The First Results of User Experience Experiment with Accessing Geospatial Information in the Kadaster Knowledge Graph with Augmented Reality

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SUMMARY

The Netherlands' Cadastre, Land Registry and Mapping Agency – in short Kadaster – collects and registers administrative and spatial data. Kadaster also maintains both the Key Registers Cadastre and Topography. Users of the data provided by Kadaster and other governmental organisations have indicated that this data can be made available in a more accessible, integrated and user-friendly way; suggesting that these improvements may support these organisations in their ambition to reach to broader and more diverse groups of data users.

Kadaster recently experimented with publishing several Key Registers as linked data and integrated these in Kadaster Knowledge Graph (KKG). The Knowledge Graph remains independent to the applications making use of it as a data source; where the connection between the Graph and the application are achieved through interfaces which are based on open standards. To provide this data in a more user-friendly way, Kadaster developed a prototype Augmented Reality (AR) application with the intention of providing users with extensive building object information originating from several of the key registers maintained by Kadaster. With this application, the user is able to scan building objects in their environment using a smartphone camera, select these objects and display associated building information through the user-interface. This application is intended to serve as but one example of how technologies such as augmented reality could be both supported by graph technologies as well as offer data visualisations which support users in accessing authoritative data contained in these graphs.

To evaluate how the users experience and perceive the aforementioned methods of data provision and visualisation, a number of consultation sessions were conducted where of users provided feedback on the information content and the interface of the AR application. Although the investigation needs to be extended to the wider group of users, the first group of testers of the AR application were in general very positive.

The results show that the new AR technique of presenting governmental data to the users are attractive and provide a positive user experience. The first results show also that the Knowledge Graph method, used in the AR app, assures that the data from different key registers used in the application remain actual and assurance is provided to the end user as to the trustworthiness of the source. From the user perspective, the AR application serves one of Kadaster's main organizational aims, namely; to provide everyone (from developers and data engineers to students and interested citizens) with the ability to use and interact with the geospatial data they produce, maintain and publish.

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1. INTRODUCTION

Many governmental organizations in the Netherlands are making a lot of effort to collect and maintain high quality data. The strategic governmental geographic data is stored in the National Key Registers and provided by The Cadastre, Land Registry and Mapping Agency (Kadaster) to governments, companies, institutions, and private citizens.
Although that data quality meets the highest standards and is easily accessible, there is still a group of users who need expert support to understand and make meaningful use of it. For non-experts, it can be a challenge to get information from the right registers about an object of interest. For example, data about a building can be found in more than one key register: Key Register Topography (BRT); Key Register Addresses and Buildings (BAG); Key Register Large-scale Topography (BGT). Those three different registers describe the same building in a slightly different way and provide different geometry for this object. For an unexperienced user, this may be confusing and can discourage users from using these datasets.
There have been many initiatives undertaken by governmental organizations to investigate user-friendliness and propose techniques that support better user experience with governmental data. One of the techniques is Augmented Reality (AR) that the real world with computer-generated content. Another technological development that supports user–friendliness and easy access to various key registers and/or other data sources is a Knowledge Graph (KG). Both have recently been used by Kadaster in various research and innovation projects. This paper shows how the combination of KG with an AR interface application can help reach the non-professional group of users and increase access to information based on valuable governmental data from the key registers.

2. PROTOTYPE OF THE AUGUMENTED REALITY APPLICATION

Augmented Reality (AR) is a technique used by a growing number of companies. AR is implemented on devices such as mobile phones or tablets to combine digital content with the real world, helping to present data in a user-friendly, understandable way by making it more understandable. The Innovation Board within the Dutch Kadaster gave the green light to the research and innovation team to start investigating AR to improve user experience with the governmental data. At the end of November 2021, the project group transformed data from the key registers to a more user-friendly and more understandable form using AR technique. To realize the project, the Kadaster team, in collaboration with VR Innovations, realized the first application prototype. In addition to developing a user-oriented interface realized by means of AR technique, the Kadaster Knowledge Graph (KKG) was used as a data source, providing access to the most actual data about the building and its surroundings by connecting various key registers. Once the application was ready, the marketing team was asked to conduct further research on the user friendliness of the application.

