

# CARTOGRAPHICALLY AUGMENTED REALITY

**Karel STANEK, Lucie FRIEDMANNOVA**

MSc., Ph.D., Karel, STANEK;

Masaryk University, Faculty of Science, Department of Geography, Laboratory on Geoinformatics and Cartography;

Kotlarska 2, 611 37 Brno, Czech Republic;

Tel.: 00 420 549 49 7430, Fax: 00 420 549 49 1061, E-mail: karst@geogr.muni.cz.

MSc., Ph.D., Lucie, FRIEDMANNOVA;

Masaryk University, Faculty of Science, Department of Geography, Laboratory on Geoinformatics and Cartography;

Kotlarska 2, 611 37 Brno, Czech Republic;

Tel.: 00 420 549 49 3823, Fax: 00 420 549 49 1061, E-mail: lucie@geogr.muni.cz.

## **Abstract**

*Virtual environments of the Digital Earth were from its beginning quickly enriched by usage of the augmented reality. The following paper is focused on possibilities to include strictly cartographic methods of visual representation of data into the Digital Earth representation. The idea is to embed cartographically processed and visualized thematic information into the augmented reality without actually using a map. A map apart from factual information about concrete objects displays relationships between them and also gives overall information about spatial trends and distribution. Even if augmented reality cannot fully substitute a map as such, in some cases, the fusion of methods of cartographic representation with augmented reality is better solution for a user than simple use of the products at the same time or concurrently.*

## **Keywords**

*Augmented reality, cartographic method*

## **1. INTRODUCTION**

With the expansion of computer technologies is increasing also amount of geo-aware devices. Such devices are often equipped with displays and distinctive visualization abilities which open a new field for cartography. This kind of development represents for cartography great challenge. Main technical reasons of the challenge are various limitations related to the size of a display and a colour fidelity issues. Cartography has always fought with space (just recall the issue of map folding) and colour (mainly due to weaknesses of print and later display technologies), but it was always a trade-off. Nowadays, the size of a map and heterogeneous display abilities are the hard limit for cartographic procedures for many of the new types of environment. Another technological issue is the complementarity of the map features to an unchangeable visualization background which claims a significant portion of the graphical fill (this issue of course existed before, in cases of special thematic maps hand-drawn over a standard topographic map). But successive conceptual limits are maybe more important than technological limits. The role of cartography has changed during times from a recording of topography to imaging of the visual representation of a spatial knowledge. With this shift, a thematic visualization became *raison d'être* for the cartographic science. In new environments, especially 3D or quasi 3D ones, is topography again dominant issue, and more over, there is a little space for an efficient transfer of thematic information (main value of the thematic visualization is representation of patterns and comparison of features, this is simply matter of displayed extent). On the other hand, there is a huge amount of advantages, which new technologies offer to the cartographic representation. There are common advantages of computer environment like user interactivity or a visual and contentual variability that allow a map adaptation and geo-location support. Beside these features, new environments are more accessible to regular reader due to the lesser abstraction of representation. Basically, maps are created for users, so despite serious obstacles, it is necessary for cartography to enter such environments.

The most visible representatives of above mentioned “new” environments are virtual globes, virtual realities and augmented realities. These environments are often mutually linked by geo-services (for example Google Earth is an virtual globe, with a possibility to dislocate virtual 3D objects on it, in addition there is a link on Google StreetView,

which is, in some sense, an augmented reality service), but each of them introduce a separate issue to cartography. This paper is focused on an augmented reality (hereafter AR) which is conceptually the most distant from cartography. The reason is an increasing importance of this type of the visualization tool.

From the Digital Earth point of view we can observe steadily growing world-wide databases of geo-located photos and also increasing coverage by panorama systems like the above mentioned Google StreetView. These tools allow virtual travelling in desktop computer environments. Moreover, increasing amount of mobile devices, equipped with cameras, GPS, orientation sensors and access to geo-services, create a visually attractive tool competing with mobile maps. For practical reasons, we will use the StreetView as the main background for the description of AR issues represented in this paper. The StreetView service can be used as a virtual travel tool, a specific mobile AR tool and finally like a simulation of real-time AR services.

