Visualizing Property Assessments and Taxation: A Danish Case Study

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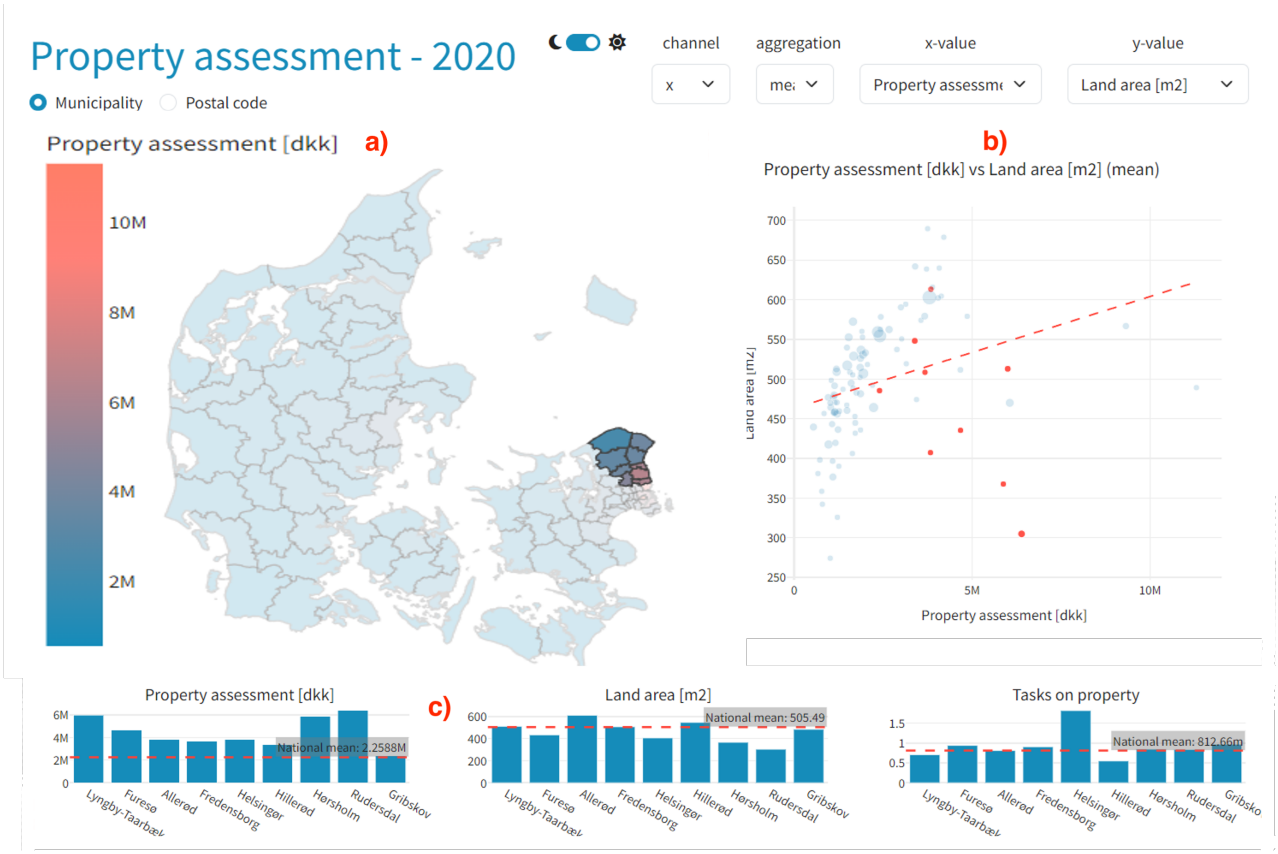

Figure 1: *Overview of the interlinked visualizations:* ***a)*** *Choropleth map for aggregated data of selected features,* ***b)*** *Scatter plot showing correlation of features,* ***c)*** *Bar chart visualizing quantity of features from the selected regions.*

Abstract

In recent years, the use of property assessments to establish a basis for implementing equitable property taxation has become commonplace. In Denmark, the Danish Property Assessment Agency calculates and determines valuations of all properties, forming the basis for property taxation. Each homeowner is obligated to pay taxes on their property, with these assessments serving as the foundation for determining the tax calculation. In this context, we present an interactive visualization tool to enhance understanding and awareness of these property assessments and associated features. Our visualization tool is composed of five interconnected plots with integrated and extensive options for filtering the data. Initial feedback has found the tool to be effective for data exploration within this context, with the Section for Process Optimization and Automation at the Danish Property Assessment Agency calculates evaluating the tool's potential implementation and scope for the future.

