FLÄVIZ IN THE REZONING PROCESS

A Web Application to visualize alternatives of land-use planning

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Abstract. The rezoning process primarily deals with proposed changes on land-use and zoning plans. More and more often, the public is asked for its opinion and feedback. However, there are two main obstacles in today's practice: On the one hand land-use and zoning plans, in general, only define the potential of areas and so do proposed draft plans; they usually say nothing about the implementation of land-use in the built space. On the other hand, the untrained majority can hardly grasp the current form of representation as two dimensional plans with accompanying written information. In order to enable a wider public participation (and understanding), the authors present FLÄVIZ, a 3D visualization of potentials on land-use and zoning plans.

Keywords. Alternative land-use and Zoning plans; Three JS; Visual Representation.

1. Introduction

Land-use plans aim to define or guide the future evolution of cities. This influence the way citizens will live together in the future. Since local people are directly affected and know their neighborhood/needs best, public participation in project development becomes more and more important: In many cities, the public can examine, receive and discuss draft plans and related documentation at the municipality. The accompanying documents may include textual explanation of the proposed changes, a draft of the request for the municipal authorities, a statement of the advisory council for urban planning and design, an environmental report and other planning documents. However, typically, the proposed plan amendments are static; in most cases without any additional diagrams showing influences of dynamic aspects such as wind, noise, functional usage, pedestrian flow or pollution. Then again, the officials provide general planning material; in the authors case study region, Vienna, that includes a 3D map of existing buildings and the digital 3D terrain model, which can both be downloaded from the Open Government Data Portal [01]. However, this wealth of information is difficult to grasp without background knowledge: On the one hand, the overall regulation conditions (building regulations, standards and guidelines) are complex and, on the other hand, the impact of the planned changes is difficult to present. Our proposed application addresses both difficulties by using visualization and simulation.

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According to Arpornwicharnop et. al (2007) the authors believe that the aim of land-use and regulations is to maintain the quality of life - which is influenced e.g. by population density, viewing and day lighting. At the same time, dealing with land-use and zoning plans means that diverging interests collide - 1) investors want a positive return (as quickly as possible), 2) local residents want to ensure that they will not suffer any negative consequences (e.g. no further deterioration of noise nuisance) and 3) the authority may simply be interested in solving the lack of housing. Hence, if there is a public interest to discuss and manage all these different interests, a common level of understanding is necessary. Additionally, zoning and land-use projects become better 1) if decisions can be tracked at all times (communication), 2) if citizens' opinions are taken into account (participation) and 3) if new plans can be tested beforehand (analysis). In order to achieve these objectives, adequate methods have to be developed that supports stakeholders, officials as well as the public. In short, a face-to-face discussion can only be achieved with an effective and easily comprehensible method for all participants. This will, finally, lead to a better quality of life.

2. Background

The Web application FLÄVIZ is mainly related to two objectives: 1) the visualization of alternatives in a form everybody can quickly read and understand and 2) to provide feedback about alternatives in form of an objective comparison.

The first objective belongs to the group of support tools for discussions about land-use and zoning in order to communicate and facilitate understanding of decisions. This is especially important, because of the diverse audience, different knowledge, different educational qualification and not least because of emotional issues (Kellett et al. 1998). Basic requirements of such a tool, including site modeling, scenarios and feedback are discussed in Kellett et al. (1998). A different approach concerns prediction and forecasts of land-use changes. This include cellular automata as basis for a generic model of urban land-use dynamics (White et al 2000, Lau 2005) and agent-based models that model urban land-use change (Matthews 2007, Schwarz 2012). Good experience has been made with land-use/transport modeling - including, e.g., the analysis of air pollution and traffic noise (Moeckel et al. 2007) - although there still remains challenges to integrate them in practice (Moeckel et al. 2018). Another aspect deals with collaborative design itself in order to form an optimal layout that meets the highest demand of the community (Bai et. al 2018). The system described in Bai et. al (2018), e.g., collects the preference data of each user through interacting gaming which then serves as information for a self-adapting urban layout. Regarding the visualization of possible (urban land-use and zoning) changes it is obvious that web-based systems - such as ArcGIS [02] - have a big advantage, since they are available to everybody (who has access to the internet). ArcGIS Urban combines landscape information and city information models (context) with projects and (manually added) regulations, such as zoning and land-use codes (content). Building scenarios (e.g. building projects) are visualized in 3D enabling impact evaluations (e.g. shadow impact regulations).

