3D City Model Visualization with Cartography-Oriented Design

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1   ABSTRACT

This paper investigates and discusses concepts and techniques to enhance spatial knowledge transmission of 3D city model representations based on cartography-oriented design.

3D city models have evolved to important tools for urban decision processes and information systems, especially in planning, simulation, networks, and navigation. For example, planning tools analyze visibility characteristics of inner urban areas and allow planers to estimate whether a minimum amount of light is needed in intensely covered areas to avoid "Gotham city effect", i.e., when these areas become too dark due to shadowing. For radio network planning, 3D city models are required to configure and optimize wireless network services, i.e., to calculate and analyze network coverage and connectivity features.

3D city model visualization often lacks effectiveness and expressiveness. For example, if we analyze common 3D views, large areas of the graphical presentations contain useless or even "misused" pixels with respect to information content and transfer (e.g., pixels that represent several hundreds of buildings at once or pixels that show sky). Typical avatar perspectives frequently show too many details at once and do not distinguish between areas in focus and surrounding areas.

In this case the perceptual and cognitive quality of visualized virtual 3D city model could be enhanced by cartographic models and semiotic adaptations. For example, we can integrate strongly perceivable landmarks as referencing marks to the real world, which establish more effective presentations and improve efficient interaction.

The referencing aspect in depictions of 3D city models is essential: Only correctly perceived elements can fulfill referencing tasks. With misleading perception, the same elements may cause false understanding. This circumstance leads to media-dependent semiotic models that aim at supporting effective transmission of spatial contents.

This contribution compares different dynamic 3D visualization approaches for virtual 3D city models and demonstrates applied cartographic techniques to enhance information transfer. The underlying concept is based on a model for 3D semiotics, includes a number of pragmatic components, and presents examples of visualizations of adapted 3D city model visualizations.

2   INTRODUCTION

Virtual 3D city models evolve to substantial tools in planning, analysis, documentation and heritage management. Their power to support naïve geography is used by the wide public and results in easy understandable geospatial presentations. In contrary to traditional 2D maps with highly abstracted contents, map elements in 3D follow some natural/naive coding that can easily be accessed even by layman in map-reading. For instance Gaerling and Golledge (1993), Keller (1993), Robinson (2004) or Anglin (2004) see map-reading as subject to education processes: the reconstruction of coded information must be learned throughout years for specific cases of application (politics, topography, ...).

The use of virtual 3D city models as main communication tool in a wide public assumes the correct handling of transmitting media, which means that the content is unmistakably perceivable. This handling of transmitting media will have to bear in mind resolution, extension and interaction issues. In most cases transmitting media will be in form of large format displays, touchable points of interest (touchscreens) or even multi-touch large displays. Resolution issues mainly follow rules of expressiveness, where the content has to be adapted to the transmitting characteristics of the media. Issues of transmitting media extension underlie expressiveness as well as effectiveness, especially when a large display also enhances resolution and thus supports deeper information content and expands field of vision as important depth cue parameter at the same time. Interaction issues are mainly subject to effectiveness, when the impact of contents can be enhanced via multiple coding and mouse over events. All cases are reliant on and focusing at appropriate use of transmitting values. Picture elements are generally restricted and thus have to specifically used. Each pixel

is able to transport one information value. Therefore concentrating several information values to one single pixel leads to perceptional problems that will cause, e.g., undifferentiated pixel areas. In the following these areas will be called "dead values" of the presentation interface. Especially virtual 3D city models easily contain dead value areas due to lacking generalization algorithms for 3D building aggregation, simplification or appropriate highlighting. At least the aim is to reduce dead value areas in virtual 3D city models by viewport variations and simple cartography-oriented design.

The following aspects list the actual status of 3D city models today, explain the main requirements of cartography-oriented design, exemplary analyze actual virtual 3D city models, and describe one basic approach to minimize dead value areas in virtual 3D city models.

