The pilot 'Living with water in Amsterdam' as proof of concept of the Amsterdam Time Machine approach

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ATM vision. It is the dream of anyone passionate about the past: to travel through time and experience a place the same way people did decades or centuries ago. Walk around your own neighborhood during the Dutch Golden Age, step into houses to get a glimpse of daily life at that time and see where the paintings now at the Rijksmuseum originally hung. Watch a movie in a cinema in the 1920s, go out in an eighteenth-century café or attend a play in the seventeenth-century municipal theatre.

Allowing anyone to virtually explore the city throughout its 750 years of history is the main goal of the Amsterdam Time Machine (ATM) project. Since 2017, the ATM has been working to materialize this ambition, together with a growing consortium of partners from the fields of research, cultural heritage, government and creative industries, coordinated by Julia Noordegraaf and the researchers and programmers of the Creative Amsterdam research program and lab.

ATM approach. The ATM aims to act as a public resource and infrastructure to enable scalable humanities research on the city of Amsterdam. The historical city is seen as a lab, where both micro-stories of daily life (zoom in) and long-term socio-economic processes and patterns (zoom out) can be observed, analyzed, and interpreted. As such, the ATM provides a knowledge base for the long-term development of present-day urban phenomena and challenges.

In order to make such scalable research possible, the ATM aims to systematically collect all available data on historical Amsterdam from heterogeneous sources and link them to maps and 3D models. In this way, locations act as anchor points to contextualize persons, objects, and events that have contributed to making the history of the city throughout time.

To provide access to this repository of linked data, a public front-end element will be developed, which will include multiple functions to match the needs of different target groups. On one side, a 3D/4D urban model of Amsterdam will act as a true virtual 'time machine', allowing users to travel back in time and walk through a digital replica of historical Amsterdam at the levels of neighborhoods, streets, houses, rooms, even zooming in on the pictures that adorned the walls. To this aim, the development of

immersive and augmented reality interfaces and other tools, which allow to build data-driven historical simulations, is key.

On the other side, the ATM aims to act as an entry point to a wealth of data sets, currently stored in various heritage and research institutions, which can be mapped and visualized together, based on queries run by users. The possibility of querying heterogeneous data sets to obtain spatial representations that integrate such data is of particular interest for researchers, who may for instance use layered maps to combine information on different aspects (socio-economic, demographic, cultural, infrastructural, etc.) of Amsterdam in the past, and rely on the resulting visualizations to find new angles of enquiry on historical phenomena. In this sense, the ATM platform can act as a heuristic tool for researchers to sharpen their research questions or formulate new ones entirely.

Furthermore, the ATM – like other Digital Humanities initiatives – uses computational techniques to process historical data in a meaningful way, as well as to support the development of reconstructions – both narrative and visual – of the past. The combined use of digital methods and tools, such as natural language processing (NLP) and HTR, helps unlock data that have been overlooked so far, thus providing new entry points to discover untold stories about the city. At the same time, computational pipelines allow to reconstruct virtual replicas of cities in a semi-automated fashion, instead of manually modelling each individual building, thus making the development of historical 3D 'digital twins' of cities feasible. To be able to achieve this, a sustainable technical infrastructure will be developed according to the latest widely accepted data standards.

ATM as a tool to address present-day urban challenges. The ATM approach described above is not just aimed at providing researchers with access to data and new heuristic tools, or at facilitating the public's engagement with the past by means of visual reconstructions. In fact, the historical 'digital twin' of Amsterdam is also instrumental in addressing present-day urban development challenges. Collecting and visualizing, in a spatio-temporal fashion, information about how the city has coped with specific infrastructural or environmental challenges in the past can serve as a source of knowledge and inspiration for imagining and designing solutions to contemporary issues. In this sense, looking back – by making use of the (spatially located) 'Big Data' of the Past and of the related visualizations – is also a way to look forward and plan for a more sustainable future.

For example, historical knowledge of how a specific city managed its transportation system and infrastructure before the beginning of the era of mass motorization offers an opportunity to imagine different ways of living the city compared to the current one, thus reducing the risk of pattern dependency in urban planning policies and decisions. At the same time, data-driven visualizations are a powerful tool to (virtually) test alternative scenarios – and not just in the hands of architects or urban planners. In fact, digital interactive systems are not only useful to inform or raise awareness in the general public over specific issues; they also offer an opportunity to collect input and contributions from users, with the aim of co-designing the city in a more inclusive and democratic manner.

The pilot 'Living with water in Amsterdam' and its consortium. To test the validity of this vision and its applicability to concrete situations, the ATM has joined forces with other partners for a pilot 'proof of concept' project focused on Amsterdam's special relation with water. The project 'Living with water in Amsterdam' is a collaboration between the Amsterdam Time Machine, Arcam – Architecture Center Amsterdam, Waternet (the water company of Amsterdam), the Municipality of Amsterdam, the Adamnet network organization of Amsterdam libraries and heritage institutions, and the Amsterdam University of Applied Sciences (AUAS).