2.1 How It Works

The application prototype allows the user to ‘scan’ using the camera any buildings in a given neighborhood and receive information about that building on their screen (Fig1).

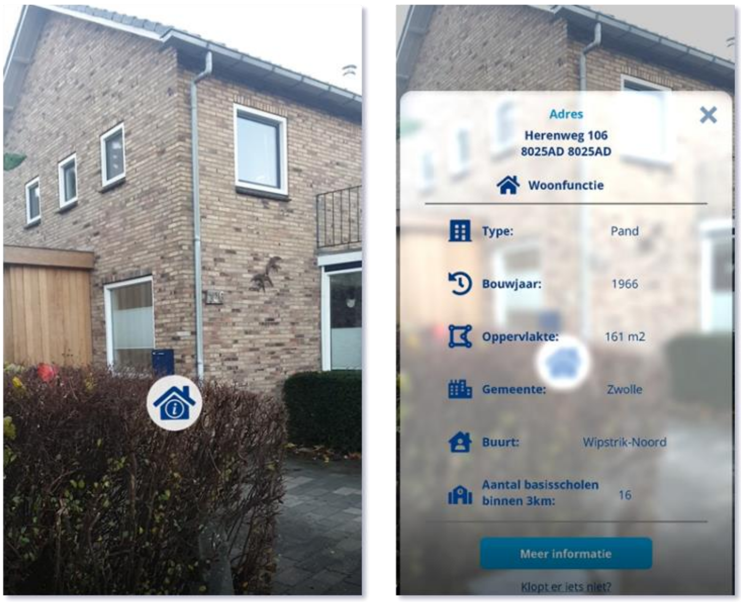

Figure 1. Screenshots from the Augmented Reality application built on the Kadaster Knowledge Graph (Rowland, Folmer, Baving, 2022)

The displayed information is based on several distributed data sources maintained by Kadaster. The data such as: the address of the building (adres), function of the building (woonfunctie); type of the building (type), the building year (bouwjaar) and the floor size of the building (oppervlakte) were originally sourced from the Key Register for Addresses and Buildings (BAG). The other data such as: neighbourhood (buurt) and the number of schools within 3km (aantaal basisscholen binnen 3km) were sourced by the Bureau of Statistics in the Netherlands (Dutch acronym: CBS).

In order for the application to provide users with the information seen in the figure above, the KKG endpoint needs to be queried by two different queries and that data made available through an API to be integrated into the application itself. Both queries are SPARQL queries being performed on the SPARQL endpoint for the KKG and the resulting APIs for each query simply integrated as API variables in the application.

The first query, has two input parameters pertaining to the latitude and longitude of the users location, the data for which is provided by the application. The query returns the identification and address of all the buildings within a given radius of these coordinates. In practice, this radius is only a couple of meters and allows the application to display all the buildings within the radius in the application as the user is walking through the environment.
Clicking on the house icon (shown in the screenshot) will then run the second query to return the details of this building. The second query, takes the identification of the building provided by the first query and then returns the information about the building related to floor size, building year, usage information and statistical information to be rendered onto the screen by the application as shown in the screenshot in Figure 1. Although the queries could have theoretically been combined into a single query because they make use of the same data source, in practice the queries were split to improve the performance of each individually and because the application returns the data first as a simple icon needing only coordinate information (first query) and once a suitable building has been selected, to display the relevant information (second query). Combining the queries would mean the same, less performant query was run twice to display information in the application.
As more information becomes available in the KKG from new data sources, the same endpoints can be used to display more detailed information about a building in the AR application. The only changes that would need to be made are in the application itself to transform and render the information for display on the screen. From the user perspective, the AR application serves one of Kadaster's main organizational aims, namely; to provide everyone (from developers and data engineers to students and interested citizens) with the ability to use and interact with the geospatial data they maintain and publish. An application in this form, specifically, provides a low-threshold, gamification-type experience for the user, who needs only access to a smartphone and a network connection; arguably improving the accessibility and overall experience of interacting with Kadaster's data and the KKG (Rowland, Folmer, Baving, 2022).