3   VIRTUAL 3D CITY MODELS TODAY

The use of 3D city models for planning, analysis, or documentation has been established in the last decade. In former times, physical models had been used for these tasks for a long time and still form an important presentation medium, particularly when public is involved in decision finding processes. Although virtual 3D city models add to these working mechanisms and provide higher flexibility with respect to the contents, which helps for planning as well as analysis issues, a pragmatic use of virtual models is still not that accepted as physical models. The main reasons claimed by planning institutions include time-consuming model generation and complicated interaction handling [Lubanski 2007]. The time needed to generate models depends on the degree of automation and the required graphics and appearance complexity. For 3D expert users, the model generation does not overtop a comparable physical modeling process, even if no automatisms are incorporated. Graphics and appearance quality, e.g., physically-based lighting, requires detailed modeling processes, which have no direct equivalent in the case of physical models, e.g., night and day situations.
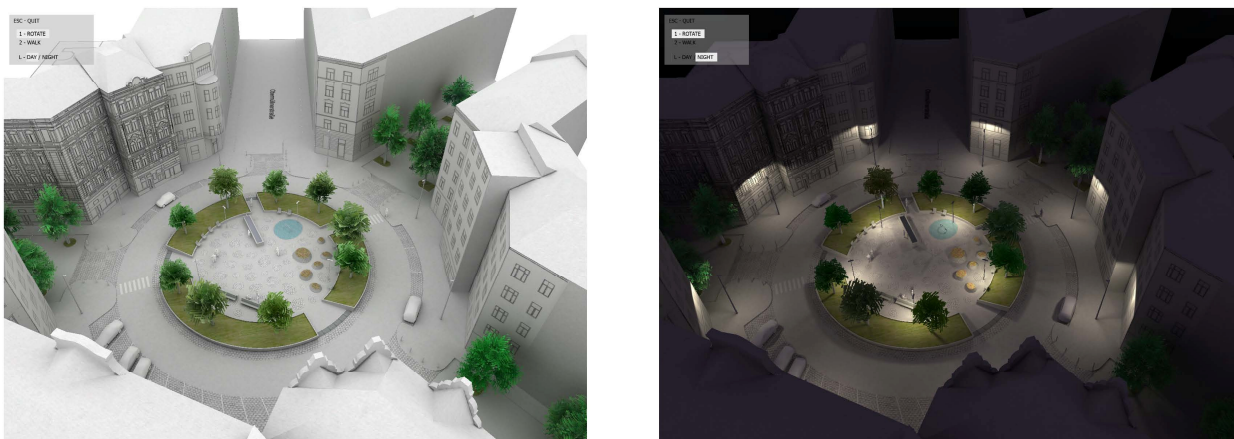

Fig. 1: Lighting situation in a non-photorealistic virtual 3D city model; published with authorization, by Lubanski 2007.

Lubanski (2007) could show in his work that virtual 3D models are accepted in the same way physical models are, if several conditions are fulfilled. He used physical models and virtual 3D city models of specific projects at the same time to discuss the planning situation and used questionnaires to reach first results. The necessary conditions that were identified in these questionnaires focus on automated generation, platform independence, and naïve user interaction in context with clear perceivable content. An automated generation of virtual 3D models concerns economic values as in most cases there is no time and budget for detailed, time-consuming hands-on modeling. Therefore cut backs are accepted in may cases. An automated or even semi-automated creation process would help to establish virtual 3D city models as discussion tool in planning processes. Platform independence applies to requirements of a virtual 3D city application on a guest system. For instance a client's engine uses an old graphics card or the application has to be shown on a laptop. Then the application has to show the same result as on the designing engine without requesting Plug-Ins or similar premises. For this reason encapsulated applications served best for Lubanski (2007). When virtual 3D models are embedded in an executable file that incorporates all premises, the chance for portability is high [Quest3D, Acrobat3D]. Naïve user interaction names the users' real-world movement simulation by an interface. The more a realistic movement can be simulated by an interface, the more

familiarity a user will have. At least the interaction with mouse should be as easy as possible to reduce cognitive load.

Virtual 3D city models are not only used in the domain of planning. Other important areas are analysis, documentation or heritage issues. Here the applicability does generally not follow as strict economic guidelines as in the area of model creation for planning issues, but has different concerns. Analysis calls for precise reconstruction, a well-defined topography and a working topology within the virtual 3D city [Hilbring 2002, Germs et al 1999]. Applications are then used for various kinds of distribution models' analysis (Telecom, WLan, ...), flood analysis or even a building's shadow and reflected sunlight movement´s analysis for planning the traffic spoiling. Documentation and heritage issues focus on open and well-documented file formats as well as Open Source viewing applications. The aim is to keep up the model's access in future and thus provide sustainable documentation [Fleet 2007]. In combination with high quality recording methods (e.g., laser-scanning, photogrammetry), reconstructions of endangered or lost architectural treasures should be enabled. Its importance on a virtual 3D city model level became once again obvious when the World-Heritage site, City of Bam, Iran, was destroyed by an earthquake in 2003 [UNESCO].