There are different understandings what encompassing the cartographic approach within the new geo-aware environment means. The obvious way is to incorporate a map like representation into the target environment's visual field (for example overview map with visualization of view field). This way is to some extent generally useful, but from cartographic point of view it is just a design of a simplified traditional map. We would like to consider a different point of view - how to define a cartographically conform visualization within the target environment. For this we need to discover how to:

- **Exploit abilities of the environment** – it is pointless to try to emulate the traditional map. New environments have abilities which make them attractive and usable, the enforcement of the look and handling mechanisms of traditional maps has usually detrimental consequences.
- **Transfer cartographic principles of definition and handling of abstract features.** Cartography has a long tradition of visual representation of spatial knowledge. There are verified mechanisms how to deal with graphic variables of symbols, how to generalize symbol arrangement etc. Nevertheless, there is always a necessity to confirm cognitive mechanisms in the new environment due the fact, that not everything can be transferred.
- **Integrate thematic visualization into the new environment** - as was previously mentioned, the dominant focus of the modern cartography is to discover new ways how to represent spatial patterns. In this respect, especially in the case of the AR, we must be realistic. The amount of concurrently displayed abstract features is very limited due to the nature of the environment and as such, the space for the cartographic visualization is very tight. For the establishment of patterns or relations we need to rely almost completely on the long term memory.

## 2. AUGMENTED REALITY

Before we start the discussion about cartographic procedures within AR, we need to clarify the usage of this term in the frame of this paper. Basic reason for the terminology specification is not only formal. Very wide usage of the term AR encompasses variants of it, which are out of the focus of this paper. The core of our discussion is augmentation of a panoramic view derived in real time from mobile camera device or, more significantly, from a global database of panoramic views accessible through internet services.

### 2.1 Scope of the AR

In one of the early definitions by Ivan Sutherland [1968] is an AR described as a virtual world supplementing the real world with additional information. Such definition can cover an immense amount of interactions between the real and the virtual world. The practice of an early virtual reality was strongly related to the usage of a head mounted displays showing information overlay in front of the user's eyes. In the later definition of the AR, used in [Caudell and Mizell, 1992], is accented computer origin of the virtual part, which is overlaid on top of the real world. Despite the fact, that the definition still remains very open, it more reflects practice. Classical definition is provided by R. Azuma [1997], describing the AR as systems that are characterized by three following characteristics:

1. Combines real and virtual;
2. Is interactive in real time;
3. Registers in 3D.

Motivation for introducing such a definition was to exclude from the AR movies, rich in virtual figures and decorations. The other target of exclusion from the definition was 2D drawing overlay. This kind of visualization is nowadays usually considered as a kind of the AR if it fulfils the condition of interactivity.

From the practical point of view we can distinguish following cases of the AR:

- **"X-ray vision"** - with an aid of a head mounted display is 3D scheme of internal features projected over the corresponding object in reality. This technique is often used in engineering and medicine to help with the real world object manipulation. For geo-application there is possibility to use "x-ray vision" for the support of movements in a limited visibility (night, smoke). Nevertheless, because the visual combination of the augmented features with the real world is almost entirely missing, there is a question if it even belongs into the virtual reality.
- **An enhancement of observed real objects by virtual parts** - with a head mounted display or 3D projectors are artificial objects inserted into the reality. Here we are again on the edge of a virtual reality, but the key identifier is, that the significant portion of the real object remains in the observer's view. Typical cases of the "enhancement" are virtual museums or, for us more interesting, combinations of paper maps and 3D objects (3D terrain, 3D land cover features etc.) This type of the AR is more focused on an enhancement of tools for exploration of the reality then on the reality itself. Some applications are also focused on augmenting virtual reality as is for example the case of service augmenting an orthophoto covered virtual globe by dynamic parts which were acquired from live camera sensors.
- **Tagged reality** – directly in the view of the observer are visually identified object tagged with additional information, important for the observer. In this case we can distinguish:
  - o **Real time automated identification of observed objects** (by per pixel analysis of unknown objects or photo comparison). This type of the AR is typical for the military use (for example heads up displays or head mounted displays in helicopters or fighter aircrafts). Nowadays the popular automated face recognition allows also use of this mechanism for civil purposes. The Figure 1. is a screenshot from the Polar Rose demo of the AR system "*Recognizr – Augmented ID*" tagging recognized faces by their internet spaces (facebook, e-mail, ...).