This pilot project has already shown that in order to achieve the ATM's goals, the development of consortia based on a complementarity of expertise and scopes of action is of primary importance. This is particularly clear for the ATM – Arcam partnership. As the architecture center of Amsterdam, Arcam organizes programmes, exhibitions, and research projects aimed at bringing together a variety of stakeholders and audiences to explore and discuss current urban challenges. In particular, the 5D ExpoLab of Arcam employs data visualizations on 4D city models as a design tool to inform, decide, and speculate on future developments in the Amsterdam metropolitan region. With its emphasis on urban design assignments that will shape the city in the coming years, Arcam represents a natural complement to the ATM's focus on historical Amsterdam. Furthermore, both projects use maps and geo-coordinates to provide location-based access to information on the city: a similar approach, which makes it easier to combine efforts. By joining forces, ATM and Arcam can provide a truly longitudinal view on the city and its developments, as an uninterrupted line linking the past to the present and future.

A concrete area of potential application of this synergy is linked to the Municipality of Amsterdam's plan for the celebration of the 750th anniversary of the city, in particular the program line called 'A new map'. This new map of the Amsterdam metropolitan region – to be developed in both physical and digital formats – will act as a visual document of the current state of city as well as of planned interventions, while also serving as a participatory tool for public discussion on future developments. The creation of a 4D 'digital twin' of Amsterdam, which combines historical reconstructions with simulations of potential design solutions for the future, has the potential to address the need – described in the Municipality's plan – for a such a tool to map, design, and engage a broader public in complex future spatial development scenarios based on historical knowledge.

The pilot project 'Living with water in Amsterdam' is a first proof of this concept.

The pilot as proof of concept of the ATM approach. Water and its management are a central issue for Amsterdam nowadays, as they have always been in the past. Over the centuries, a complex system of locks and dikes has been developed to manage the water level in the city. Due to climate change and the housing crisis, this system is now under pressure and will be increasingly so in the future.

The project 'Living with water in Amsterdam' aims to collect, study, and visualize historical data on the relation of the city with water, and to increase public awareness of the functioning and importance of the Amsterdam water system. The ambition and structure of this project make it a valuable occasion to put the ATM approach outlined above to test against a concrete, tangible challenge – the rising water levels – which has explicit spatial effects on everyday life.

The project constitutes a 'proof of concept' of the ATM's approach in several ways. Firstly, it firmly establishes the Amsterdam Time Machine as a platform that collects and makes publicly available historical data on Amsterdam, not solely for research purposes, but also to inform and engage citizens with topical issues for the present and future of the city and its inhabitants. What is more, the project constitutes an example of a partnership in which ATM contributes historical data and knowledge, which are then used by other partners for their own reconstructions or projections of future scenarios.

Secondly, layered maps are at the core of the ATM approach, as they allow to combine visual representations of different phenomena or angles of observation into the city. Together with the use of locations as anchor points for other data – such as

prosopographic, economic, event-related data, etc. – maps enable an exploration of heterogeneous information at different scales and on both dimensions, temporal and geographical.

Thirdly, from a technical point of view, this project is making use of semi-automated modelling pipelines to generate visual reconstructions of historical buildings (in particular, from photographs and similar images). This pilot therefore combines the ATM's vocation as a platform for research and public engagement with the use of computational methods to create visual representations of the past at scale.

The exhibition 'Fluid matter' at Arcam. A first, concrete result of this project is the exhibition 'Fluid Matter – Designing with water in Amsterdam', which opened at Arcam on July 8th. The exhibition showcases several installations on the history and future of waterways in the Oosterdok/Kattenburg area of Amsterdam, created by students of the MA Digital Design at the University of Applied Sciences Amsterdam (AUAS) in response to an *ad-hoc* design challenge. The task was to create a physical 3D map of Kattenburg, over which data of different nature were projected in context, i.e., in connection to specific locations on the map. The challenge was to combine on a map of present-day Amsterdam heterogeneous historical data, together with compelling and attractive visualizations of potential scenarios for future developments in those same locations. The resulting installations represent concrete instances of how historical data contributed by the ATM provide knowledge and inspiration to create awareness of contemporary challenges in urban planning and offer potential solutions to them.

A clear example relates to the variability of water levels in the Amsterdam canals. Nowadays, the canal belt in the center of Amsterdam has an open connection with the IJ, the body of water that connects Amsterdam to the North Sea and the IJmeer. Such an open connection is made possible by the current water management system, which through a series of locks keeps the level of the IJ stable. However, before the installation of the 'Oranje Locks' in 1872, both the IJ and the canals were affected by the tidal action of the sea, and ebb and flow alternated inside the city. A physical 3D model at the exhibition *(picture on the left)* uses bright trails to show how the return to an alternation of ebb and flow, forced by the rising sea levels, would affect the routes of the numerous boats currently passing under bridges in the Amsterdam canals.