Nowadays virtual 3D city models affect working procedures and their initial intentions, expand traditional contents and thus broaden traditional fields of usage. The virtual 3D environment's existence and its public access (e.g., via Google Earth, Virtual Earth) provide a geographic fundament that can easily be adapted and expanded to personal needs or targeted statements [e.g. Boulos 2007]. The main working procedure does not superficially focus on model creation, but on adapting and expanding the existing fundament to a specific statement. The adaptation mainly uses thematic topics, 3D city model extensions [e.g. SketchUp] or time-based developments. Virtual 3D city models especially expand traditional geospatial information systems (2D maps, 3D terrain models, etc.) with varying details for the buildings' third dimension. According to the model's precision and complexity diverse problems can be attended. Complexity reaches from block models, which simply extrude the building's footprint, to precise models that combine roofs, facade details, and precise topographic surfaces.

However, although existing applications expand usage, traditional content and help to focus on initial intentions, their presentation form has not reached a satisfying status for most of uses. From a cartographic point of view, enhancements for 3D views are needed that remove restrictions of digital maps and support general tasks of cartography.

4   REQUIREMENTS OF CARTOGRAPHIC DESIGN

A general task of cartography can be seen in expressive communication of geospatial content, which means that map elements are clearly readable, follow their semantic meaning, and are useful for a specific aim. In addition to these preceding terms of expressiveness, effectiveness enhances the pragmatic dimension and provokes naïve interaction [Mackinlay et al 1990]. Effectiveness describes the impact of interface capabilities on the user, who is the recipient of the geospatial human-computer interaction. Virtual 3D models support effectiveness if appropriate interfaces, that support human behavior or at least human depth cues, are used. In terms of expressiveness many examples lack of perfect integration, which can be traced back to main restrictions in digital cartography and usable transmitting media.

Restrictions in digital cartography base on transmitting media's extension and resolution [Kraak et al 2000]. Several actions that help to overcome these restrictions (panning, zooming, etc.) take up additional cognitive load, which deflects from directed information extraction and thus complicates the usage of the map [Blackwell 2000]. Extraordinary large displays, as these are used for HDTV in home cinemas, are not a serious solution at the moment. These interfaces will bring a higher extension of the viewing plane, but do not increase resolution in a way that it would be useful for digital cartography. Similarly, projectors (beamers) result in a large viewing planes. Their resolution is fixed to standard display resolutions (VGA, SVGA, XGA). Thus the size of the projected picture element increases and becomes clearly visible if the viewing distance is not changed. Therefore the information content is not increased compared to standard displays [JOBST 2008]. Although perspective 3D views contain main geometric disadvantages, these characteristics can be used as an advantage, especially when infinite numbers of scales can be combined in a "natural" way or spatial content becomes accessible by naïve interaction in the virtual world. The main

advantage of scale combination is the direct and intuitive comparison of large and small scales, which would be neither possible in a single large nor a single small-scale map alone.

Cartographic design for virtual 3D model visualization should consider internal as well as external components of the presentation form. Internal components include element-based adaptations, such as appropriate generalization, element combination, and rendering methods. Depending on camera distance and viewing angle, details of information elements need to be changed in terms of aggregation, highlighting, or selection. In the same way rendering methods provide a wide range of mechanisms to support a clear graphical language for information transmission. For example non-photorealistic renderings with their ability to directly use graphical variables according to user interface specifics will be more expressive than indistinguishable photo-realistic textures for specific camera distances and viewing angles. At least nine graphical variables (form, color, brightness, pattern, orientation, size, transparency, position xy) can be used to build up expressive information elements out of a far larger amount of data [Bertin 1974, MacEachren 1995]. A selection of data and assessment of priorities has to take place.

The external component of the presentation form contains viewport variations. Whereas classical 2D maps make use of orthographic top-down views, which are the result of any geographical projection, 3D visualizations consist of all geometric freedoms for the viewport depiction, which span from perspective to orthographic views. Following considerations will exemplary analyze actual perspective views as these are used in most common virtual 3D city models. A marking of ineffective picture values (dead values) will then lead to possible ways for varying the external component and enhance information transmission.

5 EXEMPLARY ANALYSIS OF ACTUAL VIRTUAL 3D VIEWS

Perspective views are defined by camera parameters for projection and viewport. These parameters define the field of view, camera distance, and orientation within the 3D scene. Changes of these parameters can rapidly change the amount of "dead values" in the resulting virtual 3D city visualization due to perspective characteristics and transmission media attributes. Dead values define picture elements that cannot clearly transmit information, i.e., these pixels cannot clearly be related with the embedded elements or the overall visualization topic.