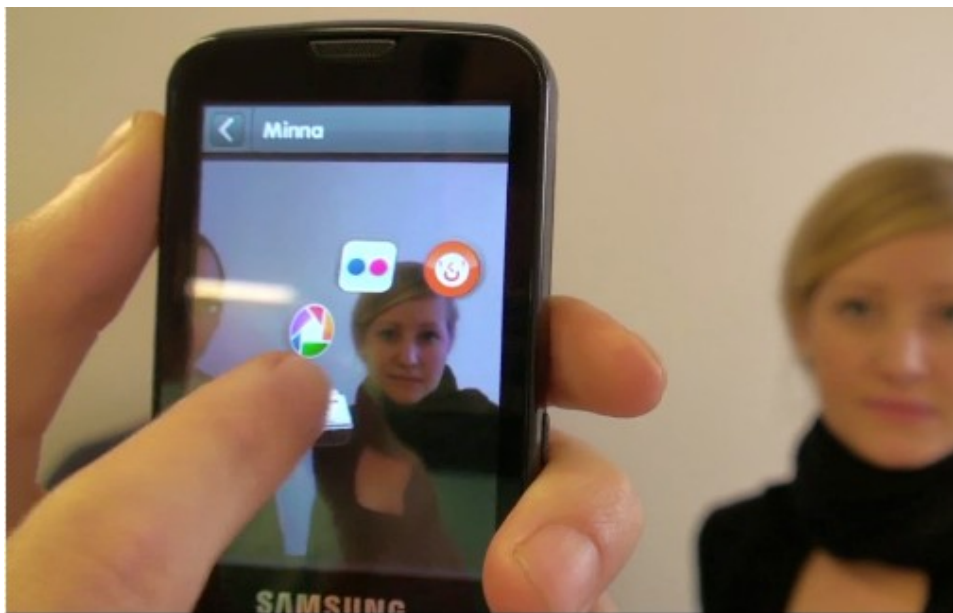


Figure 1. Screen shot of *Recognizr – Augmented ID*

- o **Blind identification by location of the object from existing geo-database** - this is the easiest way how to combine geodata with reality. From the position and orientation of the observer is identified a field of visibility and the 3D objects are selected. From the visual point of view its application is not different from the previous case.
- o **Image overlay derived from panorama photos** - in both previous strategies placement of tags was very imprecise either due to the limited amount of identifiable objects or due differences in perspective of the view between the model and reality. This approach allows us to manually select objects and transform them into graphical features stored in a separate database linked with pictures.
- o **Interactive drawing of the user** - simple case of image overlay, used for collaboration of observers in tasks related to commonly viewed reality. Typical case is so called electronic pen used in TV sport commentaries.

In the frame of the AR are also worth mentioning virtual cases of augmented reality. In virtual reality systems are simulated not only real objects but there are also simulated the enhancements of artificial objects. Especially the world

of a role playing games, where are to some extent simulated AR systems, can be very inspiring for designing of effective visual representations for navigation or information purposes.

