts to define the place associated with a particular attraction by locating the positions of all photo-graphs taken of that attraction and by adding adequate network connections between these positions. For the sake of simplicity, an approximation of the network hull was used that could readily be computed using the tool.

5 Image-based versus time-based popularity

An aspect that is often overlooked in the analysis of touristic popularity is the ambi-guity of visual content associated with a geographic position. In our data set we found several cases where a tourist has photographed a place A followed by a place B without changing position, sometimes the images even come in the form of alternating place sequences $ABAB$. As a consequence, place models should admit that regions of touristic interest overlap. Fig. 2 illustrates the most complex situation found, a mutual overlap of networks representing four places.

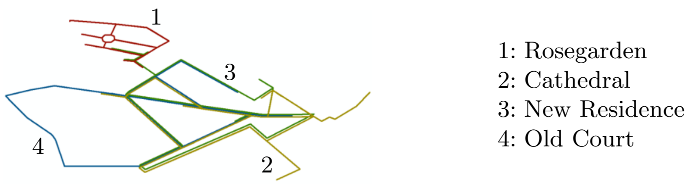

Fig. 2. Overlapping touristic footprints

Determining the time tourists spend at a place needs to deal with this fact. The so-lution adopted consists in simply dividing the time spent in overlapping places among those places (e.g. a third of the time for positions in a triple overlap network).

We are now in a position to determine for each of the 11 places in the data set four basic parameters related to touristic popularity: (1) the total number of images taken at the place, (2) the number of visitors who have taken at least one image at the place, (3) the total time that visitors spent at the place, (4) the number of people who spent at least 1 min at the place. The threshold for determining (4) has been chosen to exclude tourist that just pass by a place without devoting time to a closer visit. Visual popularity is determined according to the measure proposed by Schlieder and Matyas (2009). This image-based popularity combines the number of photographers of a place with the number of photographs they have taken according to a logarithmic law of diminishing returns. Tab. 1 shows the image-based popularity scores and the implied ranking of the places.

The high resolution of the GPS track data provides a reliable basis for the time a tourist spends at a place. It is obvious that the total time that tourists

Place	OC	OT	CA	GP	GC	LV	MP	MM	NR	UP	RO
images	16	34	40	4	3	30	23	17	19	4	36
visitors	7	12	14	4	3	11	6	7	11	3	10
pop.	16.1	28.8	32.5	8.0	6.0	25.8	14.9	16.3	24.0	6.3	24.3
rank	7	2	1	9	11	3	8	6	5	10	4

Table 1. Image-based touristic popularity

OC = Old Court
OT = Old Townhall
CA = Cathedral
GP = Geyerswörth Park
GC = Geyerswörth Castle
LV = Little Venice
MP = Michaelsberg Park
MM = Michaelsberg Monastery
NR = New Residence
UP = Upper Parish
RO = Rosegarden

have spent at a place does not constitute a good indicator of popularity because it is heavily affected by individual tourists with very long visit times. We propose to generalize the approach of Schlieder and Matyas (2009) for image-based popularity to a time-based popularity measure which uses two parameters, the number of tourist that have visited the place and the amount of time that they have spent there. Again, this time-based popularity measure controls the effects of individual long visits by applying a law of diminishing returns. The first minute spent at the place increases the popularity by 1, while the second minute increases popularity by $\log 2$, and the n-th minute by $\log n/(n–1)$. With T_p denoting the set of the k tourists that have visited place p, we define the time-based popularity score as

$$\mathrm{pop}_{\mathrm{time}}(p) \quad = \quad \sum_{x\in T_p} \big(1+\log t(x)\big) \quad = \quad k+\sum_{x\in T_p} \log t(x).$$

Tab. 2 lists the time-based popularity scores together with the implied rankings. Some differences between image-based and time-based ranking are immediately obvious. For instance, image-based rank 3 is downgraded to a time-based rank 6. This can be explained by the fact that the place (Little Venice) allows photographing a scenic river front but is easily explored in a few minutes. On the other hand, image-based rank 7 is upgraded to time-based rank 4. Again, a geographic explanation can be given. The place (Old Court) covers a vast area which cannot be overseen from a single vantage point and therefore invites visitors to engage in exploration. On the other side, this place does not offer spectacular buildings or vistas.