Fig. 2: Standard perspective views of 3D city models. Produced by the LandXplorer system.

Expanding the field of view results in a higher degree of perspective distortion. Therefore, a higher range of scales from the foreground to background can be combined. This also means that the range of element details highly varies throughout the depiction. Whereas large-scale elements in the foreground have to be very detailed, the recognizability of distanced elements declines with increasing camera distance. If no cartography-oriented adaptation is done, dead values increase with an increasing FoV. As consequence generalization algorithms have to be incorporated according to field of view, camera distance as well as graphical values should be more clearly applied via formalized rendering.

By reason that 3D views combine ground-view and front-view, either the ground-view or front-view has to be accordingly enhanced, depending on the view-angle of the camera. For example it does not make sense to enhance the footprint of a building when looking at the front-view. Therefore the characteristic of the front-view has to be highlighted, if that specific object is important for information or specific task, e.g., as visual landmark.

Depending on the viewing angle the information area becomes restricted or consists of massive overriding. A top-down view or ground view will be restricted according to transmission media's resolution and extension. The extreme case of 90 degrees results in a perspective distorted "2D map". Then, buildings are overturning according to their height and field of view. On the other hand a viewing angle of 0 degrees, as it will be the case for natural views or ego-views, which simulate a person's view, consists of massive overriding, which uses highest detail (largest scale) near at the camera. In this case information contents will mostly be dominated by the first buildings, which override other content of the virtual 3D environment. This situation prevents the perception of reference points, which will be used for orientation.
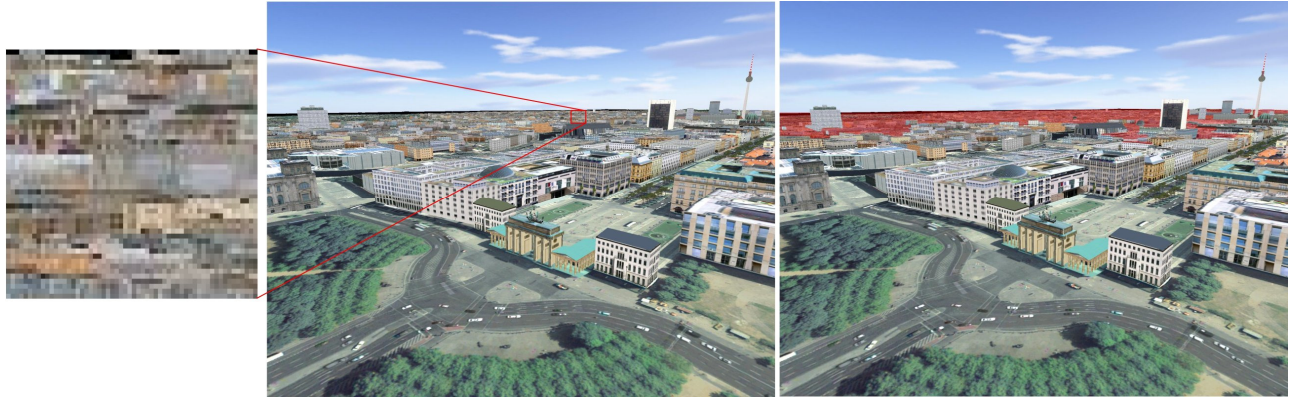

Fig. 3: Dead value identification in a standard perspective view, Produced by the LandXplorer system, interpreted by Markus Jobst.

Apart from the two extreme cases a virtual 3D model will generally be used in a mixed situation. Hence information growth bases on the mixture of ground view and front view. Depending on the viewing angle we can observe an increasing field of dead values, if no semiotic rules (for a cartography-oriented design) are adapted to the elements. The smaller the viewing angle becomes, the more dead values occur. This effect is coherent with a reduction of the buildings' footprints size on the transmitting media. An adaptation of the map elements' footprints according to generalization rules is one possible solution. Viewport variations for the virtual 3D environment are another possible approach, which may establish new perspectives in 3D visualization pragmatics.