## 2.2 The visualization and the AR

Dominant part of the AR research is still focused on the object recognition. Nevertheless, there are some discussions about visualization. The closest to the frame of our interest is approach described in article [Bell, Feiner and Höllerer, 2001], where are identified following constraints for object's tags:

- **Visibility** - objects are classified according to the occlusion by virtual objects. Some of them is always possible to occlude (roads, grass patches), another just temporary (buildings) and some cannot be occluded at all (faces);
- **Position** – the minimum and the maximum distance of a tag from an appropriate object for keeping linkage between them;
- **Size** - limits for tags, a visible tag need to be distinguishable but at the same time cannot cover major part of the view;
- **Transparency** - variable transparency is suggested for compensation of an occlusion - if a tag covers whole objects or its significant part, the tag is made more transparent;
- **Priority** - each tag has appointed priority in case of graphical conflict is just more important tag included into view

The main part of the article's discussion is related to the label placement and is establishing a parallel between the map label placement and the same issue in the AR. Other visualization related articles are focused on cognition issues related to the simple geometric shapes placement in the view. For example in [Livingston et al, 2003] is tested cognition of wired and filed virtual objects in respect to their opacity, intensity and position. The role of symbols is in related articles discussed only on examples - as a description of their particular application. Therefore, we can look at some typical examples of how popular AR services solve the symbol placement and usage.

**Layar** (www.layar.com, Figure 2.) is quite complex AR service and mobile environment, which allows users to create they own layers in a 3D environment and use them together with other available layers. If we are focusing on carto-like layers, there is possible to see two significant types of representation. The first case is composed from simple geometric symbols - symbol in focus is visually highlighted and supplemented by tag (photo, icon or text). Symbols are displayed either horizontally, displaying direction, or slightly inclined to the display's position. The user can filter symbols by the maximum distance and by an attribute. In fact, the link between symbols and reality is very low, as it shows only directions. The second case is limited to immediate environment – there are icons, appearing near to real objects hyperlinked to the detailed info.



Figure 2. The Layar on the mobile device, available from <http://www.soundwalk.com/blog/2009/08/17/augmented-reality-soundwalk-with-layar/>

**Wikitude** by Mobilizy ([www.wikitude.org](http://www.wikitude.org), Figure 3.) is, like in the previous service, an AR environment with open application interface (API), allowing to the user creates “words”. Symbols are simple rectangular bubbles attached to real objects. Bubbles are graphical symbols defined by user. The symbol in focus is supplemented by transparent bubble with info text.

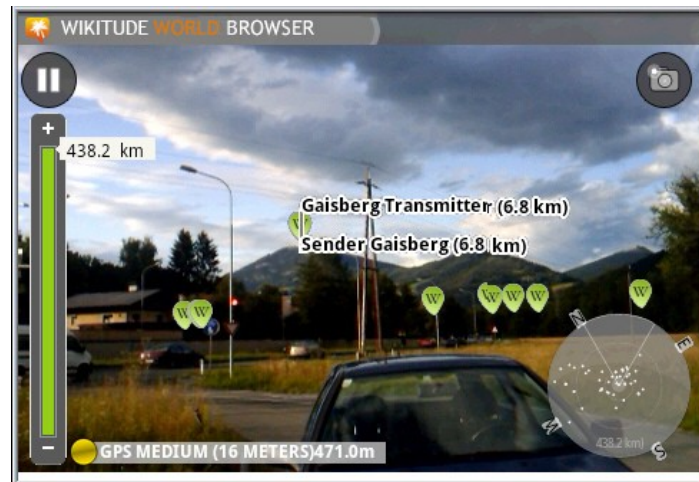


Figure 3. The Wikitude on a display, available from <http://theunlockr.com/downloads/android-downloads/android-applications/>

**Nearest Tube** by acrossair (<http://www.acrossair.com>, Figure 4.) is application for iPhone, showing the way to the nearest underground station when moving through London. When the user is holding the device flat, lines of the London underground are displayed as coloured arrows. By tilting the phone upward, symbol of the nearest station appears, together with the information about the direction, the distance and the line in relation to user’s location. By continuing to tilt the phone upward, the stations further away appear as stacked icons. There are two interesting aspects from symbology point of view in this type of visualization. The first is the usage of a usual underground line logotype and the transparency of the info-block, the second aspect is the change of content based on the horizontal angle of the device. The application exists also for Paris, Barcelona, Madrid and Washington Metro, New York and Tokyo Subways etc.