Place	OC	OT	CA	GP	GC	LV	MP	MM	NR	UP	RO
images	98.0	270.2	150.0	52.7	15.7	44.3	90.9	80.6	113.9	11.9	151.4
visitors	15	16	16	6	3	9	6	7	15	4	12
pop.	41.6	51.7	45.7	23.4	11.7	24.5	18.0	20.5	43.0	14.5	36.7
rank	4	1	2	7	11	6	9	8	3	10	5

Table 2. Time-based touristic popularity

The examples for rank downgrade and upgrade reflect environmental differences between places that can be expected to appeal to different touristic interests. This suggests that image-based and time-based popularity scores cover to a certain extent complementary aspects of places. A Spearman rank correlation coefficient of 0.85 shows that the image-based and the time-based ranking nevertheless show a good overall agreement. For the purpose of comparison we consider a third rather naïve, but computationally inexpensive popularity score: the number of images (no matter of what content) that fall within a 50 m buffer around the point features associated with the 11 places on the tourist office map. Tab. 3 shows the results of this popularity ranking method.

Place	**OC**	**OT**	**CA**	**GP**	**GC**	**LV**	**MP**	**MM**	**NR**	**UP**	**RO**
images	16	41	17	9	13	10	4	3	38	2	40
rank	5	1	4	8	6	7	9	10	3	11	2

Table 3. Naïve popularity score based on photo count within a 50m buffer

The Spearman correlation coefficient for the naïve ranking and the image-based ranking is 0.63, that for the naïve ranking and the time-based ranking 0.79. Note that the image-based and the time-based rankings show more agreement among each other than each of them with the naïve ranking. We interpret this as evidence that the image-based and the time-based score provide a better, though complementary, assessment of the touristic popularity of places.

6 Discussion and Conclusions

We presented a data set on touristic exploration behavior in an urban environment and provided a solution to the spatial data aggregation problem. Furthermore, we described a network-based model for places of touristic interest and a method for determining image-based and time-based popularity scores from basic parameters of the data set. Our analysis of the two approaches for measuring popularity showed that they are both better at reflecting the properties of the data than a simpler measure of popularity. We also found that there are cases were the image-based and time-based popularity disagree. Since geographical explanations could be given for the cases, we argue that image-based and time-based express complementary aspects of the data.

Studying tourist behavior means to study processes that complement the so-cial production of touristic places, that is, processes of place consumption. A basic insight from our research is that the consumption of places is a process that takes different amounts of time, not always in congruence with the photographic popularity of the place. In a city we may find scenic places that are widely advertized in visual media by touristic marketing but that turn out to take very little time to visit. Introducing a time-based popularity score constitutes a first step towards a better understanding of the spatial and temporal choices made by tourists.

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How Visible are Different Variations of Spatial Features and Relations in Logos and How Does Visibility Affect Prototype Generation?

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Abstract. We present an approach to prototype construction and prototype change for complex object representations including visual form, metrical and categorial features as well as metrical and categorial relations. This approach is intended as a computational model for dynamic similarity-based aesthetical judgements as proposed by Carbon (2010, 2005). In the context of modeling aesthetic judgements of brand logos, we conducted a psychological experiment to determine which aspects of objects (visual, metric/abstract, featural/relational) are dominant in similarity judgements. In this work in progress report we present the psychological background and the computational model. Furthermore, we present the application domain of brand logos and the experimental results.

1 Introduction

Categorization is a basic human ability which is central to many cognitive tasks such as communication, inference, or decision making (Sternberg & Ben-Zeev, 2001). For example, by categorizing an object as "chair", we identify this object as something to sit on and at the same time differentiate it from other categories as "stool" or "bench". A prominent cognitive approach to categorization is prototype theory (Rosch, 1978). Categories are assumed to be represented by a prototypical object which represents an average over the exemplars belonging to this category. There is strong empirical evidence that categories are learned from experience (Medin & Heit, 1999; Ashby & Maddox, 2005). Consequently, categories differ – slightly or strongly – between different humans.