2.2 Target Audience and Method

The intention of the project was to test the application and its user-friendliness with the pedestrians on one of the streets in the city of Zwolle in the Netherlands. Unfortunately, because of the COVID-19 lock-down, physical contact was hardly possible. The marketing team from Kadaster found a solution by introducing and testing the application with colleagues, friends and family members. A mixed group of 16 people was formed who were acquainted with the data from Kadaster. In terms of age, the testers ranged from 20 to 73 years. In terms of digital skills, the group scored between 3-9 on a 10-point scale. Most testers already had some experience with other AR applications or applications with similar functionalities. However, there were also several testers who had limited or no experience with AR. The testers received a briefing with an explanation and QR code for installing the app. The tester group was testing the app without any guidance. After the testing, the number of questions were sent to the testers to collect their feedback. The questions included: user-friendliness, intuitiveness, information completeness in the application, the difficulty level of its installation, and ideas form the users how to improve the app.

2.3 First Results

The application was experienced by the majority of the testers to be user-friendly. They appreciated its simplicity, lack of menus or too many choices and options. One of the additional feedback items was a suggestion to provide a short introduction after opening the application. In general, the idea of the app was clear to everyone. Testers automatically pointed their phone to a house and clicked on the icon to get more information about that house. The testers provided some feedback concerning the number of icons on the screen. Some of the testers noted that there were too many icons on the screen in the densely built area. Most testers claimed that the information provided is helpful and valuable. Mostly the year of construction and surface were appreciated and considered interesting. There were some questions about the necessity of the information about the number of elementary schools in the neighborhood.

The test application was provided via a download link on the website of VR Innovations and not via app stores and additionally, was only available for use on Android mobile phones. This caused some challenges and extra instructions from the coordinator were needed. Where the application was tested with colleagues, another challenge was identified related to various security limitations on Kadaster mobile phones. The user was confronted with many warnings. Because of that some participants were not able to test the application.

2.3.1 Ideas from the Users

There were a number of suggestions made by the testers for additional information about the buildings such as:

- An actual value of the house;
- Plot area;
- Information about the neighborhood;
- Houses for sale nearby;
- Distance to shops;
- Distance to train stations;
- Distance to village center;
- Contents of the house;
- Energy label;
- Whether the house was available for rent or purchase.

Although the representativeness of the group can be questioned, the first feedback gave a valuable input for the adjustments and improvements. The updated version of the application will be assessed again by a wider group of testers in May 2023.

3. KNOWLEDGE GRAPH

The data foundation provided for use in the AR application was the Kadaster Knowledge Graph. Although the concept of Knowledge Graph is not recent, the term was first popularized by

Google in 2012 and has since formed part of technological solutions from various multinational corporations and as part of search engines such as Google and Yahoo. The concept of the Knowledge Graph is essentially a way to make data available through a fully open, interoperable and standards-based approach. In doing so, the Graph uses the power of the Web to integrate data from distributed data sources and make this data available to the end users in a transparent, flexible and application independent manner; either by simply displaying data in the browser based on a dereference unique resource identifier or in an application built using the Knowledge Graph as the source (Rowland, Folmer, Baving, 2022).

3.1 Kadaster Knowledge Graph

Kadaster, as the national agency tasked with the publication and maintenance of several key geospatial registers, also actively publishes and maintains these key registers and geospatial datasets as linked (open) data. Linked (open) data make the data more structured, interlinked with other data and more useful through semantic queries. Contained in these datasets is administrative and spatial data concerning property ownership and real estate rights; both on a national and international level.
The KKG is composed of several key registers including the Key Register for Addresses and Buildings (BAG), the Key Register for Large Scale Topography (BGT), the Key Register for Topography (BRT) as well as several other notable datasets including the National Monument Register for the Netherlands (RCE). Each key register and dataset is first made available as a siloed linked data source through an Extract, Transform and Load (ETL) process based on a number of steps extensively discussed by Rowland et al. (2022) and as illustrated in the figure below (Figure 2).

