Including a Social Perspective into Urban Planning using Visualisations based on Self-Organising Maps

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Abstract. Integrating social factors into the rather technical urban planning process in Switzerland is believed to support the development of liveable and socially sustainable environments. Social factors are currently used on an ad hoc basis only. We suggest the use of self-organising maps (SOM) to reduce the massive data set of relevant social variables, such as population density, age, or income, to accessible visualisations that can be updated and compared for different planning scenarios. The SOM process clusters the analysed social factors. Colouring the different spatial units of the planning area according to the SOM results allows visual comparison of those units. The non-deterministic nature of the SOM process calls for the implementation of a colour transformation to make the results consistent between different analysis runs. The process is integrated into existing planning software and exemplified for an area in Langenthal, Switzerland. Informal evaluation has shown great interest from planners but also a need for further evaluation of the implemented approach.

Keywords: Urban Planning, Social Factors, Visualisation, Self-Organising Maps (SOM)

1. Introduction

The technical process of urban planning in Switzerland is normally defined by aspects such as maximum building heights, gross floor space, type of use, or connection to public transport. Such a guiding framework ensures a controlled development of town and city districts. To create liveable and socially sustainable environments, it is imperative to additionally include a social perspective in the planning process. However, as relevant social information often consists of a myriad of factors and combinations of those factors, such multidimensional information is difficult to consider or to routinely integrate into the planning process. Consequently, this paper presents how considering social factors through the use of self-organising maps (SOM) and suitable visualisations of the results can support a more integrative planning process.

The presented work ispart of the 'modularCity'[1]research project which is run by two academic institutes – the Zurich University of Applied Sciences and the University of Applied Sciences and Arts Northwestern Switzerland FHNW – as well as two partners from private industry – tsquare[2] and urbanis[3]. tsquare is a software provider for urban plannerswhichhas developedthe uRd (urban ROI designer[4])software package.urbanis provides services in the field of urban planning.Multidisciplinary approaches are needed to ensure a sustainable development of urban areas and an efficient use of the limited land resources in Switzerland. Among other aspects, the integration of socio-spatial factors isnecessaryfordevelopinga more appropriate and comprehensive model of urban areas as a basis for future planning. The 'modularCity'project focuses on two aspects: how to determine and prepare the relevant social factors and reference them to their proper spatial dimension and how to process and to present this information to planners so that they receivean enhanced view of the study area whichgoes beyond the previous technically oriented ‚hard factors', such as maximum building heights.

The socio-spatial data, which come from various sources,are pre-processed and then analysed using Self-Organising Maps (SOM). In section 2,we introduce the relevant social aspects forurban planning.The reasons for employingSOM are presented in section3 and the study area in section4.Sec-

[1]http://www.fhnw.ch/ppt/content/prj/s256-0042

[2] http://www.tsquare.ch

[3] http://www.urban-is.com

[4] http://www.urbanroidesigner.com

tion5 presentspreliminary results before section 6 concludes with a summary and an outlook.

2. Social Aspects in Urban Planning

Social aspects often play a marginal role in urban planning activities. Ordinarily,technical and financial parameters determine the discussion onwhat and how one should build the urban environment. This is true particularly in the phase of problem description when urban planners must deliver convincing proposals to the decision makers, proposals which should be politically as well as financially favourable.

Often at this time in the planning process, social question arise, e.g., what kind of social infrastructure is needed or how social tensions in a neighbourhood may be targeted. Especially in the context of restricted resources and building densification, important social issues about access to space, infrastructure and societal inclusion in general arise (Drilling & Weiss 2012). An integrated view ofurban planning issues, supported by corresponding analysis and visualization techniques like SOM, may help to include such questions in the further planning decisions and give urban planners as well as decision makers a more distinctive view of the planning problem.

One topic of the current debate is the principle of *social sustainability*. Often neglected in favour of economic or ecological issues, the concept of social sustainability is gaining in significance in urban planning and development (Drilling 2009). This guideline delivers a sound basis with which to evaluate which social factors are relevant in urban planning and how they may be integrated into the urban planning process.