Figure 4. The NearestTube – mobile phone and reality, available from [http://images.businessweek.com/ss/09/11/1102\\_best\\_iphone\\_reality\\_apps/7.htm](http://images.businessweek.com/ss/09/11/1102_best_iphone_reality_apps/7.htm)

**VirtualCable** from Making Virtual Solid, LLC ([www.mvs.net](http://www.mvs.net), Figure 5.) is very simple representation of a track. It consists just from red line above the road. To know the immediate movement of the track gives advantage to the driver especially during the night ride. From the symbology point of view, the visualization is very efficient and understandable, but its usage is limited.



Figure 5. The VirtualCable in the night, available from <http://www.mvs.net/>

**StreetView** by Google ([maps.google.com](http://maps.google.com), Figure 6.) is panoramic photo service, which is in its raw form supplemented only by the labelled semitransparent line, representing the road. The service has documented API, so each user can provide his own graphical overlay with the aid of standard html technologies. StreetView was used for simulation of AR in the research presented in this paper.

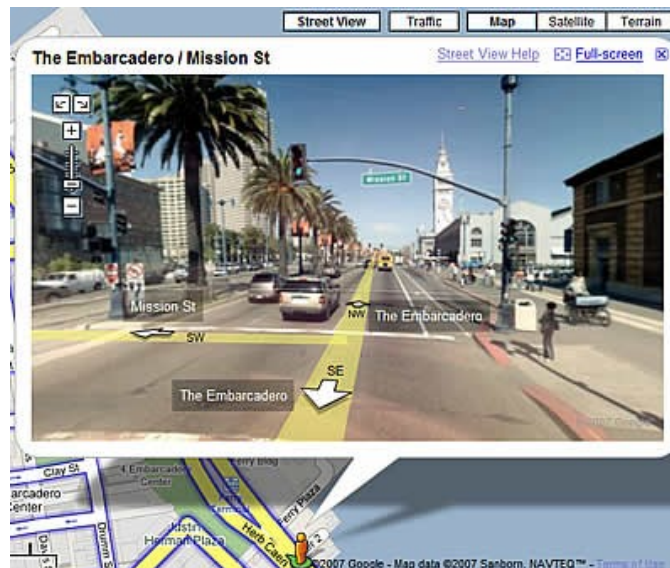


Figure 6. The StreetView by Google, available from <http://www.topnews.in/google-street-view-alluring-mapping-scheme-2256728>

It is obvious that the most of the above mentioned services allows users, in accordance with Web 2.0, to create their own content. The basic symbol placement and the symbol definition logic are quite simple. Except for some collision management there are almost no carto-like constraints involved. The definition of symbols suffers from the syndrome “pushpin cartography” and has strong inclination to the preference of logotypes.

### 3. CARTOGRAPHIC METHODS AND AR

The discussion on cartographic aspects of the AR is usually limited to the two following cases - either is the AR considered as a replacement of the map or a link between reality and the map (or the geodatabase content). The enhancement of the AR representations by the cartographic mechanism is somewhat different approach as will be elaborated further. This enhancement or implementation has considerable limitations imposed by the very principles of use of cartographic representations. Cartographic methods are quite strongly depending on the sufficient spatial extent. The main concept of a thematic cartographic representation is a **parallel display of the detail and the whole**. This concept of dual display is the cornerstone, on which the generated rules, used in the process of generalization and symbolization, are build. An angle and a field of the view in the AR are nevertheless not sufficient to build any visual pattern. While the AR is built over complex graphics and a background, a map of course contains only symbols. The

AR requires sufficient visibility of the background graphic, which means there is considerably less space for symbols. Nevertheless, the requirement for building the comprehensible graphical field remains. In the case of spatial patterns, in the AR the cartographic visualization can only assist indirectly. Far greater role plays the gradual establishment of the pattern in the user's memory.