The collaborative part of the first objective brings up another aspect. Thinking about different file types of 3D terrain data, 2D hand sketches and simple block models, data exchange becomes relevant as well. In this context, Arpornwicharnop et. al (2007), e.g., propose a simulation software that concentrates on the information interchange by integrating a topological analysis tool, a constraint checking module and a geographical information process module (related to street name, street width and property number).

Concerning the first objective, FLÄVIZ provides the possibility to visualize proposed changes on land-use and zoning plans. The visualization is web-based, using JavaScript to select and analyze data. At the current stage of development, automation, exchange of additional data and interaction (for communication) are not yet implemented. Especially the possibility of exchanging notes seems to be an important task for the future.

The second objective of FLÄVIZ addresses quantities and qualities of alternatives; only a few of which have been implemented yet. In principle, quantities and qualities includes measurements such as incorporated in Modelur for SketchUp by AgiliCity company [03] - Modelur is a parametric urban design tool that 1) calculates important urban control values (including floor area ratio, built-up area, building height, number of stories, site coverage, number of apartments, required parking spaces and site coverage), 2) modifies buildings parametrically (adapting each building to already known zoning rules) and 3) warns if buildings are placed too close. However, feedback about alternatives should not only include urban control parameters but also additional information resulting from simulations. Other solutions are provided by Esri Inc. (Environmental Systems Research Institute), an international supplier of geographic information system (GIS) software. Preconfigured solutions for planning and community development includes, e.g., shadow impact analysis, flooding inquiry and calculation of solar relations [04]. Currently, FLÄVIZ only simulates sun/shadowing and wind. The feedback in both cases is given visually and not yet as a comparable number. Future work, nevertheless, will address other characteristic values as well.

FLÄVIZ not only uses 3D data of terrain and existing neighborhood, provided by the authority [05], but also for possible land-use (especially housing). Technically it is based on Java ThreeJS, using the standard data format 3DS - which reduces problems caused by exchange of different data formats. The primarily objective is not to predicting future developments, but to visualize jointly developed land-use alternatives (as 3D block models), giving quantity to certain objective criteria for each alternative (see figure 1). The 3D model serves as basis for certain simulations ranging from wind-simulation to analysis of shading, which complements the “standard” urban control values.

3. Method

Proposed changes on land-use and zoning regulations include two main objectives: 1) the dedication of an area (type of zoning; e.g. residential, industrial, commercial and open space; see figure 2 left) and, 2) the permitted construction class and housing type (e.g. 12-21m permissible building height, buildings aligned with their neighbors; see figure 2 right). Both are specified as symbols, colors or numbers on a two dimensional plan, which makes it hard to understand for non-experts. Therefore, the proposed application visualizes the construction class and housing type in a 3D environment (partly including general regulations as well). This allows a broad public to understand the proposed changes.