2.1. Social Sustainability and Social Factors in Urban Planning

With the publication of the Brundtland Report in 1987, a worldwide discourse regardingsustainable development started in political as well as in academic circles. Atits core, the concept requires an integrated view ofsocietal developments, i.e., taking into account economic, ecological and social aspects for future decisions on every level of society (global, national, regional, local) (World Commission on Environment and Development 1987). Because social scientists were, for various reasons,not involved in the academic discourse atthe beginning of this debate, it was long dominated by economic and ecological factors, also regardingurban planning issues (Drillling 2013). Therefore, the concept of social sustainability found its way into urban planning activities comparatively late and the first urban development projects in Europe termed *socially sustainable* were implemented only in the 1990ies (see, e.g., www.werkstatt-stadt.de).

In the last 15 years, different systems of indicators have been developed to evaluate the social sustainability of housing estates, neighbourhoods and cities (Drilling & Blumer 2009). Since then, the variables of "social equity" and "sustainability of community" have been established as the key dimensions of social sustainability in urban planning issues (Drilling 2013). Therefore, many evaluation systems include indicators ofstructural aspects (e.g. social structure, social infrastructure, distribution of public spaces, etc.) as well as social aspects (e.g. social inclusion, social cohesion, participation, etc.). One of the most recent publications onthis topic is the VLP-ASPANbrochureentitled "SozialeNachhaltigkeit in der Siedlungsentwicklung"(Drilling & Weiss 2012). The authors selected five subjects and corresponding questions which should be considered and negotiated in any urban planning project (see *Table 1*).

Social structure	Which social groups live here and how can their community life be enhanced?
Usage	What kind of (social) infrastructure is needed and where should it be located?
Design for All	How can the accessibility of buildings, public spaces and mobility be improved and ensured?
Mobility	How are living spaces, workplaces, leisure activities, supply infrastructure and educational institutions spread over the area and how are they connected to each other?
Participation	How can residents participate in the planning and decision making process?

Table 1. Key Negotiation Areas of Social Sustainability

In conclusion, planning socially sustainable urban environments means not only asking about where and how we should build but also for and with whom we want to build. Therefore, more information is needed about how social factors and the social context shape the conditions of urban planning activities - and how such activities conversely influence social realities.

2.2. The Importance of Visualisation and Communication for Urban Planners

As mentioned above, the problem description stage represents a crucial point in the whole planning process because it is at this point that the framework conditions for urban development projects are discussed and fixed. For example, in the case of an urban design competition, social issues may be included as a basic strategy, which would serve as a guideline for the urban planners (Drilling 2013).

It is exactly at this point whenurban planners must communicate their visions to stakeholders and decision makers in such a way that social questions arise and may be discussed. Urban planners may use the power of visualization to make visible what normally is not (social aspects) and thus set a new agenda about what should be considered in urban planning decisions. Therefore, socially sensitive planning software is needed to raise the awareness ofsocial issues and bridge the gap between the idea of social sustainability and its implementation. In this way, not only social problems and challenges may be targeted but also future potential in urban environments may be identified. The 'modularCity' research project evaluates how this can be improved and how best practice can be found and implemented.

3. SOM in the Context of Urban Planning

Since the beginning of the 20th century,the social sciences have tried to describe and analyse socio-economic differences in cities (Spielmann &Thill 2008 and Harris et al. 2005 both give an overview of the history of research in the field of Geodemography). The fundamental assumption of geodemographic analysis is that there is a relation between the livingplace/address of an individual and the socio-economic level, and the socio-cultural consumer behaviour and preferences such as political orientation (Nemeet al. 2011;Niemelä&Honkela 2009; Harris et al. 2005). The reason for the assumed correlation of numerous variables to a person's residence is founded in so-called neighbourhood effects (Harris et al. 2005.): Residents of a neighbourhood mutually influence each other'sbehaviour. In the broadest sense, this corresponds to the assumption of the first law of Geography (Tobler 1970).

The concept of Self-Organising Maps (SOM) (Kohonnen 2001)is a special form of artificial neural network (ANNs). As the name SOM suggests, this technique uses algorithms whichfaciliate the self-organisation of the multi-dimensional input data (often called input vectors) through a series of iterations. The outputs are thematic relationships of the input data represented ina two-dimensional network structure (a network of neurons). In this unsupervised learning approach, the definition of the size of the output network structure, i.e. the number of neurons used, influences the results (Bação et al. 2008). The SOM process is non-deterministic. Each calculation gives different, even though most often, similar results. In urban planning, as well as in most other application areas, SOM serves as a tool to reduce complex, multidimensional data to a two-dimensional regular grid while emphasising the data's topological relations. Additionally, it clusters the data to organise it according to semantic similarities (Skupin&Agarwal 2008).