Prototype theory is criticized because it does not take into account contextual information. For example, Labov (1973) could show that drawings of cups and cup-like objects with different width-to-depth ratios and *presence* or *no presence* of a handle were categorized differently in different functional contexts, such

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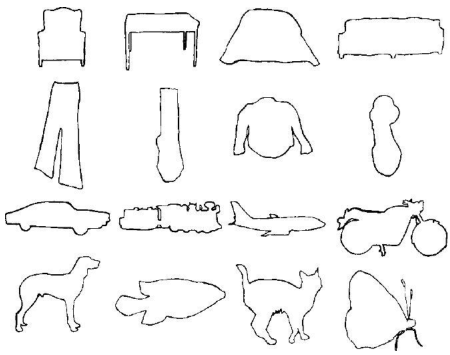

Fig. 1. Averaged shapes of objects (figure from Rosch et al. 1976, fig.1, p. 402)

as holding tea, food or flowers. Furthermore, prototype theory in its pure form does not consider information concerning the number of objects and their variability. Both aspects are covered in exemplar theory (Nosofsky, 1988). From the perspective of machine learning (Mitchell, 1997), prototype construction corresponds to eager generalization while example theory is reflected in lazy learning approaches such as k-nearest neighbors.

While prototype and exemplar theory differ with respect to their assumptions about what kind of experience is stored in memory, both theories postulate that categorization is based on *similarity assessments* between given objects and entities stored in memory (Goldstone & Son, 2004). Consequently, objects which are more similar to a stored concept are rated more typical, can be identified faster, and are acquired earlier (Smith & Medin, 1981) .

When designing a computational model for similarity-based categorization, the decision of what aspects of real-world objects are to be included in the internal representation is a fundamental issue, since it determines the type of similarity measure which can be applied. The kind of information which is used to construct prototypes varies widely between different studies and models. For example, prototype theory is used to model averaging over visual information such as shapes. In a series of experiments in the context of natural categories, Rosch could show, that humans average over visual shape information for base categories (see Figure 1) – such as chair (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Posner and Keele (1968) could show that humans form prototypes over abstract visual patterns. In other studies and models, prototypes are characterized by simple visual features such as size or color (Smits, Storms, Rosseel, & De Boeck, 2002). Further proposals consider categorial information or abstract semantic features, such as *can sing* (Rosch & Mervis, 1974).

In general, features and relations can be either metrical or categorial. Metrical features or relations represent properties that allow quantitative orderings, while categorial features or relations represent nominal information. Dependent on which information is used, different types of similarity measures are applicable. For instance, similarity between metrical features typically is assessed as Euclidian distance, similarity between categorial features with the contrast model (Tversky, 1977). For relational representations structural similarity measures, such as alignment based approaches are used (Goldstone & Son, 2004).

Intuitively, for real-world objects, humans might refer to a variety of information when classifying an object. For example, a mental representation of a car might contain

- **holistic visual information** such as shape, which characterize a car as racy, comfortable, etc.
- **metrical visual features** such as length,
- **metrical visual relations** such as the proportion of length to breadth ,
- **metrical non-visual features** such as weight or horsepower,
- **categorial visual features** such as color (which typically is perceived qualitative and not as a metrical feature representing wave length),
- **categorial non-visual features** such as availability of a parking assistant,
- **qualitative spatial relations** such as that the radiator grill is *between* the headlights (which might be *below* them in another car).

There are no empirical findings which clearly indicate which of these different types of information influence similarity judgements of real-world objects. Since different subsets of these information types might be used in different domains, a general computational model of similarity-based categorization should be flexible enough to deal with all of them.

To our knowledge, no such computational model exists. We constructed such a model in the context of similarity-based aesthetic judgements based on a theory of dynamic prototype change of Carbon (2010), Carbon and Leder (2005). In the following we first introduce the psychological background and the general structure of the computational model. Afterwards we describe the domain of brand logos and an instantiation of our model for that domain. Finally, we present a first psychological experiment where we investigated which kind of the information types given above are used when judging similarity between brand logos.