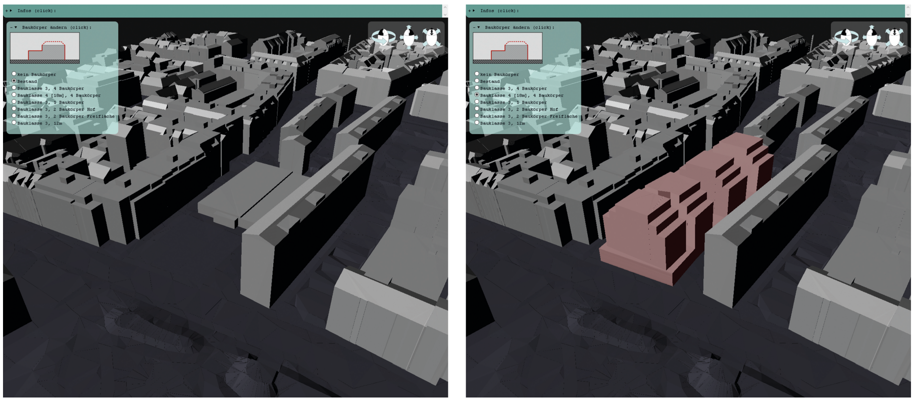

Figure 1. Possible visualization. Left: As-built model; Right: Algorithmically generated building structure for a specific construction class, housing type, including some regulations.

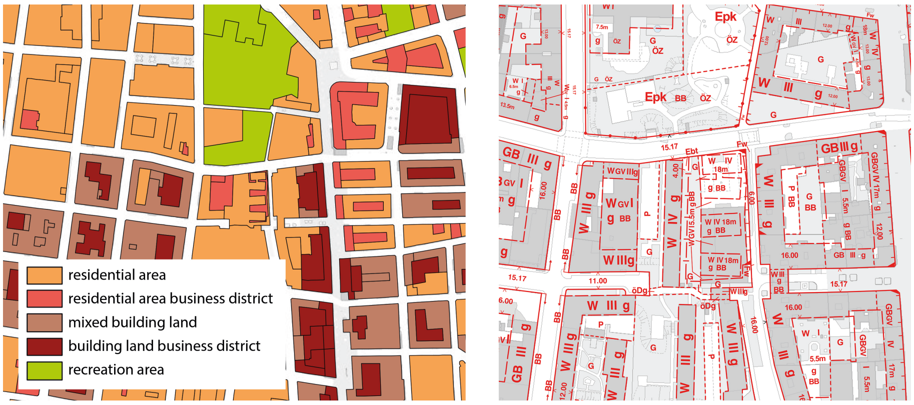

Figure 2. Zoning and land-use plan of Vienna (section); Left: zoning illustrated by color; Right: land-use regulations (maximal building height, building line and zoning).

Initially, FLÄVIZ loads the 3D terrain model and the current as-built model, which serves as basis for visualizing the inventory (see left in figure 1). The digital terrain model (DGM) contains the current terrain information for the entire city area of Vienna. DGM is provided by the open government Vienna in the following data formats: SHP (Shapefile, a geospatial vector format for data interoperability of GIS software products - contour lines or break lines), TIF (Tagged Image File Format, a raster graphics image format - one meter raster), ASC (ActionScript Communication File - one meter raster) and DXF (Drawing eXchange Format). The open government Vienna also provides the building model LOD1 (Visicom Modelling Level of Detail 1), which contains all buildings of Vienna, depicted as prisms (about 200,000 buildings with more than 650,000 building volumes). LOD2, currently used by the web application, includes accurate roofs and architectural details and is provided as DXF (triangular transformation) and SHP (basic building model data from the "multipurpose map").

With FLÄVIZ, the proposed and discussed zoning and land-use plan serves as basis for a maximum development on the building spot in question (see right in figure 1). In more detail, the maximum possible building volume is (at the moment manually) determined on the basis of the proposed construction class, the terrain profile and building regulations (proposed by the officials). Possible variations for construction classes and housing types (algorithmically or given by the residents) permits a real comparison between alternatives. Such variations may also include the density rate for buildings, number of buildings, distribution of buildings based on proposed building types and characteristics of the facade based on the intended use (not yet included). In the end, the user can easily switch between a given numbers of possible solutions. It is conceivable that within the maximum volume (defined by construction classes and housing types), building structures can be algorithmically generated, whereby regulation conditions are considered as well. This would give an even more realistic view on proposed changes.