From an urban planning perspective, Ball (2012, p.43) argues that "*...the only effective way to manage cities will be to discover their intrinsic bottom-up principles of self-organization, and then to work with those so as to guide the process along desirable routes, rather than trying to impose some unreachable or unsustainable order and structure.*"

In other words, the development of urban areas is seen as a self-organising organism, which needs to be understood in order to be managed properly. With the application of SOM tothe available socio-spatial data, this goalshouldbe at least approximately met.

Today, massive amounts of data areavailable, though not always at the same spatial level or referenced to the same spatial units. Integration of the data can be complex but is potentially well worth the effort. Spielmann &Thill (2008) conducted fundamental and detailed research on the combination of SOM and Geographic Information Systems (GIS) with a dataset describing 79 attributes of 2217 census tracts in New York City. Their findings are a starting point for the research inthe 'modularCity' project on using SOM to integrate socio-spatial data into the planning process.

Since urban structures are very complex and available data is sometimes biased or ambiguous, there is thechallenge ofhow to find a balance between the number of meaningful and representative variables and the corresponding spatial units (Harris et al. 2005). More often than not,socio-spatial characteristics are anisotropic and not discrete. This raises the question ofhow to reasonably define the spatial units for the SOM analysis. However, once the spatial units are defined, the results of a SOM analysis can be related back to the spatial geometries and displayed as choropleth maps (Figure 1) by using the SOM cluster colours for the spatial units they relate to. The resulting thematic map shows the similarities and diversities of the spatial units in the inspection area.

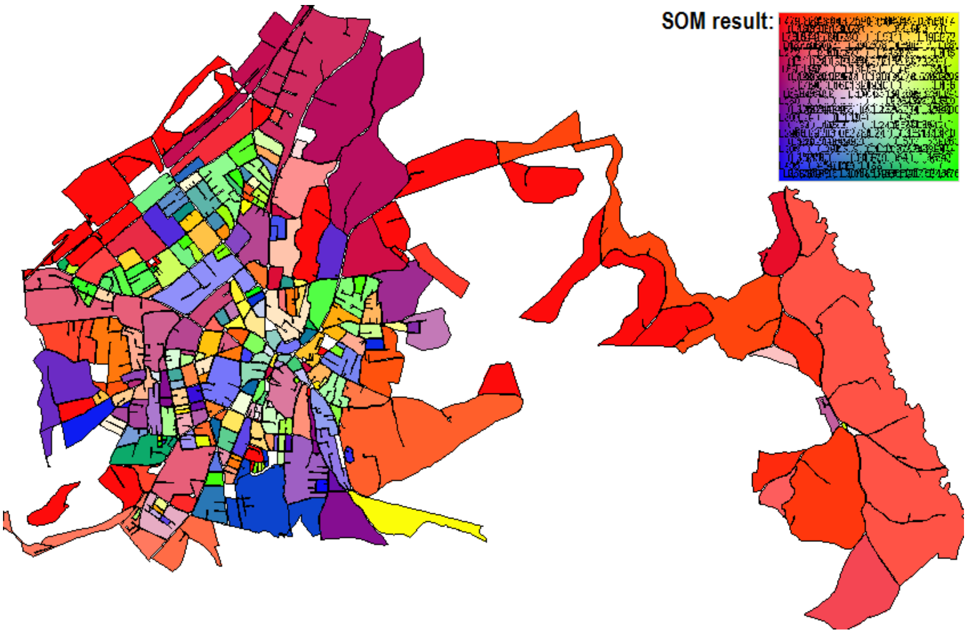

Figure 1. Choropleth map of Langenthal, Switzerland, coloured according to the results of the SOM analysis.The neurons and the SOM-cluster result are superimposed on a pre-defined colour-scheme.

4. Study area and research questions

4.1. Study Area

Langenthal, a city in Switzerland(Figure 2), was chosenfor the ‘modular-City’ project. On the one hand,Langenthal is an average city in terms of population, infrastructure and business; on the other hand, it is frequently used as modelcity for planning projects and well represents potential future target groups.Langenthal has a size of 1’276 hectares and about 15’000 inhabitants[5].