2 Aesthetic Judgements and Prototype Similarity

When making aesthetical judgements, novelity and familiarity are the most important predictors. Novelity –measured as distance from the established prototype – is crucial for innovative design (Hekkert, Snelders, & Wieringen, 2003). When buying everyday objects, familiarity can be considered a key feature for predicting consumer behavior (Whitfield & Slatter, 1979).

Based on the observation that attractiveness ratings of artefacts – such as cars or clothes – change over time, Carbon and Leder (2005), Carbon (2010) proposed the Repeated Evaluation Technique (RET) which allows to investigate the dynamics of aesthetic appreciation by systematic inspection and elaboration of the material under standardized conditions.

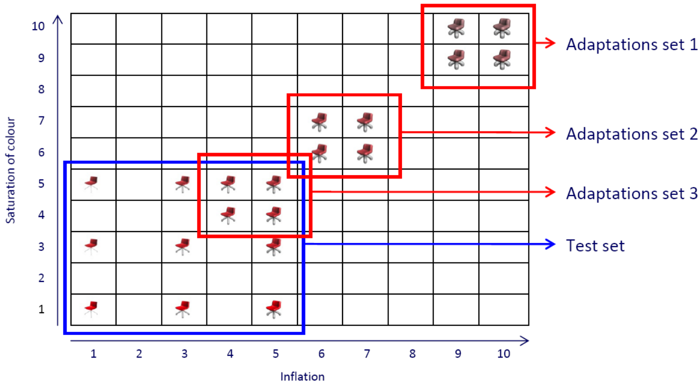

Fig. 2. Illustration of a typical experiment on varying the position of the adaptation set within the whole object space

An application of RET in the context of an adaptation experiment was realised by Faerber and Carbon (2010): Initially (t_1), subjects are presented a set of stimuli (e.g., chairs) which vary on some dimensions (e.g., inflatedness of form and saturation of color, see Figure 2). Some objects are similar to standard, that is, prototypical artefacts, others highly deviate from typical appearance. Subjects have to rate the attractiveness of the given objects. In a second phase (E), subjects are induced to engage with another set of artefacts which deviate not, moderately or strongly (see adaptation sets 1, 2, 3 in Figure 2) from the typical objects. For example, they have to rate pleasantness and functionality. Afterwards (T_2), subjects have to rate the attractiveness of the objects in the initial set again. Over several experiments, Carbon and his coworkers could show, that if subjects were engaged with strongly deviating objects during the evaluation phase, at T_2 the more deviating stimuli are rated more attractive as at T_1 while the more standard objects are rated less attractive. This result cannot be explained by mere exposure, since in the evaluation phase (E) different objects were presented than the ones used at T_1 and T_2.

Carbon and colleagues explain this effect by recalibration or dynamic prototype change: When confronted with a new artefact, which deviates too much from the prototype for this class of objects (e.g., very angular car shape, belly-bottom trouser legs), initially such new artefacts are rated as not attractive (T_1). However, if one gains more experience with such innovative objects (E), the prototype undergoes a dynamic change, incorporating the new objects. Consequently, after a while (T_2), the objects which were originally similar to the prototype at (T_1) are now more distant and the objects which originally strongly deviated from prototype are now similar to the updated prototype (T_2).

A computational model which captures these empirical observations can be constructed as follows:

– Given the ratings at T_1 a prototype over the object set is constructed such that the similarity of the objects to the prototype correspond to the attractiveness rating of these objects.
– Based on this initial prototype and the set of objects presented in the evaluation phase E, the prototype is recalibrated.
– The similarities of the objects in the initial set to the new prototype are calculated and used to predict the attractiveness ratings at T_2.