In the current stage of development, users can only switch between predefined scenarios. The authors tested the application (related to a specific rezoning process) with local politicians, citizens and public authority staff. The first two groups in particular showed great interest, since, in most cases, they could not imagine the three dimensional impact. Such a reaction supports the assumption that already the three-dimensional visualization of proposed changes is helpful for decision makings (which is currently not the case). Since only two simulations are implemented yet and alternatives are predefined, the usability is intuitive (you see what you get: Changing the day and time affects the shadow). This might change when analysis becomes more complex (regarding input and calculation). Consequently, the user interface and interactivity have to be adapted. One possible direction might be to implement different user interfaces for different applications/groups of interest.

3.1. JAVA THREE JS

FLÄVIZ is a web application developed in Java Three.js using TDSLoader (3DS Max). Three.js uses WebGL and is a JavaScript library used to display 3D graphics in web browsers. The TDSLoader is a NodeJS wrapper for the TDSLoader library in order to convert 3D graphics to Three.js. While the terrain and existing neighborhood buildings (3DS) are loaded in any case, different alternatives for the spot in question are available in the form of a drop-down list. Each element of the list is defined by a specific unique value that refers to a specific 3DS model representing an alternative building development.

4. Simulation

It is conceivable that the model can serve as input for a simulation (e.g. of the building physics properties). This would mean that all given alternatives can be compared with each other on the basis of facts (e.g. solar radiation and shading or expected noise pollution; furthermore, predefined visual axes can be compared with all alternatives, in order to show possible negative influences on the overall urban planning). Subsequently, the calculated properties can be visualized on the building structures (e.g. heat map for solar radiation), whereby calculation methods and regulation foundations can be displayed in detail on request. At any time, the user has the opportunity to move freely in the three-dimensional model and to view it from all sides. It is also conceivable that any additional information can be directly attached to the structures (virtual sticky notes or comments).

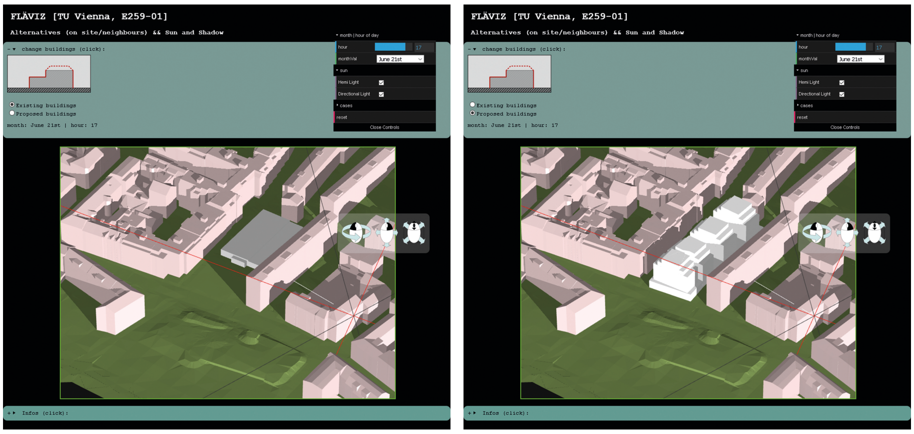

Figure 3. Shading and lighting for one and the same date and hour. Left: As-built model; Right: Proposed alternative construction.