[5] http://www.langenthal.ch

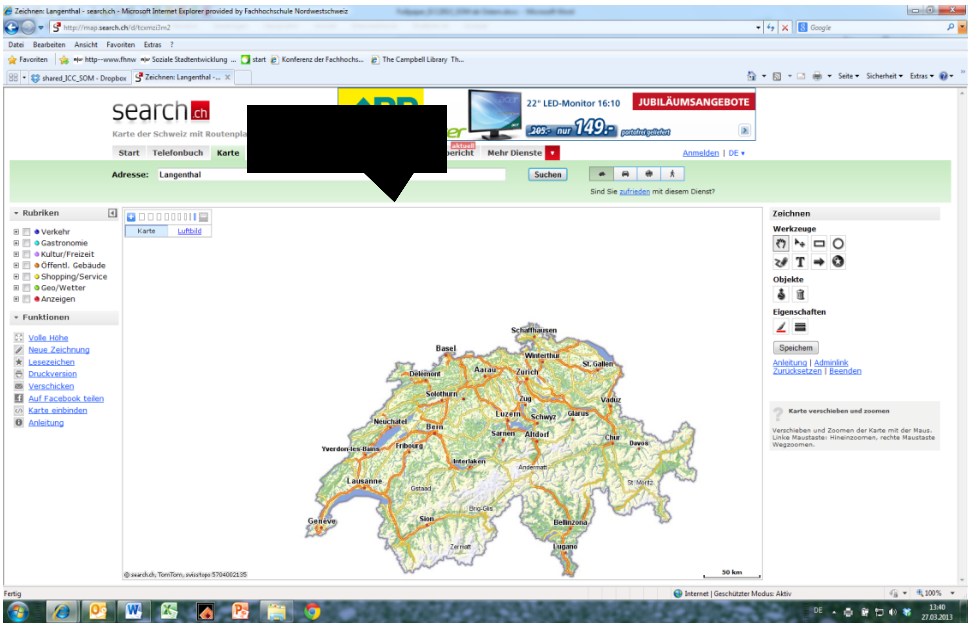

Figure 2. Position of Langenthal in Switzerland (Source: map.search.ch)

The “Markthallenareal”, a region in the city of Langenthal,(Figure 3), was chosen to investigate future planning activities for the integration of socio-spatial aspects. The Markthallenareal is characterised,according to its chief city planner,by a high development potential, which until now has only beenmarginallyexploited. The future use, function and structure of this area isin many ways still open. Also, there are only a few ideas on the future role of this area in conjunction with the centre of Langenthal. For city planners, it is essential that this area fulfil a function as a regional centre because it plays a strategic role for the centre of Langenthal.The “Markthallenareal” is connected to the centre’s context and needs to be looked at in relation to other public areas in the centre of Langenthal. Thus, the council regards the Markthallenareal as a very important development area both for the inner city and the entire city of Langenthal. Further, the area shouldalso contribute to the identity of Langenthal in general.