Whether the model can predict attractiveness ratings with satisfying accuracy crucially depends on the type of information included in the representation of the objects as well as the used similarity measure. Since it is plausible to assume that the type of information included depends strongly on the domain as well as the used experimental manipulation of objects, our aim is to work on very rich representations which allow us to use different subsets of information to model prototype change for different domains. We propose a dual visual/abstract representation for objects and prototypes (see Figure 4 for an example representation for brand logos): The visual representation can be realized as a simple mesh representing the visual shape of objects (see Figure 1). Often a 2D mesh capturing the coordinates which determinate each component of an object might be sufficient. For some cases, a more complex 3D mesh might be necessary. The abstract representation is a partonomy with the category name (e.g., chair) as root node and child nodes representing parts of which an object can be composed (e.g., back, seat, legs). When representing a given object, leaf nodes give specific values, when representing prototype objects, leaf nodes represent average values for metrical features and attribute sets for categorial features. Each node of the partonomy has a link to the visual representation. Within the partonomy, a second type of nodes represent relations between objects.

In the next section, a specific realization of this representation format is given for our application domain of brand logos. There we will also introduce the similarity measures.

3 A Computational Model Of Featural and Relational Prototypes for Brand Logos

The four logos we analyzed in our study are from the brands Adidas [3], Aldi (Süd) [4], Deutsche Post [5] and Shell [6] (see Figure 3). Every logo can be seen in a holistic way and as a composition of specific logo parts. Typically, there are many alternatives how objects can be decomposed. As usual in knowledge representation, we will decide on one suitable way of decomposition and apply it to all entities belonging to a given class (be it a car, a chair, or a logo).

[3] http://www.adidas.com
[4] http://www.aldi.com/
[5] http://www.deutschepost.de/
[6] http://www.shell.de/

Fig. 3. Logos of Adidas, Aldi (Süd) , Deutsche Post and Shell

In the following, we only describe the instantiation of our model for the Adidas logo. This logo is represented by three specific components *LeftLeaf*, *MiddleLeaf* and *RightLeaf*.

A logo as well as its components do have properties, such as the size (the width and height), which is a metric feature, or a color, which is a categorial feature. Furthermore, there exist relations between components, which also can be metric (e.g., ratio between areas) or qualitative (e.g., component x is left of component y).

In the first experiment (see section 4) we focussed on the question whether featural or relational aspects of objects contribute more to similarity assessments. Therefore, objects were varied only with respect to metrical features and relations.

3.1 Logo Representation via MeshPoints

Logos are given as bit-images. Every logo is labeled with a set of specific points on its image representation, the *MeshPoints*. For the Adidas logo (see Figure 4, the set of stimuli logos is defined as $T_{Adidas} = \{t_1, t_2, ..t_N\}$. For every logo t_i we have a set of *MeshPoints*. Every mesh point is represented by two coordinates x and y. We define three points for every leaf of the Adidas logo and one point for the dimension of the logo – the size – which is the point of the bottom right corner. The x-coordinate represents the width, the y-coordinate the height. So the set

$$t_i = \{(x_{size}, y_{size}), (x_{LeftLeaf_{TP}}, y_{LeftLeaf_{TP}}), (x_{LeftLLeaf_{LP}}, y_{LeftLeaf_{LP}})..\}$$

describes the logo. To capture the holistic impression of a logo, we consider all mesh points. Furthermore, we consider its three components *Left-*, *Middle-* and *RightLeaf*. There we selected three specific mesh points which are easily extractable from the image: the tip of a leaf and the left and right bottom. The *Curviness* of a leaf is heuristically approximated by the ratio between the Euclidian distance of tip and left bottom and the actual length of the border line (see the illustration for the middle leaf in Figure 4).

3.2 Prototype Calculation

Prototype calculation is performed over the set T of the logos: For the visual holistic representation we calculate the arithmetic average value for the

