Harnessing AI for Responsible Land Surveying and Administration

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SUMMARY

The objective of this paper is to explore the transformative potential of Artificial Intelligence (AI) in the realm of land surveying and administration, with a focus on responsible and sustainable practices. This study delves into the application of AI technologies at the Dutch Land Registry and Mapping Agency – in short Kadaster, highlighting the journey from initial implementation to current advancements, and projecting future developments.

The paper presents a comprehensive analysis of AI applications at the Kadaster, encompassing cadastral registration, mapping, and land administration. Since the inception of AI integration, the Kadaster has leveraged machine learning algorithms for text recognition in deed processing, automated detection of cadastral boundaries, and enhanced data accuracy through predictive analytics. These applications have significantly improved operational efficiency and data reliability.

The paper also addresses the challenges encountered during the AI adoption process, such as data quality issues, integration complexities, and ethical considerations. Looking ahead, the future of AI at the Kadaster are poised to further enhance land administration processes, offering greater transparency and efficiency. To harness AI responsibly, the paper emphasizes the importance of robust AI governance and sustainability practices.

In conclusion, the integration of AI in land surveying and administration at the Kadaster has demonstrated significant benefits in terms of efficiency, accuracy, and sustainability. The lessons learned and future prospects outlined in this paper underscore the critical role of AI in shaping the future of land administration, aligning with the theme of the FIG Working Week 2025: "Collaboration, Innovation, and Resilience: Championing a Digital Generation".

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INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative force across various domains, including land surveying and administration. AI, in its essence, refers to the simulation of human intelligence processes by machines, particularly computer systems. These processes include learning, reasoning, and self-correction. Generative AI, a subset of AI, utilizes generative models to produce new data, such as text, images, and videos, based on patterns learned from existing data (IBM, 2023). This technology has gained significant traction in recent years, driven by advancements in deep learning and large language models.

The journey of AI from its inception to its current state has been marked by several milestones. Initially, AI was primarily focused on rule-based systems and symbolic reasoning. However, the advent of machine learning, particularly deep learning, revolutionized the field by enabling systems to learn from vast amounts of data. Today, AI is characterized by its ability to perform complex tasks, such as natural language processing, image recognition, and autonomous decision-making (Microsoft, 2025). The current hype around AI is largely fuelled by its potential to automate and enhance various processes, making them more efficient and accurate.

In the realm of land surveying, AI is poised to revolutionize traditional methods. Currently, AI-powered tools are being used to analyse large datasets, such as drone imagery and LiDAR scans, to extract valuable insights and improve accuracy (Go Report, 2024). In the short term, AI is enhancing the efficiency of data collection and processing, reducing the time and effort required for manual tasks. Looking ahead, AI is expected to play a pivotal role in automating complex surveying tasks, such as anomaly detection and trend analysis, thereby transforming the industry (Nettleman Land Consultants, 2024)

Similarly, AI is making significant strides in land administration. The integration of AI technologies in this domain is enhancing the accuracy and reliability of cadastral data, improving the efficiency of deed processing, and automating the detection of cadastral boundaries (EuroGeographics, 2022). In the short term, AI is streamlining administrative processes and reducing human error. In the long term, AI is expected to offer greater transparency and efficiency in land administration, leading to more sustainable and responsible practices (FIG, 2023).

The objective of this paper is to explore the transformative potential of AI in the realm of land surveying and administration, with a focus on responsible and sustainable practices. By examining the application of AI technologies at the Dutch Land Registry and Mapping Agency (Kadaster), this paper aims to highlight the journey from initial implementation to current advancements and future developments. The paper emphasizes the importance of robust AI governance and sustainability practices to harness AI responsibly.

The Kadaster plays a crucial role in collecting and registering administrative and spatial data on property and the rights involved. Kadaster's main tasks include maintaining the national reference coordinate system, providing national mapping services, and offering advisory services on land-use issues. The integration of AI at Kadaster has been instrumental in enhancing the efficiency and accuracy of its operations. AI technologies are being used for text recognition in deed processing, automated detection of cadastral boundaries, and predictive analytics to improve data accuracy (EuroGeographics, 2022). These applications have significantly improved operational efficiency and data reliability, demonstrating the potential of AI to transform land administration processes (FIG, 2023).