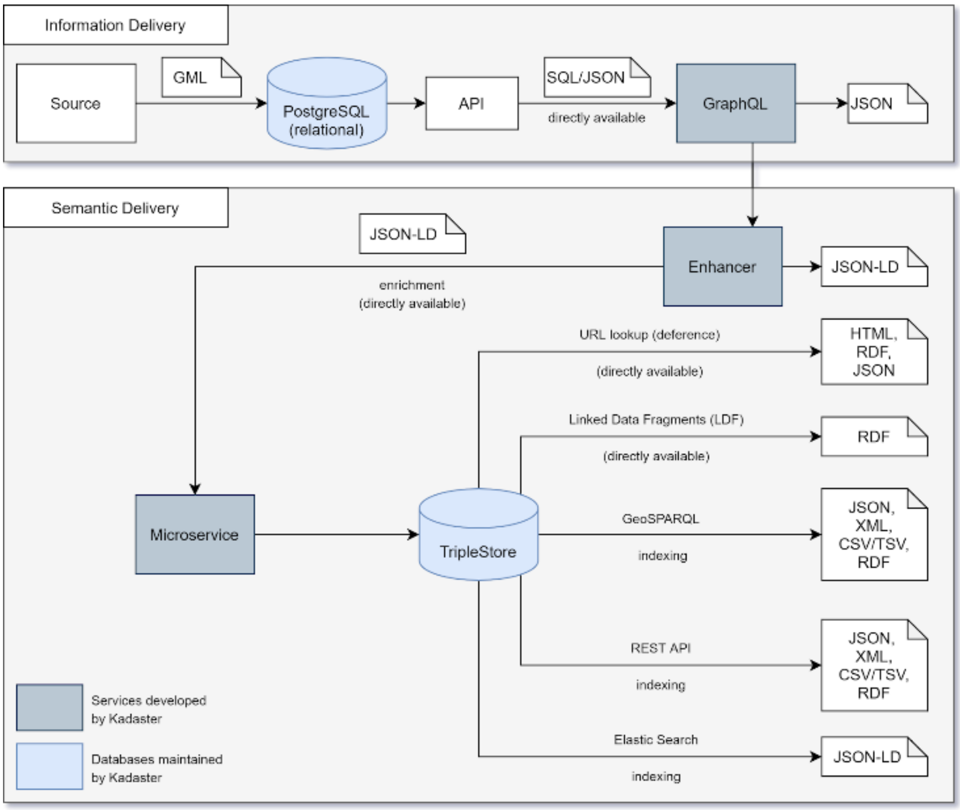

Figure 2 – Architecture supporting the ETL process which produces linked data (Rowland et al., 2022)

To briefly summarize this process, each key register or dataset is loaded from a relational database source to the PostgreSQL instance following a Geography Markup Language (GML) indexing step (Van den Brink et al., 2014) and is then made accessible through a GraphQL endpoint. An internally developed microservice, denoted in the figure above as the Enhancer, is then used to query the data and return the results in JSON-LD format. This microservice also publishes the resulting data to the triplestore, an instance of TriplyDB (https://triplydb.com/), which in turn makes the data available in a number of formats based on the instantiation of services (e.g., a SPARQL service) as shown above. A preceding step to the loading of data into the triplestore is a SHACL validation step which ensures any loaded data complies with a defined data model.