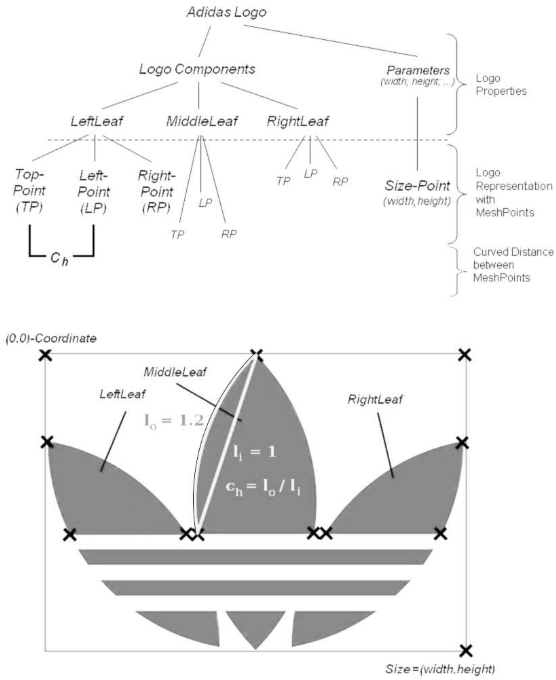

Fig. 4. Visual/Abstract representation of the Adidas logo

x-coordinate and the y-coordinate of the same mesh point of the different logos over all mesh points. For example, the size is represented by one mesh point (x_{size}, y_{size}). Assume we have N logos in T, the x-coordinate for the size, or the width of the prototype, is the value

$$x_{size_{prototype}} = \frac{1}{N} \sum_{i=0}^{N} x_{size_{t_i}}$$

and the height is

$$y_{size_{prototype}} = \frac{1}{N} \sum_{i=0}^{N} y_{size_{t_i}}.$$

We do likewise for calculating the component values of the prototype. Besides averaging over the mesh points, we average over the curvature heuristic.

3.3 Features, Simple, and Complex Relations

For our first experiment, logos where varied along three metrical dimensions. Starting with the original logo, each dimension was varied in five decreasing and five increasing steps (see Figure 5).

Feature Change (Dimension 1) Height was selected as a simple example of a featural variation. In one direction, the logo is vertically compressed, in the other direction it is stretched.

Simple Relational Change (Dimension 2) We define a simple relation such that it only affects a single component of an object. In our experiment, curvature (and area) of the middle leaf was decreased or increased.

Complex Relational Change (Dimension 3) We define a complex relation such that two or more components change relative to each other. Here, an increase of the curvature of the middle leaf occurs with a simultaneous decrease of the curvature of the outer leafes and vice versa.

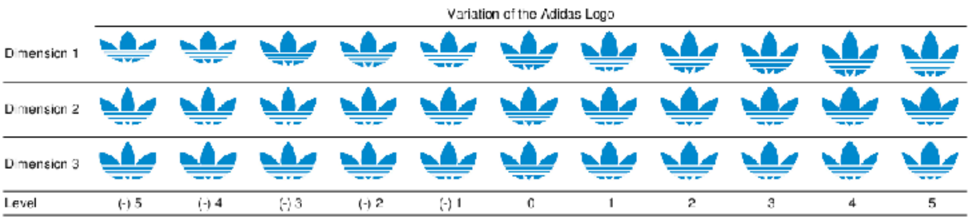

Fig. 5. Variations of the Adidas Logo

3.4 Similarity of New Objects to the Prototype

For a given prototype for a class of objects, the similarity S of a new object $L_{new} \notin T$ can be calculated in different ways. Either, similarity might be assessed in a rather general way, based on the holistic impression. In our first experiment, we were interested whether human subjects base their similarity judgement on simple features, simple relations, or complex relations. We give the definitions of these types of similarity below, again for the Adidas logo.

Holistic Similarity Currently, holistic similarity is calculated over the mesh points only. The measure is extendable to take into account further metrical information, such as curvature, and categorial information, such as color.

For now, we use all mesh points m of the logo and calculate the *Average Euclidian Distance* d_{avg}, that is, the Euclidian Distance of all x-coordinates of all mesh points of the prototype P to all corresponding x-coordinates of all mesh points of the logo L_{new} and the y-coordinates respectively. We calculate d_{avg} as follows,

$$d_{avg} = \frac{\sum_{k \in K} d_k(P, L_{new})}{m},$$

where $k \in K = \{size, LeftLeaf_{TP}, LeftLeaf_{LP}, LeftLeaf_{RP}, MiddleLeaf_{TP}, \ldots, RightLeaf_{RP}\}$ are the mesh points of the components,

$$d_k(P, L_{new}) = \sqrt{(x_{P_k} - x_{L_{new_k}})^2 + (y_{P_k} - y_{L_{new_k}})^2}$$

is the distance of every mesh point within these components, and m is the count of all mesh points within the logo, so all points of $t_{L_{new}}$.