In conclusion, the integration of AI in land surveying and administration at Kadaster has demonstrated significant benefits in terms of efficiency, accuracy, and sustainability. The lessons learned and future prospects outlined in this paper underscore the critical role of AI in shaping the future of land administration, aligning with the theme of the FIG Working Week 2025: "Collaboration, Innovation, and Resilience: Championing a Digital Generation".

DIGITAL TRANSFORMATION AT THE KADASTER: HOW AI IS RESHAPING LAND ADMINISTRATION

In an era where technology evolves at lightning speed, artificial intelligence (AI) plays an increasingly significant role in our daily lives. The Kadaster, responsible for the registration and mapping of real estate, is at the forefront of leveraging these technologies. This part of the article highlights several examples of AI applications, focusing on three core areas: cadastral maps, notarial deeds, and geoinformation.

The Kadaster faces several challenges. Many repetitive administrative tasks still require considerable time. At the same time, there is a looming shortage of experts due to an aging workforce. The need to work more efficiently, reduce costs, and improve the quality of registrations has led to the adoption of AI. However, why AI? As mentioned, the technology offers the possibility to perform tasks faster and more accurately, while preparing for future questions and assignments. AI applications at the Kadaster aim to reduce error margins, improve data processing, and support staff with intelligent systems. The paragraphs below discuss the three primary areas of application.

2.1 Precision in Cadastral Maps

One of the Kadaster's most crucial responsibilities is maintaining cadastral maps. These maps show property boundaries and form the basis for legal certainty and urban planning. Yet this visual representation has its limitations. The precision of the boundaries on the map has a margin of error, which can lead to uncertainty.

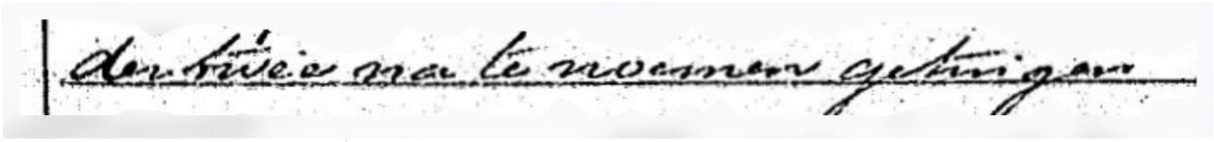
Recently, Kadaster has been working on the digitalization and vectorization of its historical archives. Kadaster's 'Kadastrale Kaart Next' (KKN) project aims to modernize the Dutch Cadastral Map by leveraging AI to process millions of handwritten field sketches (Franken et al., 2021). These sketches are transformed into structured, accurate geometries to create a future-ready cadastral map. This initiative addresses critical challenges in boundary precision and parcel size accuracy, ensuring the map meets evolving user needs.

These improvements in map representation ensure that boundaries can be shown with greater certainty. It is not just a technical advance; it also enhances citizens' and institutions' trust in the Cadastre's data.

2.2 Smart Analysis of Notarial Deeds

Every year, the Cadastre processes about one million notarial deeds. These documents, often dozens of pages long, contain crucial information about property transfers and legal agreements. Manually processing these deeds is time-consuming and prone to errors. That is why AI is used to make this process more efficient.

Kadaster is employing AI-based Optical Character Recognition (OCR) to convert handwritten deeds into searchable digital text. This process includes segmenting text lines and converting them into digital characters with high accuracy. In the digitized texts, easements are automatically detected using keyword-based searches, providing valuable insights despite the necessity for human validation. Kadaster is currently utilizing OCR techniques to digitize its entire deed archive, from 1832 till the present.



confidence	text
0.9865696377931428	der twee na te noemen getuigen

Figure 1: A digitized line from a handwritten deed.

In addition, the Kadaster has set up an "Aktenbak" (Deed Box). This system makes it possible to search the entire archive of notarial deeds, from 1838 to the present, fully digitally. The benefits are enormous: work that currently takes several days can soon be completed in just a few hours. This not only provides a huge efficiency gain but also ensures faster service to citizens and institutions.

One of the great advantages of this technology is that human oversight remains in place. AI systems present the structured data in a viewer, where staff can make corrections and add details. This keeps the human factor an essential part of the process, increasing accuracy and fostering trust and a sense of control over the technology.