### 3.1 Applicability of the cartographic methods

The following discussion is not a complete overview of cartographic methods, but only a base selection of those whose use in relation to the AR can be considered meaningful. First let's take a look at the visualization as such, which includes classification and symbolization. For the **visualization** are in cartography used following approaches:

- **The classification of objects to minimize number of features** – based on examples presented in the section 2 is possible to observe that the AR applications use either uniform or individual symbols. It is due to nature of the predominant single issue of the particular AR representation. For the establishment of the spatial pattern the categorization of displayed tags is as helpful as on maps;
- **The minimization of a graphical fill** – there is quite a high amount of the visual information related to real objects. The user can actually easily separate the virtual content from the real one. To maintain at least partial visibility of real objects, there exists significant use of transparency. Nevertheless, the use of transparency is not without its problems, caused especially by subsequent mixing of colours. Tag objects, in relation to the graphical fill, answer to the same rules as objects on the map;
- **Similar function = similar graphics** – has the same issue as a classification in the case of necessity for pattern establishment;
- **Representation of quantities and the visual proportion comparison** – it is important task for thematic cartography, in the frame of the AR are however such expressions meaningless. There is only space for categorization of quality;
- **Change of graphic variables** – given the nature of reality it makes sense to use only a limited number of graphic variables. For the categorization purposes is suitable to change the colour and, in some cases, the shape. The change of the shape and size can be useful also in generalisation procedures;

The second important part of the cartographic process is the **generalisation**. Its' absence is the main issue of the "pushpin cartography". In the scope of the AR we can distinguish following procedures:

- **Simplification of shape** – for technological and cognitive purposes is generally suitable to use simple geometric shapes fitted (with limited precision) to real objects. With the increasing distance from the observer is appropriate to use only uniform shapes (square, circle) for representation of low-visible or in-visible objects;
- **Selection** – with increasing distance increases congestion and imperceptibility. One of the solutions is the selection of important objects. This approach is more useful for real objects that are imperceptible or invisible. In the case of tags belonging to the visible objects is better strategy to aggregate;
- **Reclassification** – the use of this method is in the AR environment questionable as the hierarchization of categories of distant objects has very limited usability;
- **Aggregation** – they patronymic aggregation is especially useful strategy for tags handling. At the close, an object can have tagged detail parts, which will gradually aggregate to the one tag related to the object. The same way tags for individual objects can be aggregated into the one, belonging to the group of objects. When the object becomes imperceptible, it is more functional to use above mentioned selection strategy.

### 3.2 Implementations

The key part of the AR construction is the mechanism of the symbols placement. As was mentioned several times before, it is necessary to prevent obstruction of thematically or topographically important real objects. On the other hand, there is also the necessity to maintain a visual link between real object and its tag. The nearness or semi-identity is from cognitive point of view the predominant tool.

It is possible to distinguish the two basic contexts of the symbology design - **view arrangement** and **depth arrangement**. To the view arrangement refers following options:

- **Uniform front colour filter** – it is the easiest type of the augmentation. Unfortunately, the quantity of transmitted information is very limited and also the cognitive feedback can be unclear in the sense of what real object is targeted. This approach is nevertheless suitable for "catching" of the attention;
- **Structured front colour filter** – a partial analogy can be drawn with gridded map representation. In this case the view is divided into transparent colour cells (possibly enriched by text) with dedicated roles. These roles can relate to the information about dominant covered feature, about near invisible features, or to the display of additional information related to the focus etc.;