6 POSSIBLE WAYS FOR SOLUTION: PROGRESSIVE AND DEGRESSIVE PERSPECTIVES

The increasing areas of dead values for specific situations (camera parameters and positions) on most digital transmission media illustrate improper semiotics and the need for cartography-oriented design. Extending viewport projections in terms of reducing dead values and enhancing specific information to increase spatial literacy is one possible approach beside element based modifications. First, this extension of viewport projection is formed by a progressive or degressive perspective, which either reinforces perspective linearity or uses "blank" picture values, like in the sky area, for an overview.
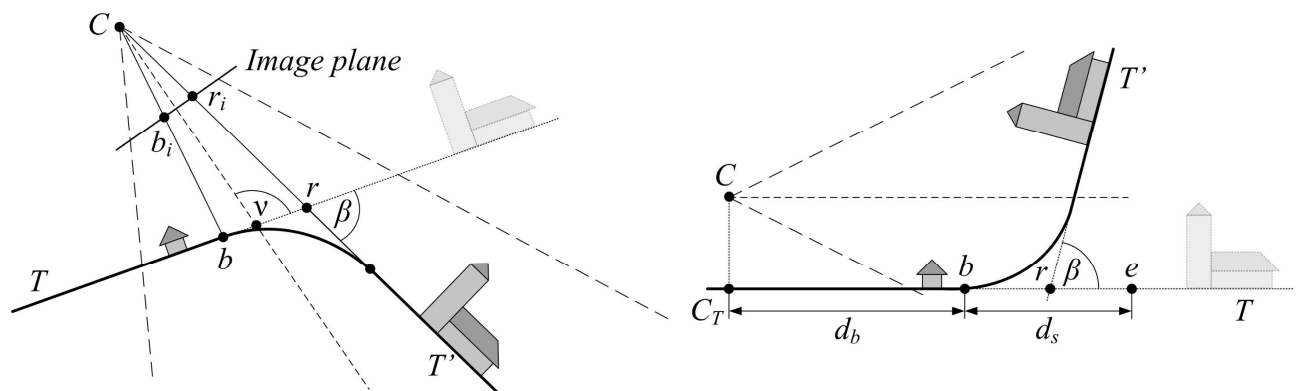

Fig. 4: Progressive and degressive concepts of a bending ground plate, based on Lorenz et al 2008.

Both concepts are implemented by a bendable ground plate that amplifies ground view and front view. Both parts of the plates are connected with a transition zone, which depicts as concave molding. This concave molding generally disturbs progressive as well as degressive perspective due to bended elements/buildings.

Therefore this zone should be reduced to an almost invisible size that simply helps for a homogeneous transition from one plate's part to the other.
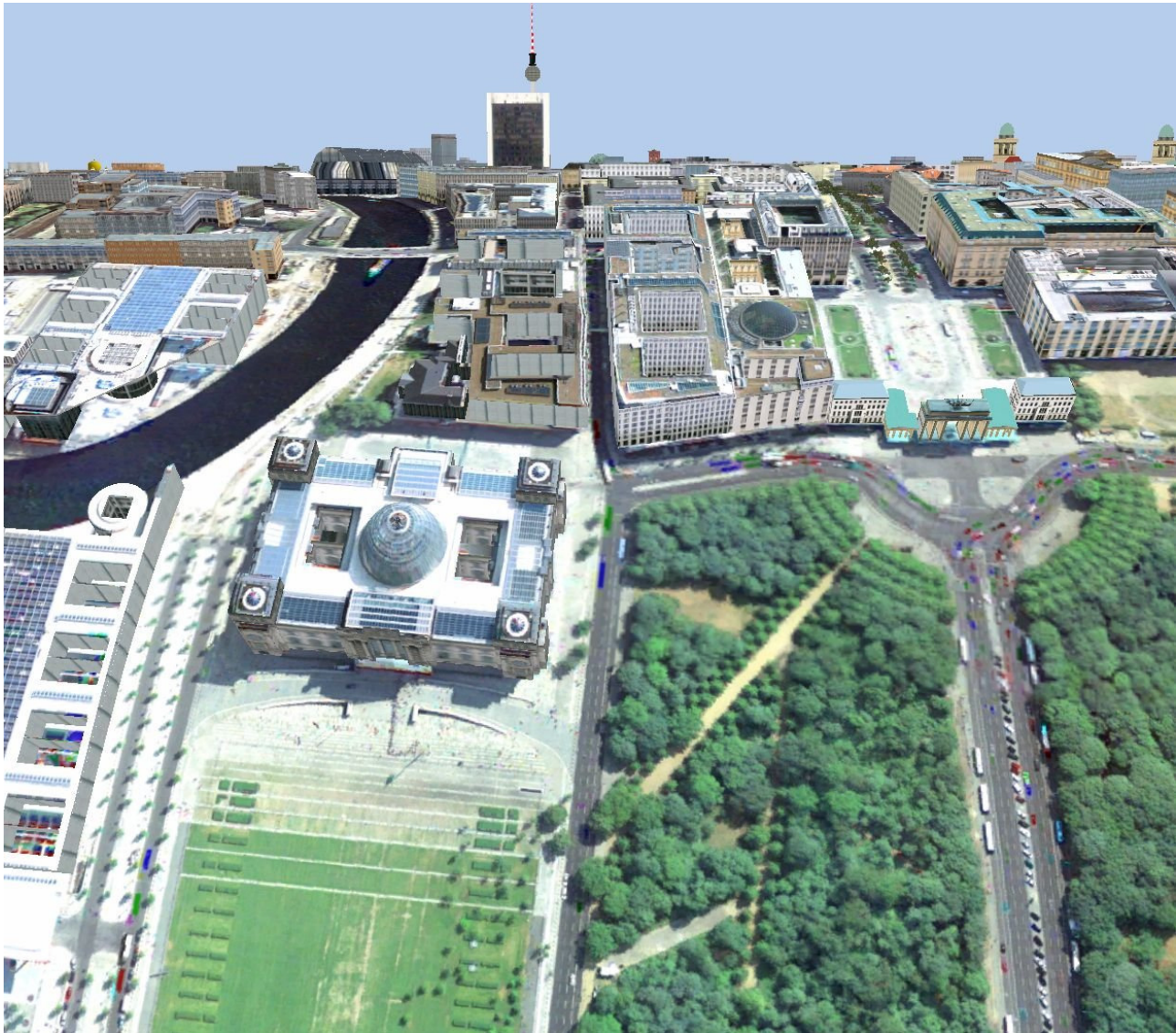