Another benefit is the ability to keep improving the models. By incorporating employee feedback, the AI models become increasingly smarter and better aligned with the Kadaster's specific needs.

2.3 Geoinformation

The third domain where AI plays a major role is geoinformation. The Cadastre uses aerial and satellite images to identify and map features in the landscape. These can include roof types, vegetation, solar panels, obstacles, and small buildings.

One of the most impressive applications is the detection of solar panels. Although most solar panels are easily recognizable, dark panels on dark roofs still pose a challenge. Using deep learning segmentation models, the Cadastre is working on solutions to identify these hard-to-detect objects as well.

Figure 2: The detection of solar panels (red) on buildings. Based on these detections, buildings are classified as either possessing solar panels (green) or lacking them (blue).

Additionally, object recognition techniques are employed to locate asbestos roofs and new buildings. This is important not only for administrative purposes but also for environmental measures and urban planning. By combining geoinformation with cadastral data, a more complete picture of the physical reality emerges, helping policymakers make well-informed decisions.

CHALLENGES AND LESSONS LEARNED

Kadaster is integrating AI technologies to enhance its operations, a process that has revealed challenges. These challenges include ensuring data quality, incorporating new algorithms into existing workflows, and addressing ethical considerations. Overcoming these challenges has proven essential to successfully implementing AI at Kadaster.

3.1 Ensuring High-Quality Data

High-quality data is critical for training AI algorithms to perform effectively. Over the last years, the focus of machine learning has shifted from feature engineering to the availability of large amounts of data over the last years (Whang and Lee, 2020). To address the need for a dataset which is both large and representative, Kadaster adopts a two-step training approach when possible.

1. Pretraining on Open-Source Data: The AI model is pretrained using an open-source dataset enhanced with data augmentations. At this point, the model has become good at recognizing general patterns, but not yet Kadaster-specific ones.
2. Finetuning on Curated Data: After this generic model is trained, the algorithm is fine-tuned on a smaller, manually annotated dataset curated specifically for Kadaster. The final model knows the general patterns, and is optimized for the Kadaster objective, resulting in optimal performance.

The two-step approach achieves state-of-the-art results while minimizing the manual labelling effort, enabling Kadaster to integrate AI effectively into its operations. Algorithms are periodically retrained, in order to keep model performance high even in case of changing input data distribution.

3.2 Benefits and Challenges of Workflow Integration

A key benefit of integrating AI is its ability to process large amounts of data quickly, enabling faster decision-making compared to standard software. AI also enhances accuracy, resulting in improved decision-making and more efficient workflows. However, incorporating new algorithms into established workflows is challenging and requires a structured, informed approach. Success depends on a clear understanding of objectives and the roles of key stakeholders. Organizations must assess current decision-making processes and how existing systems use data. Once stakeholders are aligned, the appropriate algorithm can be chosen to meet identified needs.

Implementation typically begins with developing a proof-of-concept (POC) to validate the algorithm's feasibility and demonstrate its benefits. Following validation, the POC is transitioned into a production-ready state and integrated into the organization's IT infrastructure to ensure scalability and sustainability. Once deployed, the algorithm requires ongoing monitoring to maintain performance. Key steps include setting up automatic alerts, analysing usage data, and adjusting as needed.

3.3 Addressing Ethical Considerations

While training algorithms on high-quality data, and integrating models into workflows, it is important to address the ethical considerations. How does the output of these algorithms affect the real-world people occurring in the data? How do the algorithms affect the employees collaborating with them? These are important questions which Kadaster answers for each of the AI solutions is develops.

The ethical considerations depend highly on the data which it processes, and the information domain of the AI solution. Location data are particularly sensitive as they link information across sources and can be used to infer a wide variety of personal information (McKenzie et al., 2023). For example, when detecting objects like solar panels in the geoinformation domain, ethical challenges arise. There has to be ensured that the objects are not linked to real-world people. Therefore, only the objects are disclosed as a dataset, not the images which they have been detected on.

It is of utmost importance for Kadaster to enforce clear rules when using AI to process personal data. This helps ensuring that the outputs from potentially biased algorithms do not lead to unintended consequences. A good example of a challenging situation is detecting easements in digitized handwritten deeds. While the OCR technology provides results that are generally accurate enough for human readers and supports the automatic identification of easements, errors can still occur. For this reason, the system is used only as a support tool for humans. It helps speed up the process, but the final responsibility remains with the human operator, who must review and confirm all results to ensure they are correct.