4.1. LIGHTING AND SHADING

Since FLÄVIZ is based on Java Three.js, which already allows lighting and shadowing, it seemed obvious to implement this category first. The current version of the application allows to switch on and off two kinds of lights in order to light up the scene: a directional light and a hemisphere light (see Figure 3). However, only the directional light allows shading (the hemisphere light only gives a general light to the scene). For the moment, the settings are hardcoded and do not automatically react to the size of the scene (this includes the shadow map size and the shadow camera limits). Nevertheless, as shown in figure 3, differences between alternative constructions are immediately displayed in the scene, corresponding to the adjusted date and hour of the day. While the day of the year corresponds to a significant predefined date, the hour can be adjusted via slider. In future, the four main sun positions of the year (days of equinoxes and solstices) should serve as comparative values, reflecting the effects to the surrounding area (facades of buildings as well as open space). The ratio of shaded areas to the overall facade is then an indicator for the impact of the proposed land-use and zoning change.

4.2. WIND SIMULATION AND VOXELIZATION

For the wind simulation, it seemed appropriate to deal with a discrete world (i.e. split into cells) instead of a continuous one. That is not least because the authors made good experience with simulations of building effects in NetLogo (Wurzer et al. 2012; Wurzer et al. 2019), but also because it produces a considerable saving of time. NetLogo (Wilensky 1999) is a multi-agent programming language with an integrated modeling environment. It is most appropriate for simulation, where agents - the active entities within the simulation - operate in a discrete world consisting of n X m X o cells. The authors have shown that agent-based simulation (ABS) is able to compute and visualize dynamic factors in order to enable a quality assessment about multiple design variations (Wurzer et al. 2012). The key issue is that planning aspects can be evaluated by ABS, using simplified models. Simplification not only concerns the model itself but also the world that is discretized (turned into a grid). This leads to a similar environment of both, FLÄVIZ and the preceding models using NetLogo.

Technically, the transformation of the data set (continuous world) into a discrete world (boxes in a grid) is based on voxelization. Voxelization is a term from computer graphics and refers to a grid point in three-dimensional space that is well-defined by its coordinates (x, y, z). The position of a voxel (grid point) implicitly results from its relation to the other voxels. The process of voxelization is based on the decomposition of the geometry (stored in the "source" data format) into individual, continuously smaller triangles (Lorenz et al. 2015, Lorenz et al. 2016). A division algorithm decomposes each triangle until no cell of the world can be placed within the area of □□the remaining triangle. This ensures that cells within a triangle are detected as well. The advantage of a so-called voxelization lies in the analysis. It is thus possible that each cell contains additional storage of information about effects of certain criteria (e.g. the direction of light and intensity can be stored in each voxel, influencing the color of the voxel).

4.2.1. Prototype Simulation

Changes to the zoning plan are comparable to the early stage planning. In both cases, decisions (should) depend on numerous influencing aspects such as wind, topology, flooding, visibility, circulation, parking facilities, development of the site and solar radiation, to name just a few (White ET. 1983). Urban planner may be either interested in evaluating current spatial configurations or they want to predict the behavior of future layouts that do not yet exist.

The prototype comes with a simulation of wind. It is the interplay of wind, temperature, humidity and rain that determines (micro-)climate. Therefore, the authors believe that sustainable building design is based on these decisive factors. Nowadays, sustainability is an important issue and, in the view of the authors, little noticed when dealing with proposed changes on land-use and zoning plans. For instance, heat islands can be located in a city; however, the countermeasure is often limited to installations such as “artificial drizzle”. Wind simulations may be one small part of finding the optimal structural and zoning solution to avoid heat island at all. The simulation of wind also means to visualize wind pressure and to detect undesired turbulences. The authors made good experience with Lattice-Boltzmann cellular automaton for performing calculations of wind direction (Wurzer et al. 2012).