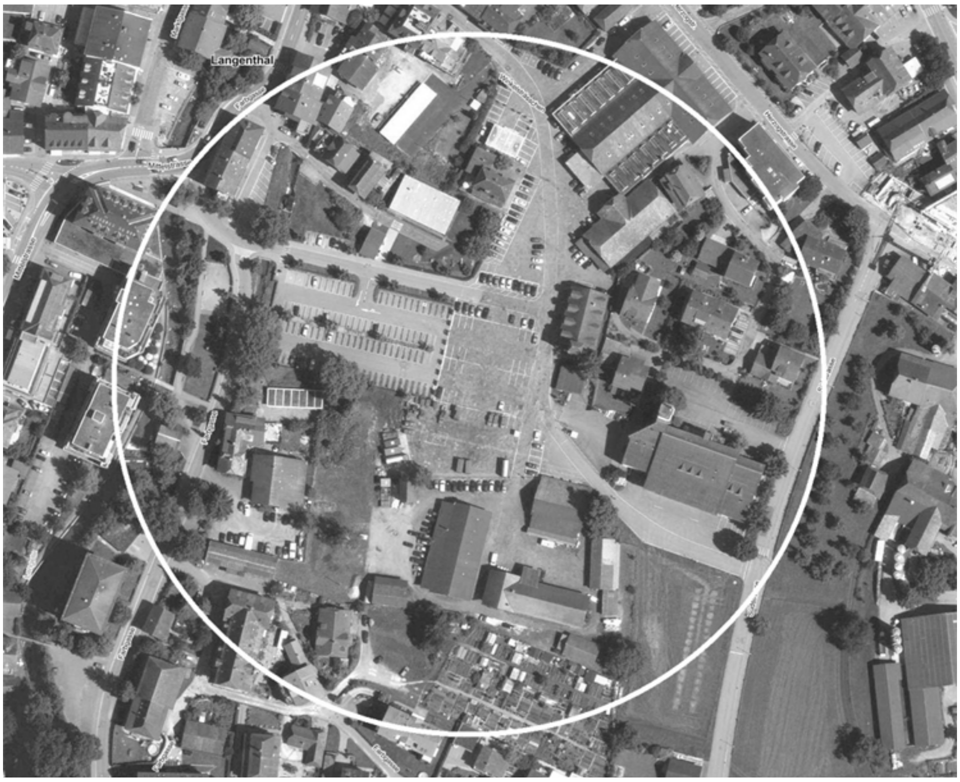

Figure 3. Markthallenareal in Langenthal (Source: map.search.ch)

4.2. Research Questions

The ‘modularCity’research project wasdesigned as a pilot project to assess how social aspects canbe integrated into urban planning software (methodological interest) and what benefit such a tool would generate for urban planners (implementation interest). To this end, the project team selected some of the most important social (or related) variables(cf.*Table 2*) for inclusion in the study.

Social structure	Age, Sex, Nationality, Income
Density	Building Density, Density of Public Spaces, Density of Local Infrastructure, Population Density
Building structure	Year of Construction, Number of Rooms, Relation Ownership/Rent

Table 2. Selected social variables in the 'modularCity' project

One aim of socially sensitive planning software is to visualize the actual distribution of these variables. This serves to provide abroader view of the planning problem. Inthenext step, the software should react according to changes of these variables triggered by the changesinthe construction plan. Thus, there is a need to process socio-spatial data in near-real time and to exploit the uRd-software’s advantage of quickly and easily modelling different planning scenarios. This implies that whenplanners create different variations of planning scenarios in an urban area that the future socio-spatial information changes as well. Thus, the SOM analysis needs to be re-run after the completion of a new scenario or major changes tothe model and shouldshow the plannersthe impact of the changes on the study area. For example,howdid the area of investigation move in the overall or sub-clustered attributespace? Or, according to its descriptive data, such as number of inhabitants, foreigners, etc., which existing area will it be similar to? In other words, what effectswill the planning scenarios have in terms of similarity toexisting urban areas in the vicinity?

As for the planning scenarios of the Markthallenareal, the entire city of Langenthal serves as its context. Due to the diversity of its districts, the different scenarios may vary greatly and the SOM analysis will show how the character of the Markthallenareal will change the character of the entire city and whether the city planners'plans for the area's future function are met.

5. Results

As mentioned above, the 'modularCity' project has an interest in both methodological and implementation issues. The following sectionsgive an insight into methodological findings (chapters 5.1 and 5.2). Because the SOM analysis in Langenthalhas not yet beenfully completed(at the time of writing), no results for implementation issues can be discussed.

5.1. SOM based application

As discussed in section3, the definition of spatial units is crucial to the results of a SOM analysis. Since the developed approach isnot only applicable to the Markthallenareal in Langenthal but generally toSwitzerland, a "global" approach on how to define the spatial units must be defined. One option is to use streetblocks.

Swiss cadastral data are described in the format-independent data description language INTERLIS[6]. Since municipalities have access to their official map data, they can document and deliver it in INTERLIS to planners. From INTERLIS, street-axes maybe extracted and serve as raw geometries to construct streetblocks. These streetblocks are defined by the intersection of streetaxes. As alternative to official map data, free OpenStreetMap data may also be used to construct the streetblocks. Additionally, the user may define which classes of street should be used for the construction of the streetblocks. The entire process of street block building is a semi-manual process andcan easily be carried out by a personfamiliar with GIS. In 'mod-

[6] http://www.interlis.ch

ularCity', the concept and implementation was successfully tested with the two GIS, QGIS[7](Figure 4) and Geomedia from Intergraph[8].