To conclude, Kadaster has addressed challenges in data quality through its training approach, ensuring models are both generalizable and optimized for specific tasks. Seamless workflow integration is achieved with structured processes, from proof-of-concept to deployment. Ethical considerations are prioritized by tailoring safeguards to the data domain, ensuring trust and accountability in AI solutions.

AI AT KADASTER: THE ROAD AHEAD

Kadaster is dedicated to advancing its services by continuously exploring and implementing innovative AI solutions. Collaborating closely, the core innovation teams—the Data Science Team and the Emerging Technology Centre—focus on identifying key opportunities for AI integration. These teams work hand-in-hand with domain experts and stakeholders to design and seamlessly incorporate innovative solutions into existing workflows. Current areas of exploration of Kadaster include leveraging generative AI for enhanced data processing and information retrieval and employing object detection techniques to automate object indexing, paving the way for efficient land administration and surveying processes.

4.1 Leveraging Generative AI

Generative AI has emerged as a transformative technology worldwide, and Kadaster is actively embracing its potential. One notable initiative is the development of a generic chatbot powered by a diverse set of data repositories, such as the Kadaster wiki and the customer service knowledge base. Instead of interacting with a 9-to-5 customer support worker, employees will now have easy on-demand access to real-time information. With fine-grained access control, the chatbot enables employees to retrieve authorized internal data effortlessly through a user-friendly chat interface. Because of its generic nature, the chatbot allows every component at Kadaster to contribute and manage their own data repositories.

Another promising application of generative AI at Kadaster is the automatic generation of metadata for Kadaster datasets. Datasets collected by Kadaster include objects like borders, houses but also topographic items like storage tanks and even parking garages. This solution ensures consistent and accurate metadata across datasets while reducing the potential for human error. The metadata facilitates easy discovery of datasets through the generic chatbot. By streamlining metadata creation, dataset authors can keep their focus on producing high-quality datasets.

In order to achieve the goal of leveraging generative AI to optimize the work of Kadaster employees, the Generative AI solutions must be properly integrated in existing workflows. An investigation needs to be done which processes are impacted, and this impact must be addressed by properly instructing employees. It is also important to have good AI governance in place, to address the associated risks coming with these new solutions. When the risks are mitigated, the different components within Kadaster can embrace the solution by indexing and maintaining their data sources, in order to keep serving reliable and up-to-date information. AI governance will be discussed in section 1.5.

4.2 Automating Object Detection

A key area of AI research at Kadaster focuses on further automating data collection. Traditionally, manual labour was heavily involved in data acquisition and map creation. Because of the high costs associated, Kadaster has been working on BRT Next, the goal of which is to reuse data from other sources as much as possible. AI will play a crucial role in validating data collected from these sources. While BRT Next introduced significant automation, ongoing research leverages advanced AI techniques to further streamline this process. Specifically, efforts are underway to automate the detection of diverse objects such as storage tanks, parking garages, and greenhouses. Existing standalone detection processes, optimized for individual object categories, have proven time-consuming. To address this, a standardized detection flow is being implemented, allowing the reuse of various object variants with the only modification being the training data used for training the AI model.

Achieving automated object detection requires access to high-quality training data. A diverse range of data sources is necessary, including aerial, panoramic, and oblique imagery, as well as Kadaster data and even crowd-sourced information like OpenStreetMap may be useful. Therefore, a robust data infrastructure is essential to ensure algorithms can access and integrate these diverse sources effectively. Efforts are underway to construct this datahub. Also, upon algorithm training, extensive validation mechanisms must be implemented to guarantee the adherence of detections to Kadaster quality standards.

By fulfilling these requirements, automated maintenance of many Kadaster data sources becomes feasible, enabling the provision of up-to-date and high-quality data. The up-to-date and complete datasets significantly benefit the many individuals, companies and government agencies using them, as they will be able to make better-informed decisions.

AI GOVERNANCE

Artificial Intelligence (AI) governance is a critical framework that ensures the responsible, ethical, and sustainable development and deployment of AI technologies. It involves establishing processes, standards, and oversight mechanisms to address risks such as bias, privacy infringement, and misuse while fostering innovation and building trust. The necessity of AI governance stems from the increasing integration of AI into various sectors, including the geoinformation sector, which has amplified its potential for both positive and negative impacts. High-profile incidents, such as the benefits affair in the Netherlands, have underscored the need for sound governance to prevent harm and maintain public trust.