- **Virtual signs** – it is basically a simulation of the traffic control. The view is complemented by virtual road signs related to real objects. This very close parallel to the real world is disqualified by the limited amount of appropriate space in the view area;
- **Non-building areal coverage** - grass areas, roads and sky present usable space for placement of information. Nevertheless, from the technological point of view, the implementation of such an approach would be quite difficult. Another complication is a greatly varying amount of usable space for displaying information in similar views;
- **Coloured features** - the reality is overlaid by transparent version of the objects, filtered by one particular colour. This approach can be particularly useful in the case of a grey toned background. The disadvantage of this method is fluctuating reliability of the real object's shape identification and also a limited possibility to use additional virtual objects;
- **Rectangles over objects** - simple and effective way to appoint real objects. For visual understanding is sufficient to combine opaque outlines and a very transparent fill. The only technological complication is a transformation of rectangles in relation to the angle of the view;
- **Text bubbles** – a very frequent way to appoint tags to the object. There is an easy parallel to the visualization of a dialog in graphic novels, but if we are looking for quick look, the identification of attached objects can be unclear. The advantage in using bubbles is the possibility of a rich internal content; nevertheless there are issues with possible congestion and overlaps;
- **Symbols attached to the object** – from the technological point of view it is the most simple and also the most cartographic approach. The effective use of the symbols is strongly related to proper generalization procedures. To effectively use attached symbols requires, the same way as in cartography, at least some level of adoption of the concept on the side of the user.

According to the 3D aspect of the AR, the depth of symbol placement is an important aspect of visualization. We can adopt following approaches how to deal with depth

- **Placements in perspective** – symbols, including their position, are defined in 3d environment, usually on a virtual globe. The rendered scene, composed from virtual objects, is superposed over a panoramic photo view. Tremendous complication is the precision of the placement. On the other side, advantage is an easy synchronization during the change of observation parameters;
- **Front layer** - for selected views are prepared drawings which are superposed over the photo view. Precision is better than in the case of the placement in perspective, but there is necessity to apply transformation logic on the drawing, to ensure synchronization with the panoramic view;
- **Modified photo** – is the most precise way of the placement, but it is very exhausting when processed manually. And automatic variants have still limited options (for example the face detection is nowadays widely supported).