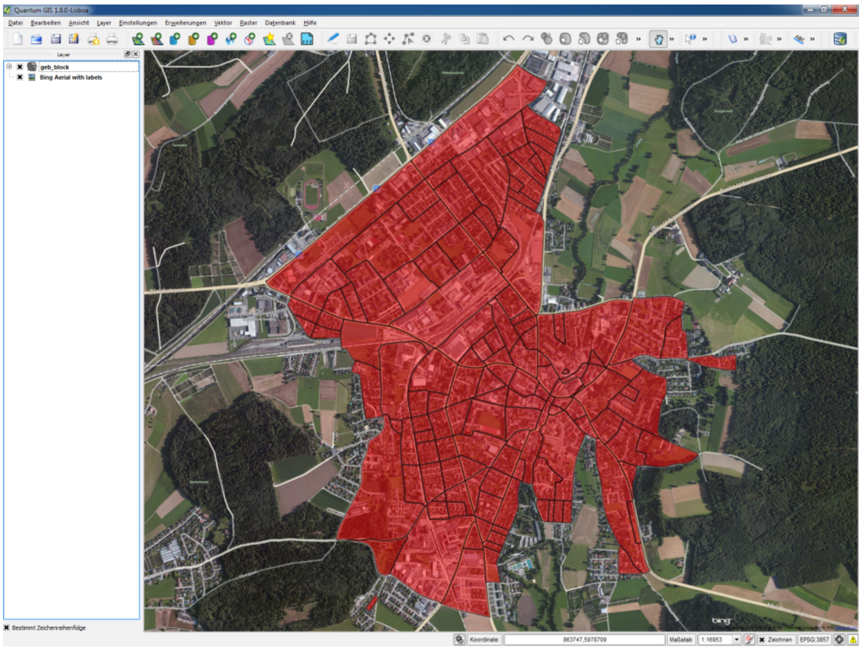

Figure 4. Computed streetblocks in Langenthal, Switzerland, based on streetaxes visualised in QGIS (Backdrop map: Bing Maps).

The next step is to match and then, if necessary,combine and aggregate and rescale the socio-spatial data to the spatial units, i.e., the streetblocks. This is a time-consuming process due to the different origins of data and shouldtherefore beconducted in a spatial database (PostgreSQL/PostGIS[9]). The aggregated data is exported into a Microsoft Excel File whichserves as a basis for the SOM analysis.When all the data is processed and available at the streetblock level, a global SOM analysis is run to evaluate the global attribute similarities of the area of interest.

To get a more distinct picture of the characteristics of the streetblocks, subtopics may be defined. This means that certain variables can be grouped together and evaluated with their own SOM analyses. Thus, it is not only possible to get an overall, i.e., global image but also an analysis ofsubtopics.

[7] http://qgis.org/

[8] http://geospatial.intergraph.com/

[9] http://postgis.net

In an extensive workshop[10] with professional planners, we learned that the integration of socio-spatial data as such is being already done,but the variables are always looked at as individual values only. In other words, the connection or correlation thehidden, but potentially very useful, information is not taken advantage of. AnSOM analysis is able to include the entiremultidimensional data set and, thus,leads to more profound results. One obstacleisthe different results of the SOM for subsequent analysis runs. The dataset is positioned differently in the SOM attribute space after each run. Since we use a four-colour space to create choropleth maps for the planner, the ever different positioning of the datasets (=spatial units) in the SOM attribute space may be confusing because the colour is apt to change with every analysis (Figure 5).

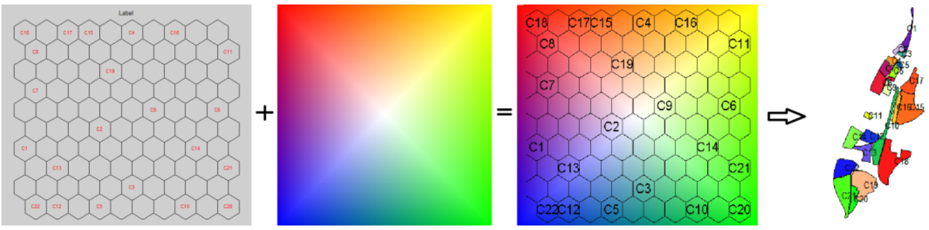

Figure 5. SOM result (left) with a sample dataset after a single analysis run. This is superimposed onto a colourscheme (middle) which leads to the colouring of the corresponding streetblocks (right). Due to the ever changing position of the datasets with each re-run of a SOM analysis, the colour-coding can vary even though the topical clusters are very similar.