Fig. 5: Progressive perspective view of Berlin 3D. Produced by the LandXplorer system, based on Lorenz et al 2008.

Progressive perspective intensifies perspective impression by forcing a ground-view nearby the camera and a front-view for far elements. A similar technique was used by various panoramic landscape painters to highlight selected element's front view in the background of the presentation. In fact the enhancement of the ground-view in the foreground presents an overview around the current position that can clearly communicate the buildings' footprints and thus also transmits topological structures of this virtual geospatial space. Forcing a front-view in the background removes almost all footprints, but enhances visual landmarks by their front-view (as the buildings are seen in reality). A highlighting of the "important" buildings' front view will then allow to get an overall direction for the movement in virtual 3D space and more precisely build up a mental map.

In addition the progressive bending of the ground plate leads to a reduction of dead values. On account of the enlarged ground-view and front-view zones transmitting pixels of the interface are more appropriate used for information transfer. The area of dead values on the transmitting interface can be enormously reduced. Independent from usability the syntactic aspect of cartographic semiotic could be enhanced.

Fig. 6: Degressive perspective view at various camera heights. Produced by the LandXplorer system, based on Lorenz et al 2008.

On the contrary degressive perspective generally destroys perspective view, although perspective distortion exists in all parts of the picture. Degressive perspective changes the bended ground plate in a way that a front-view area dominates the picture near the camera and the sky area is used for the ground-view of far elements. Also this kind of presentation form can be meaningfully used. The front-view near the camera generates a high identification with a specific area. If this area should deal as reference area for real-world objects, then high quality rendering and detailed modeling has to be used for these large-scale regions. The massive overriding in the front-view region and the sky area are used by a bended ground-view part. This will allow users to get a wider overview for far objects and support individual geospatial planning. In order to not confuse a user that much, the rendering method should be changed for the ground view according to its scale and aim of action.

Although this degressive perspective takes time to get cognitively used to, a useful application can be seen. On one hand an efficient reference area can be established, on the other hand prospective tour visualization is supported. Regarding dead values on the presentation area, more information transmitting pixels can be used. The area of dead values on the interface becomes reduced.

7   CONCLUSIONS AND OUTLOOK

We can conclude that innovative techniques of cartography-oriented design in virtual 3D city visualization can enhance information transmission in terms of dead value minimization. The modification of standard perspectives with the techniques of progressive and degressive perspectives reduces dead values on the information interface. Consequently, the restricted interface space can be used more effectively for information transfer. It also shows that traditional 3D projection techniques, constrained by the underlying 3D hardware for a long time, now allows us to consider advanced, cartography-oriented projection concepts.

The impact on a recipient's mental model due to these presentation techniques has to be proven in further research. It is an open question if this syntactic approach is also valid by semantic and especially pragmatic means. User testing for various application fields will deliver answers in future.

8   ACKNOWLEDGMENTS

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