5. Discussion

The web-based 3D visualization of rezoning is a first step to allow the laypeople to read and understand proposed changes on land-use and zoning plans. Proposed changes can “easily” be implemented (by hand or algorithmically) and serve as alternatives for later comparison. At this point, the question arises: who is able to implement such alternatives and in what form. For the moment, the application uses the coordinate-system of the City Surveyor Vienna (which enables a consistent import of different digital maps - from the terrain to the buildings). All components including maps and buildings (and alternatives) are loaded in the file format .3ds, which is a common format used by the Autodesk 3ds Max 3D software. It retains the essential geometry, texture and lighting data. The advantage lies in its popularity as exchange format. However, one has to be able to create such a .3ds file and to place it on the right coordinates in the system. Therefore, one of the future questions deals with the implementation of a simple 3D drawing plug-in. This will allow untrained users to delete and draw simple building shapes. The other implementation of algorithmically based alternatives is even more difficult. The idea here is to implement (parts of) the building regulation, in order to find good and valid solutions. Good solution also means to define parameters that characterize a “good” solution. Since both implementations (by hand and algorithmically) require knowledge, “easily” refers to the data exchange by a trained person. So, for the moment, alternatives are hardcoded and selectable by a dropdown menu. This allows the user to switch through different scenarios. The benefit lies therefore in the comparability by the layperson and the simplicity in the data exchanged by a trained person (planner).

FLÄVIZ is a good basis for simulations acting on such variations in order to verify them with respect to hard facts (such as solar radiation, shadowing, viewing and so forth). The main advantage of the simulation model is the experiment in a non-existing environment instead of an already built-one: Paper is patient the environment is not! As mentioned in the introduction, FLÄVIZ addresses three groups of interest: investors (accomplish profitable investments), local residents (ensure quality of living) and the authority (solve the lack of housing). If citizen participation is desirable in the rezoning process (as it is propagated in many European cities), then, at first, a common level of understanding is necessary. This can be achieved by providing quality features based on calculable analysis (which means objectivity). That means, with simulation analysis, on the one hand citizens get a deeper understanding of the plan, and on the other hand investors can argue on facts (to reassure the residents). And, there is yet another advantage: the authority can test alternatives beforehand (before investors come into play): to answer “what if” questions.

Local decision-makers already have the possibility of using commercial software that includes analysis tools for urban planning. E.g., ArcGIS Pro allows evaluating the shadow impact of proposed buildings on the surrounding. This is important in order to determine the additional shadow impact of a proposed development on a neighboring public park or school playground for any day in the year. [06] Some cities also provide a solar potential cadastre in order to display the energy potential of roof areas (energy potential affects the value of the property). However, this potential may change due to rezoning. Real estate appraisers may also be interested to determine visibility (to and from the building) in order to estimate the value of a proposed development. [07] For all of these considerations, the advantage of simulation lies in a quantitative and transparent assessment of the property in general (and of the effects on existing buildings/property in particular). However, available software so far implements only a few basic analysis tools. Last but not least, the relevance of the proposed simulation lies in a verifiable calculation, especially when different interests collide: diminish/prevent heat islands based on larger green areas (or the small inventions such as green facades) versus investment. Only calculations will show the real impact.

6. Outlook

Assuming that simulation models for many different factors are incorporated into the web application (shading, viewing, flooding, and so on) the question arises how they are weighted. In short: What counts more, e.g. shading or viewing? This is a question, the authors will deal with in the future. Another aspect concerns the input and output of the simulation models mentioned before, since planning issues and their evaluation often deals with fuzzy terms. This means to interpret the input and the output (in the ideal case turning it into a “comparable” number). Moreover, the implementation of other simulation models (apart from wind) will also be addressed in future work. Beside climate, described in this paper, other possible aspects concern 1) travel times, which deals with circulation, transport infrastructure and has influence on urban sprawl, 2) visibility to and from the site, which influences orientation in the city and well-being (especially if nature comes into play), 3) solar radiation and shading, which influences possible solar yield and natural cooling in the summer and 4) neighborhood context including 4a) social aspects, which goes hand in hand with demography or crime rate and 4b) noise and pollution, which may make costly noise protection walls obsolete.

In future work, it should be possible to generate possible zoning plan changes automatically, which are analyzed and simulated in the existing contexts. They can be stored on a web server and shared via link. The latter would allow discussions about different (previously calculated) alternatives.

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