For the planners, however, the colours should remain stable so that with every variation of themodel they can easily perceive what has changedinthe attribute data and has led to (dis-)similarities of the spatial units. To meet this requirement, we try to use the first SOM analysis as a reference analysis and define a one-dimensional-colour space. Then, we search the most peripheral datasets in the SOM attribute space and use these as the poles of the one-dimensional-colour space. One criterion is that the area of investigation cannot be one of the poles. Since changes inthe attribute data are only applied on the area of investigation,thisshould be the only dataset to change in the one-dimensionalcolour space. Thus, any shift inthe area of investigation in the attribute space can be displayed.

[10]The workshop took place on 15th September 2012 in Zurich. Participants were representatives of five Swiss planning businesses.

5.2. Integration into planning software

The integration of the developed solution into uRd was designed as an "interfacesolution". In other words, uRd does not integrate the SOM algorithm into its own source code. The open source application Octave[11] is used to compute the SOM.

Therefore,the planner can use uRd to easily model a planning scenario. The socio-spatial data is already available at that point to be integrated into uRd. While the planner models his ideas and adjusts the socio-spatial figures,uRd calls the SOM algorithm implemented in Octave and displays the SOM results inits own environment. uRd may show the overall SOM analysis or sub-themes like age or country of origin or economic data, etc. (Figure 6). This visualisation helps the planner to imagine how – depending on the planned model – the character of the area of investigation, (in Langenthal the Markthallenareal), might change.

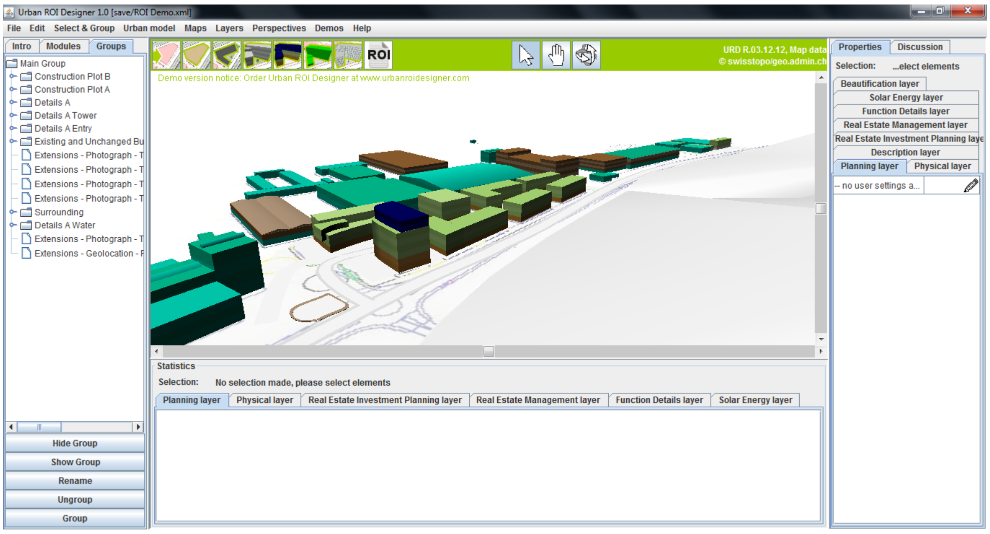

Figure 6. Potential visualisation of SOM analysis results projected at thebuilding level in uRd. Different colours on different storeys show different types of use.

6. Outlook

In general, SOM may be an innovative contribution to the analysis of socio-spatial disparities on a macro level.First, SOM analysis helps the social context of a building project already in its planning phaseto be understood, and secondly, it permits the effects of urban planning activities on the entire city and its districtsto be assessed. Its strength lies in the possibility for compar-

[11] http://www.gnu.org/software/octave

ative analysis of city districts according to their socio-spatial characteristics. In this sense, it offers a valuable complement to usual planning software, which normally focuses on the micro conditions of construction projects.

In discussion with planners, we found a great interest in innovative and new visualisation and processing approaches for social variables. However, the visualisation and its correct and easy readability are crucial for the acceptance of the presented approach. Since repeated SOM analysis usually positions the datasets in the attribute space at an absolute level differently, an unchangingcolouring algorithm should be implemented to present and evaluate shifts in the similarityof streetblocks after manipulation of the attribute data bythe planner. A formal evaluation of the integration of social factors into the planning process through a SOM-based visualisation is planned.

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