Effective AI governance helps balance technological innovation with responsible implementation. It encompasses “ethical, legal, and societal frameworks, including policies and regulations to guide AI development, ensuring transparency and accountability, addressing ethical considerations such as fairness, privacy, and bias, and involving a wide range of stakeholders, including AI developers, users, policymakers, and ethicists” (Gartner, 2024). Due to the rapid developments in generative AI, it is increasingly important to closely monitor this technology and map out the opportunities and threats, such as privacy, information security, ethics, and sustainability. Therefore, Kadaster decided to establish AI Governance, which is currently in the middle of implementation.

5.1 Responsible AI at the Kadaster

To establish policies and frameworks at the Kadaster, the following main question with sub-questions needs to be answered: "How does the organization ensure that we responsibly harness the potential of AI and generative AI?" To answer this main question and define this responsibility, it can be broken down into three sub-questions: What is our AI ambition? What are we capable of doing? What are we allowed to do? In more detail, we look at what costs we are willing to incur for what benefits, which knowledge and expertise we need and have, what technical robustness is needed, and who is responsible for the AI applications.

At Kadaster, a task force has been set up to explore the path towards a well-functioning AI Governance. This task force includes key stakeholders such as the Algorithm Officer, innovation lead, AI experts, and research staff.

However, there are still some challenges to be faced, such as financial accountability, the need for a culture shift within the organization, and a lack of knowledge experts. Addressing the challenges in constructing AI Governance within Kadaster is crucial for several reasons. Firstly, financial accountability is essential to ensure that AI initiatives are cost-effective and provide a clear return on investment (can also be social value). Implementing robust financial accountability measures helps in tracking expenses, justifying investments, and ensuring that AI projects align with the organization's strategic goals.

Secondly, a culture shift within the organization is necessary to foster an environment that embraces AI and its potential benefits. AI governance requires a collaborative approach, where different departments and stakeholders work together to develop and implement AI solutions. This cultural transformation involves promoting a mindset that perceives the implementation of AI applications as a paradigm shift. It consists of values innovation, continuous learning, and ethical considerations. Encouraging employees to adopt new technologies and processes can lead to more effective AI integration and utilization. Moreover, a culture that supports AI governance can help in addressing ethical concerns, ensuring transparency, and building trust among stakeholders.

Lastly, the lack of knowledge experts poses a significant challenge to AI governance. AI is a complex and rapidly evolving field that requires specialized skills and expertise. Without sufficient knowledge experts, the organization may struggle to develop, implement, and maintain AI systems effectively. Investing in training and hiring AI professionals is crucial to bridge this knowledge gap. Additionally, fostering partnerships with academic institutions and industry experts can provide valuable insights and support for AI initiatives. By addressing the shortage of knowledge experts, Kadaster can ensure that its AI projects are guided by informed decisions and best practices.

5.2 Sustainability in AI

Sustainability practices in AI governance focus on ensuring that AI technologies are used responsibly and ethically, with considerations for security, privacy, ethics, potential impacts on society, and the environment. AI governance for sustainability is crucial because it helps mitigate the environmental impact of AI technologies, such as energy consumption and carbon footprint, ensures that AI applications contribute positively to societal goals, including the Sustainable Development Goals (SDGs), promotes transparency and accountability, building trust in AI systems, and encourages the development of AI solutions that address global challenges, such as climate change and resource management (Gartner, 2024). By implementing robust AI governance, organizations can ensure that AI technologies are aligned with sustainability goals and contribute to a more equitable and sustainable future. In the background sections of the paper, the transformative potential of AI in land surveying and administration at Kadaster has been discussed, highlighting the importance of robust AI governance and sustainability practices.

AI governance has a significant and sustainable impact on the geoinformation sector, particularly in land surveying and land administration. The integration of AI in these fields enhances efficiency, accuracy, and overall capabilities, transforming traditional methods into more advanced and reliable processes. For instance, AI-driven automation in land surveying, such as the use of Unmanned Aerial Vehicles (UAVs) equipped with sophisticated sensors and cameras, allows for the efficient capture of high-resolution aerial imagery, topographic data, and 3D models of landscapes (Nettleman Land Consultants, 2023). This not only improves the precision of land measurements but also reduces the time and resources required for data collection.