For each dataset, the linked data model used for publication is made available in linked data 'as close –to –the source' as possible. The intention here is that the linked data publication of a siloed dataset is as recognizable as possible for domain experts in order to ensure that the linked data is directly usable for these users. When combining these datasets for the construction of the KKG, a central data model is used which simplifies some of the complexity seen in the siloed datasets with the goal of making the KKG more suited for a wider range of user groups, including domain experts and developers as well as interested citizens, researchers and industry experts. In the initial development of the KKG, the data model used for publication was based

on the schema.org specification. Current versions of the KKG use the same architecture defined above for publishing linked data in the KKG but now make use of the first version of the Samenhangende Object Registratie (SOR); a data model in development by Geonovum (https://www.geonovum.nl/), a Dutch government foundation which supports the standardization and management of geospatial information in the Netherlands. This data model, which in English is called the Connected Object Registration, is being developed with the goal of improving the way the base registers and other related datasets are connected to each other based on, for example, the KKG.
As illustrated in Figure 3 (below), the KKG is realized through the creation of a layer on top of the key registers as linked data and is created by performing mappings between the data models of the source datasets and the SOR data model. As extensively discussed by Rowland, Folmer, Beek & Wenneker. (2022), the implementation of these mappings is done through LD views which transform the data from the key register source dataset to linked data conforming to the SOR model based on predefined SPARQL construct queries. This process is a key part of the architecture outlined by the authors as this serves to preserve the provenance and traceability between the source data and that available in the KKG.

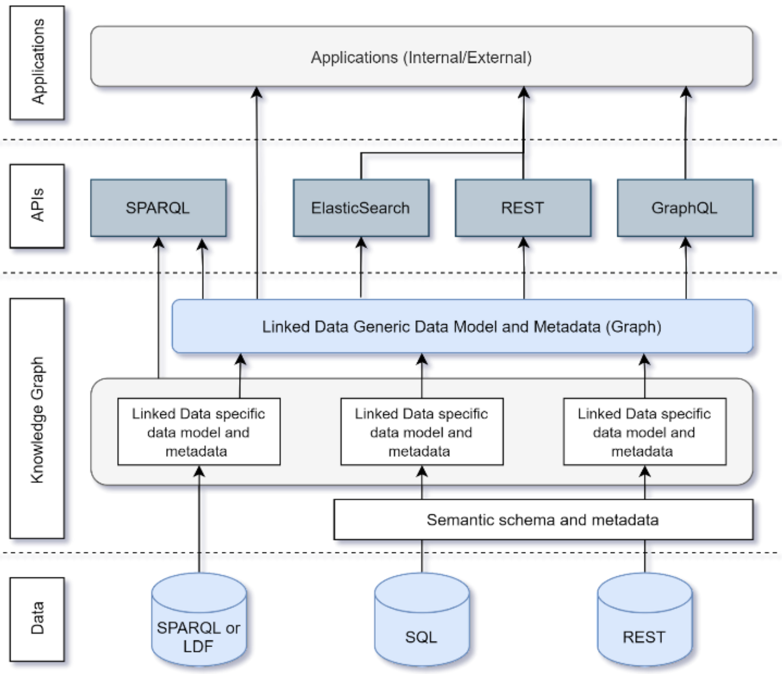

Figure 3 – Architecture for the implementation of the Kadaster Knowledge Graph (Rowland et al., 2022)

The KKG is now available for use in the Kadaster triplestore environment (https://data.labs.kadaster.nl/) and contains approximately 680 million triples. As highlighted in Figure 3, it is the intention that the KKG is used directly by applications which access the data through a number of service options (e.g., SPARQL, REST or GraphQL) and, indeed, it is in this manner that the Augmented Reality (AR) application described in the following sections makes use of Kadaster data in providing functionality to end users (Rowland, Folmer, Baving, 2022).

4. DISCUSSION AND CONCLUSIONS

The development and implementation of the AR application on the KKG provided a illustrative test case for the standards-based system architecture proposed by Rowland, Folmer, Beek & Wenneker (2022) as illustrated in Figure 3. This test case highlighted various advantages of using this approach, arguably the most important of which is the ability to store the data independently of the application while still allowing the developer to have complete control over the content and format of the data it receives from the source. In practice, it was clear that this independence between data storage and application challenges the traditional architecture and requirement set that accompany innovative applications such as the AR application but that over time the advantages of this approach become clear to developers. While offering many advantages to the developer, the end-user themselves also benefit from the ability to develop and implement a wider range of applications because it improves the accessibility of authoritative, actual data to end users without the skills to access data through APIs. This application in particular, provides users with a gamified way of interacting with Kadaster's data; hopefully acting as an additional driver for the ongoing development of these types of applications in the future (Rowland, Folmer & Baving, 2022).