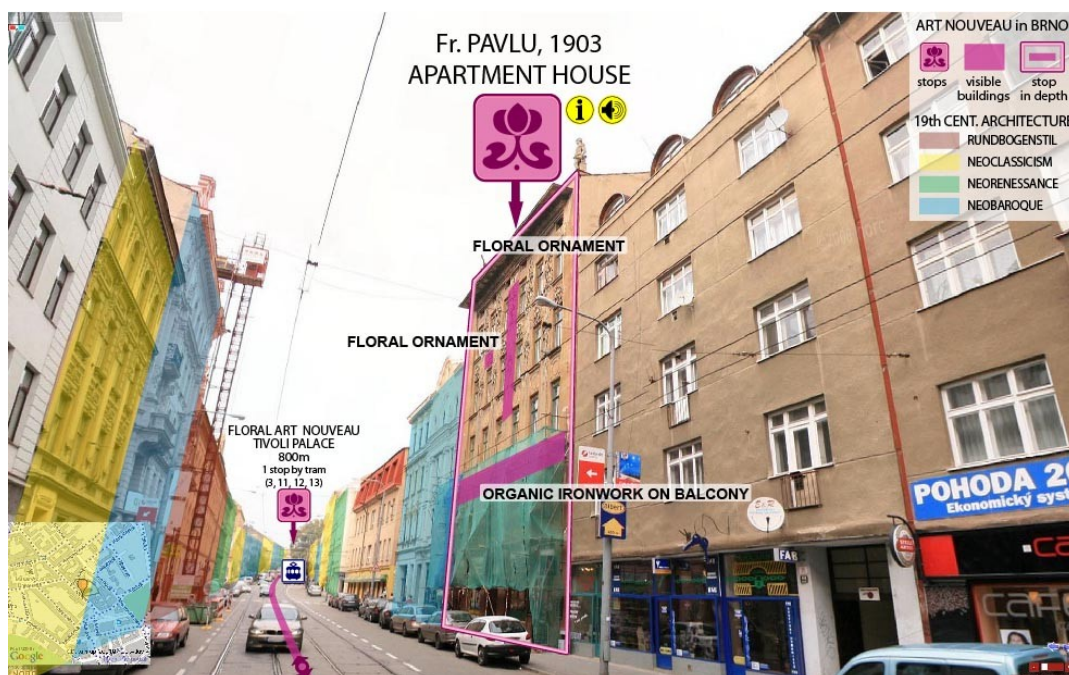


Figure 7. Example of cartographic methods testing within the AR simulation

After careful consideration we have used for the view arrangement method rectangles over object in combination with text bubbles and symbols attached to the object. For the depth handling the front layer approach was used. The initially chosen technologies - combination of javascript, html and Google maps API - were not possible to apply, because unfortunately, in the chosen area there was insufficient Google StreetView coverage. As the substitution of the Google StreetView was used panoramic system NORC. The NORC system is working in krpano flash based panoramic viewer, parameterised by XML definition files and accessible via javascript.

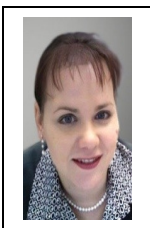
#### 4. CONCLUSION

With the easier availability of the Internet services dealing with panoramic photos, the testing of the AR representations have become more accessible. For cartographic research it is an interesting opportunity. Despite the differences between a map and the AR, there are also many similarities. The similarities between the two literally call for the introduction of methods used in one environment into the other, or to put it differently, they call for the use of cartographic methods in the AR. After the initial exploratory phase, when the possibilities of cartographic methods application in the AR were evaluated, we expect to continue to design the AR system. It is obvious that more cognitive tests for evaluation of variants of the symbology management will be necessary. The only drawback of the web based simulation is the inability to use inertial sensors inside mobile devices. Another option would be to use parallel virtual reality on mobile devices. It is necessary to determinate how far is possible to push the level of abstraction, before the connection, the mental link, between the reality and the representation of the spatial information, is interrupted.

#### REFERENCES

- Azuma, R.T., 1997. A survey of augmented reality. *Presence - Teleoperators and Virtual Environments*, 6 (4), 355–385.
- Bell, B., Feiner, S., Höllerer, T., 2001. View Management for Virtual and Augmented Reality [online]. In *Proceedings of the UIST '01*, Orlando: UIST, 101-110. Available from: <http://graphics.cs.columbia.edu/publications/uist01.pdf> [Accessed 21 February 2010].
- Caudell, T. P., Mizell, D. W., 1992. Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes. In *Proceedings 1992 IEEE Hawaii Intl. Conf. on Sys. Sciences*, Kauai: IEEE, (2), 659-669.
- Livingston, M. A., Swan, J. E., Gabbard, J. L., Höllerer, T., Hix, D., Julier, S., Baillet, Y., Brown, D., 2003. Resolving Multiple Occluded Layers in Augmented Reality. In *2nd Int'l Symposium on Mixed an Augmented Reality*. Tokyo: IEEE, 56-65.
- Sutherland, I., 1968. A head-mounted three dimensional display. In *Proceedings of FJCC*, Washington, DC: Thompson Books, 757-764.

#### BIOGRAPHY



**Lucie Friedmannova** is a researcher at Department of Geography, Faculty of Science, Masaryk University in Brno, Czech Republic, where she also holds courses on Cartographic Visualization. Her research interest lies in cartographic visualization, cartographic design, relationship between art and cartography and visualization for crisis management. She is a member of ICA working group on Art and Cartography. Lucie Friedmannova has Master degree in Geography and Cartography and Ph.D. degree in Cartography, geoinformatics and Remote Sensing. She also studied the General Theory and History of Arts and Culture.



**Karel Stanek** is an Assistant Professor of Cartography and Geoinformatics at the Department of Geography, Faculty of Science, Masaryk University in Brno, Czech Republic, where he holds courses on analytical cartography, theoretical cartography, computer graphic and geoinformatics. His main research interests lies in the area of automated cartographic generalization, cartographic visualization and designing of electronic maps. He is a member of ICA working group on cartographic generalisation and multiple representations. Karel Stanek has Master degree in Discrete Mathematics and Ph.D. degree in Cartography, geoinformatics and Remote Sensing.