To obtain a similarity value $S_{holistic}$ such that $0 \leq S_{holistic} \leq 1$, we need to normalize the calculated value d_{avg}. To do so, we create a point M_{max} such that $x_{M_{max}} = max(x_{prototype}, x_{L_{new}})$ and $y_{M_{max}} = max(y_{prototype}, y_{L_{new}})$ are the maximum x- and y-coordinates, a mesh point can have. Now we calculate the distance of this point M to the minimal point $O = (0, 0)$, the zero point, as the *Normfactor*

$$d_{normfactor}(O, M) = \sqrt{(0 - x_{M_{max}})^2 + (0 - y_{M_{max}})^2}.$$

Finally, for the holistic similarity, based on mesh points, we get

$$S_{holistic} = 1 - (\frac{d_{avg}}{d_{normfactor}}).$$

Featural Similarity To calculate featural similarity $S_{featural}$, only the size (respectively the height) of the prototype and a new logo is considered. Again, similarity is calculated as Average Euclidian Distance of only the mesh points representing the size of the prototype and the size of the new logo. This similarity value will be normalized as mentioned before.

Simple Relational Similarity The simple relational similarity $S_{singleRelation}$ is the similarity of a component of the prototype to the same component of the new logo. All mesh points of the component are considered to calculate the Average Euclidian Distance for this component. The value will be normalized as before.

Complex Relational Similarity To calculate complex relational similarity, a pre-processing step is needed. For the case of the Adidas logo, the relation between curvature (value) of an outer leaf and the middle leaf has to be determined to capture the relational dependency between components. This relation, for a new object, as well as for the logo prototype is calculated as ratio:

$$relValue = \frac{value_{LeftLeaf}}{value_{MiddleLeaf}}.$$

Relational similarity is then

$$S_{relational} = 1 - (\frac{relValue_{L_{new}} - relValue_{L_{proto}}}{max(relValue_{L_{new}}, relValue_{L_{proto}})}),$$

where we need the maximum value of $relValue_{L_{proto}}$ and $relValue_{L_{new}}$ to normalize the similarity in order to get values of $0 \leq S_{relational} \leq 1$.

It is an open question, whether humans base their similarity assessment on one of the similarity measures proposed above or on a combination of them. Furthermore, combination could be realised as cascade from a rough holistic judgement to more detailed comparisons, or as a weighted sum over the different similarity measures where the weight parameters represent the empirically assessed influence of the different aspects.

3.5 Implementation of the Model

We implemented a prototype in Java which is based on XML-representations of the objects. For a given category of objects, for example, Adidas logos, an XML-schema has to be provided which predefines the features and relations which represent the objects and their prototype. The prototype is calculated over the XML-representations and stored as a Java object that holds the required values and their getter- and setter-methods. To calculate the similarity of a new set of objects to the prototype, these objects again are given as XML-files. Output of our system are the similarity values of each object to the prototype.

4 Visibility and Similarity

In the future, we plan to apply our model to adaptation experiments as described in section 2. To reach this goal, we propose the following series of experiments: (1) Assessing which features and relations are taken into account when comparing objects, i.e., which are visible when judging similarities; (2) tuning our similarity measures in such a way that a high correlation with empirical similarity judgements can be achieved; and (3) applying the model to predict aesthetical judgements by similarity to prototype and novelty with high accuracy.

We conducted a first experiment to explore how featural, simple relational and complex relational changes contribute to the overall assessment of similarity between objects. The four brand logos given in Figure 3 were systematically varied in ten steps on three dimensions. The experiment was conducted in June 2010 with 8 students of psychology from University of Bamberg. We used a signal detection design: For each brand logo, subjects received pairs presented in varying positions on the monitor and had to decide whether the two logos are identical or not. One logo always was the original logo, the other one of the 30 manipulated logos.