The first results of implementing the Kadaster Knowledge Graph in combination with an Augmented Reality prototype application show great potential to reach wider group of users (inclusive of non-professionals) as well as to spread and promote valuable data from the government. It certainly has the potential to increase access to information based on valuable and reliable data from the government. Although the prototype was tested by a limited group of participants and mostly by non-professionals it delivered enough insights to encourage the innovation team for further research and adjustments.

In May 2023, extended field work will take place. For this, students will be involved and the challenge will be to improve the user-experience of the application based on feedback from pedestrians. There will be also be opportunities to share and implement any ideas for improving the performance and content of the application. Indeed, more technical students will be able to implement the changes themselves and experiment with the queries and the KKG.

Another approach that could be tested relates to the professional group of users. Although this group of users know how to find and use governmental data, the user-friendliness achieved by means of AR application with KKG can offer this group a new way of interacting with the data. Another aspect that is interesting to explore is the variety of available data and its connectivity. The proposed data combination in de AR prototype focuses on a building as a point of interest and is limited to (except data set from the CBS data) the key registers produced or/and maintained by Kadaster. From the non-professional user perspective, it could be perceived as a limitation. Next to the key registers that are available as open data, there are many other datasets maintained by other governmental and non-governmental organizations that can provide valuable data and insights for the users. There are also closed datasets such as

the value of the houses, which are at this moment not integrated with the open data from Kadaster.
In parallel the innovation team will be involved in experiments to combine the KKG with the HoloLens 2. HoloLens, as a Mixed Reality (MR) tool, helps combine the data with the real world by means of mixed reality glasses. The user will be able to interact via hand gestures or voice commands. This part of the experiment will be realized in collaboration withVR-Innovations.

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BIOGRAPHICAL NOTES

Magdalena Maja Grus is a research and innovation consultant in The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). For the last years her passion and subject of study has been citizen's science and its applications for the governmental datasets.
Magdalena studied Land Use Planning and Management at Warsaw University of Life Sciences and Social Spatial Analyses at Wageningen University in the Netherlands. After graduation Magdalena worked first for geo related company and since 2010 for the Dutch Kadaster. Magdalena has been involved in various citizen's science related projects such as assessment of the volunteered geographic information feedback system for the Dutch Topographical Key Register. The ongoing projects and research subjects are Digital Twin, data experience and national city science youth project to collect data and increase children's involvement in the society. Since 2019 is Magdalena a bord member of Geo-information Netherlands association and from 2021 a bord member of EduGis - the platform for geo-information technology in education.

Alexandra Rowland obtained an MSc in Geographical Information Management and Applications from the University of Utrecht, the Netherlands in 2021 based on the thesis proposing a methodology for automatic GIS workflow generation using semantic technologies. Following graduation, Alexandra joined Kadaster, the Dutch Land Registry and Mapping Agency, as a PDEng student and is currently supporting the ongoing development of the Kadaster Knowledge Graph. Her research investigates the role that this Knowledge Graph and other linked data developments within the organisation could play in Kadaster's future data platform.

Erwin Folmer received his MSc in Technical Business Administration (Industrial Engineering) in 1999 at the University of Twente, based on a master thesis assignment on requirements engineering at Baan Development. From 1999 until 2001, Erwin was innovator at KPN Research involved in amongst other the order entry and billing systems of ADSL services. In 2001 Erwin joined TNO and became senior scientist on the topic of interoperability and standards. From 2009 he part-time joined the University of Twente to start PhD research on the standardization topic, while continuing his work for TNO. In 2012 received his PhD based on the 'Quality of Semantic Standards' thesis. In 2013-2014 Erwin was visiting researcher at ERCIS/University of Munster. From 2015 onwards Erwin joined Kadaster. At Kadaster he is leading the developments of the Linked Data platform for open geographical data. Currently this is the largest deployment of Linked Data in the Netherlands, and among the largest in the world.

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