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1. Introduction

In recent years it has increasingly become standard practice to utilize property assessments as a means to implement equitable property taxation [GHA12]. In Denmark, this principle is exemplified by legislation that ensures every house owner must pay equitable property tax, with the amount dependent on the value of the property. The *Danish Property Assessment Agency* (DPAA) is responsible for implementing the taxation system and has developed a new valuation system aimed at refining the calculation of property taxes [VUR23]. Despite its promise, the initial roll-out of the system in September 2023 faced significant challenges, including delays and accuracy concerns, causing much frustration for house owners in Denmark due to wrong valuations [DRN23b]. The Danish public service media *DR Nyheder* found that 35% of the assessments were wrong by more than 20% [DRN23a], which is the DPAA own margin of error. *The Section for Process Optimization and Automation* supports DPAA in optimization and automation processes and they are lacking an optimal solution to achieve a visual representation and interact with the complex data used for the property assessments to evaluate the faults and outliers in the taxation system. A vast and complex database forms the basis of the valuations of the system and there is currently no available tools to explore the data visually. This is why we aimed to create an interactive visualization tool that can support data exploration and outlier detection of the property assessments and thereby potentially aid the DPAA in flagging inaccurate assessments.

2. Data

The dataset for this case study was sourced from DPAA containing 2.9 million properties with 171 attributes. While the field of multivariate geospatial visualization is well-established, the particular dataset of housing prices in Denmark presents unique challenges and opportunities, warranting further investigation into tailored visualization techniques and methodologies, as highlighted in previous works [YCC*20, ML19, GGMZ05]. For assessing a proof of concept we reduced the dataset by examining only the specific segment of owner-occupied, year-round residences, and omitting entries lacking a 2020 assessment. This resulted in a refined dataset of 915,806 properties. We consulted domain experts from the DPAA, to reduce the 171 attributes down to 9 important key features and the rest was disregarded in the current tool. To address privacy concerns, our visualization tool relies on aggregated data, specifically by postal code and municipality, rather than showcasing individual property details.

3. Visual Design

Developing a tool suited for exploring the vast dataset was possible by taking the domain experts' knowledge and requirements into account within a participatory visualization design process [JKKS20]. The visualization tool is created according to the *Information Seeking Mantra* where we start with geospatial overview and the user can further zoom, filter, and receive the details on demand [Shn03]. Thereby the main overview is provided by a choropleth map colored by aggregated property features for regions in Denmark (see Figure 1**a**). These regions are optionally municipalities or postal codes and a filtering for a specific regions of interest is possible via click. To the right of the map, a scatter plot shows the correlation between two of the data features, which are customizable via dropdown select menus for each of the axes (see Figure 1**b** and above). These selected data features can also be used to customize the map's underlying data using the *channel* drop-down menu providing options to base the visualization on the selected features of the x- or y-axis, or the ratio between them. The tool further allows to encounter various research questions through versatile aggregation methods; it defaults to displaying mean values for each region, but users can easily switch to median, maximum, sum, or standard deviation for each geographical region. Below these elements, a row of bar charts shows the distribution of selected features in a national overview to communicate how the feature values are distributed nationally (see Figure 1**c**). When any number of samples are selected the bar charts are showing each of the selected regions against the national average. The bar charts provide a quick and easy way to compare features between municipalities or postal codes. The correlation between multiple features is visualized in a scatter plot matrix, not depicted in the figure. This matrix highlights selections made on the map or initial scatter plot, ensuring that chosen samples stand out for detailed analysis. Similarly, choices made within the scatter plot matrix itself are reflected on the main map and plots, creating a cohesive, interactive experience across the visualization tool. Additionally, the selection and deselection of features can be performed using toggle switches in a feature list located next to the scatter plot matrix (not shown).

4. Conclusion

Developed for the analysis of property assessments and resulting tax calculations, this interactive visualization tool is effective for data exploration concerning the topic, and easily identifies correlations and visualizes distributions by utilizing the choropleth map and related plots. This lets users interactively select features or new aggregation types and dynamically filter the plots to support the intended use case. This tool also specifically allows for the selection of a group of regions and facilitates the inspection of associated details in greater depth. However, while our tool relies on aggregated data to address privacy concerns, the omission of individual property details may hinder its ability to provide granular insights for specific cases or properties. As Baumer et al. highlight, it's essential to consider the political dimensions and potential for marginalization in civic text visualization, prompting a critical inquiry into the trade-offs between privacy, accuracy, and utility in aggregated data visualizations [BJSM22]. Nevertheless, further work is needed in close collaboration with domain experts from agencies like DPAA to ensure that inaccurate assessments and outliers can be detected efficiently in the future. The full potential of the visualization tool and the data set could be reached by including the full extent of data. Similarly, this should be considered with the challenges of scalability in mind, with future work focusing on enhancing the tool's architecture to handle larger datasets effectively, to its long-term usability and effectiveness as data volumes expand. Thanks to iterative continuation, this approach could then benefit from the gained insights, leading to more and more efficient or automated solutions including machine learning and artificial intelligence.

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