Results show that subjects detect differences between logos on all three dimension (see Table 1). For no logo, the smallest variation on each dimension was detected. For Adidas, featural variation was identified from the second smallest variation onwards; simple and complex relational variation was identified from the third variation onwards.

Table 1. Degree of variation from which on a logo was identified different from original

	Featural	Simple Relation	Complex Relation
Adidas	2	3	3
Aldi	2	2	2
Post	2	2	3
Shell	2	4	3

5 Conclusions

We proposed a computational approach which can model generation and updating of prototypes based on complex visual and symbolic representations. The model can be applied to data obtained with experiments on changes of attractiveness ratings based on the RET approach. In a first step, we realized the model for simple brand logos, restricted to metrical features and relations. A signal-detection experiment showed that subjects use featural as well as relational information to determine similarity between objects.

Next steps include follow-up experiments to validate our modelling approach. We plan to take into account more complex artefacts such as cars. Furthermore, we want to explore the potential of the model to guide innovative design. Given a current prototype for some class of objects, the model can be used to assess the novelty of new designs and ultimately, the appreciation such novel design might receive.

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The Spatial Visibility of Terms and Phrases on the Internet: Approaches, Observations and Perspectives

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1 Introduction

Many terms appear on the Internet with a strong spatial bias. In part, the corresponding correlations are quite surprising. Although the analysis needed to reveal these relationships is quite simple, there are various potential applications. These applications range from the analysis of the regional extend of colloquial terms in cultural studies to the use in geographic IR systems to the application in marketing. The talk reports on the basic idea and the technical concepts of the approach and outlines exemplary results. Furthermore, future research directions that build on the presented approach are.

Fig. 1. Spatial Footprint for colloquial terms for plain rolls in Germany

2 Example

The talk presents the idea to determine a spatial footprint for arbitrary terms or phrases based on well-known toponyms[1] found on web pages dealing with these terms or phrases. Based on the locations of the well-known toponyms and on some additional data cleansing (dealing e.g. with geo/non-geo ambiguities) corresponding footprints can be derived. Figure 1 gives an example for the application of the approach. It depicts the footprints of five different colloquial terms for plain rolls in Germany. Figure 2 shows a screenshot of the analysis tool for the phrase “Künstliche Intelligenz” (artificial intelligence).

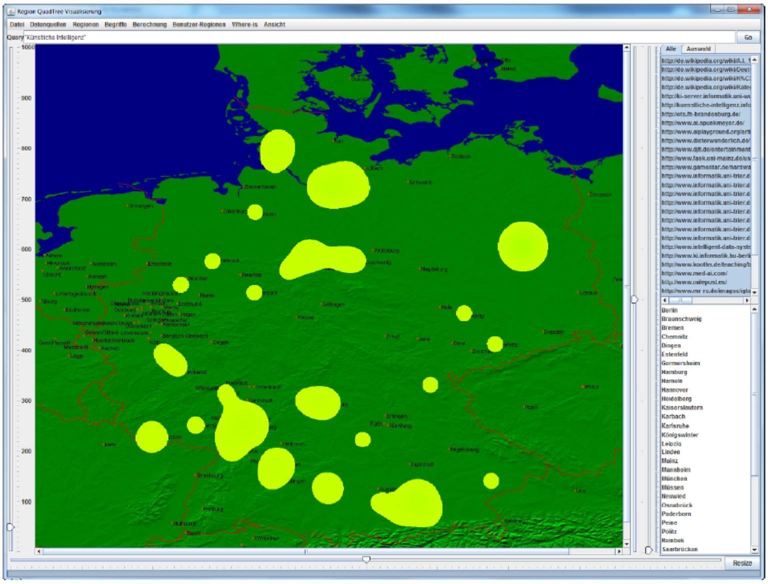

Fig. 2. Spatial Footprint for the terms for phrase “Künstliche Intelligenz”

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[1] These are the toponyms which can be found in the usual gazetteers, such as OpenGeoDB.

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