Moreover, AI governance ensures that these technological advancements are implemented responsibly, with a focus on sustainability. By adhering to ethical guidelines and regulatory frameworks, organizations can minimize the environmental impact of AI technologies and promote sustainable practices in land administration. This includes the development of AI solutions that address global challenges, such as climate change and resource management, thereby contributing to a more sustainable and equitable future (Geospatial World, 2018).

CONCLUSION

In conclusion, this paper has explored the transformative potential of Artificial Intelligence (AI) in land surveying and administration at Kadaster. Key points discussed include the significant improvements in operational efficiency and data reliability achieved through AI applications such as machine learning algorithms for text recognition in deed processing, automated detection of cadastral boundaries, and predictive analytics. The integration of AI has demonstrated substantial benefits, including enhanced accuracy, reduced error margins, and streamlined administrative processes, leading to more sustainable and responsible land administration practices.

Critical to the responsible integration of AI at Kadaster are robust AI governance and sustainability practices. These ensure that AI technologies are developed and deployed ethically, with considerations for data quality, integration complexities, and ethical implications. By adhering to these practices, Kadaster can harness AI's potential while mitigating risks and fostering trust among stakeholders.

The findings of this paper stress the importance of the FIG Working Week 2025: "Collaboration, Innovation, and Resilience: Championing a Digital Generation." The collaborative efforts between various departments at Kadaster, the innovative use of AI technologies, and the resilience demonstrated in overcoming challenges underscore the importance of these themes in shaping the future of land administration. Through responsible AI integration, Kadaster is championing a digital generation that is more efficient, accurate, and sustainable.

REFERENCES

EuroGeographics. (2022). *How AI shapes land registration in the Netherlands*. Retrieved from https://eurogeographics.org/app/uploads/2022/09/10-AI-at-the-Dutch-Kadaster-WIM-FLORIJN.pdf

FIG. (2023). *Overview of AI Applications at The Netherlandsÿ Cadastre, Land Registry*. Retrieved from https://www.fig.net/resources/proceedings/fig*proceedings/7*2023/papers/se04/SE04*bussemaker*12354_abs.pdf

Franken, J. , Florijn, W. , Hoekstra, M. , Hagemans, H.J. , 2021. Rebuilding the Cadastral Map of The Netherlands, the Artificial Intelligence Solution. Proceedings of the FIG e-Working Week 21 – 25 June 2021, 'Smart Surveyors for Land and Water Management - Challenges in a New Reality', virtual from The Netherlands, International Federation of Surveyors, Copenhagen, Denmark. ISBN 978-87-92853- 65-3. (https://www.fig.net/resources/proceedings/fig_proceedings/fig2021/papers/nl01/NL01_jeroen_florijn_et_al_11000.pdf).

Geospatial World. (2018). IOT and Artificial Intelligence in Land Administration.

Go Report. (2024). *AI in Surveying: Is It Really the Future?*. Retrieved from https://goreport.com/ai-in-surveying/

IBM. (2023). *What is Generative AI?*. Retrieved from https://www.ibm.com/think/topics/generative-ai

Lawyers Netherlands. (2024). *Land Registry in the Netherlands*. Retrieved from https://lawyersnetherlands.com/land-registry-in-the-netherlands/

McKenzie, G., Zhang, H., Gambs, S., 2023. Privacy and Ethics in GeoAI. In: *Handbook of Geospatial Artificial Intelligence*, 1st Edition, CRC Press, 18 pages. ISBN 978-1003308423.

Microsoft. (2025). *6 AI trends you'll see more of in 2025*. Retrieved from https://news.microsoft.com/source/features/ai/6-ai-trends-youll-see-more-of-in-2025/

Nettleman Land Consultants. (2024). *Navigating the Impact of AI in Land Surveying*. Retrieved from https://cnettleman.net/ai-in-land-surveying/

Whang, S.E., Lee, J.-G., 2020. Data collection and quality challenges for deep learning. Proceedings of the VLDB Endowment, 13(12), August 2020, 3429–3432, VLDB Endowment. ISSN 2150-8097. (https://doi.org/10.14778/3415478.3415562).

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