Similarly, rising waters pose a threat to residential districts of the city such as the Houthaven, where developments over the past decades have relied too much on a stable water level. Several newly built houses in this area have windows that extend only a few centimeters above the water level and, therefore, face a significant risk of flooding in the case of rising water levels. Historical knowledge suggests that the variability of water levels must be considered when (re-)designing the city, in order to mitigate its negative effects – for instance, by building infrastructure such as roads, bridges, and power lines way higher on the current water level and by surrounding them with unbuilt areas, in order to limit risks of flooding and to guarantee their functioning as evacuation routes.

Another mitigation tactic is the creation of overflow areas, as proposed in 2020 with the 'Amsterdam water forest' design study. This forest, which would replace part of the body of water of the IJmeer, would serve as a water retainment zone, ecological resource, and an area that could be flooded temporarily, while remaining accessible to Amsterdammers via boats or on boardwalks. This, however, is not the only scenario proposed over the years for the urban development of the IJmeer. The installation 'Battle for the IJmeer' at the exhibit *(picture on the left)* documents these conflicting plans on a physical 3D model and stages a battleship game, where visitors are invited to use their preferred building plans as ships in a real-time battle against an opponent. This interactive, gamified experience is one of the several examples of how the exhibit conceives its audience not just a passive recipient of information, but rather as an active and engaged co-designer and co-contributor to urban planning decisions.

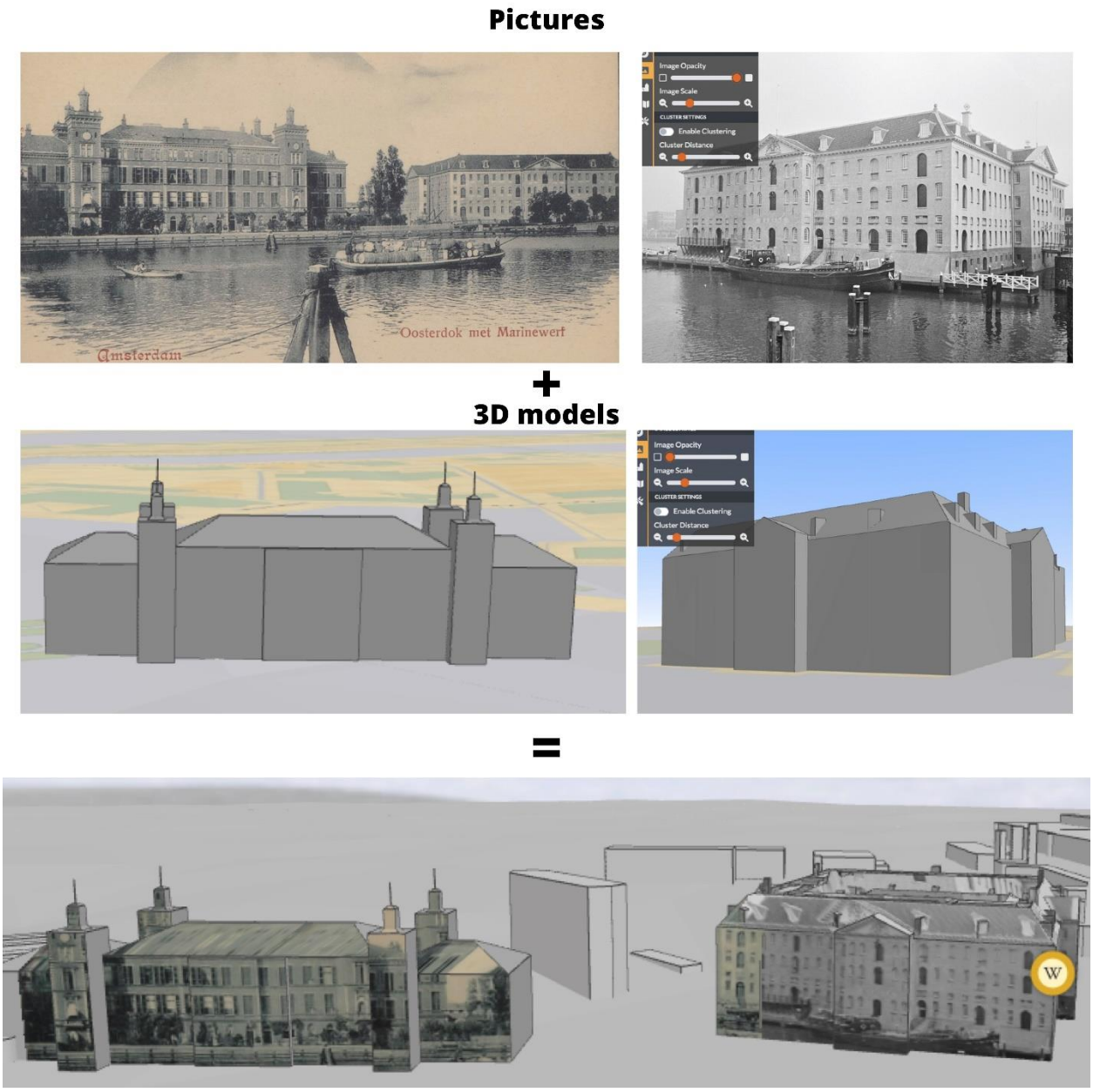
Water, however, can be turned from threat into a valuable resource, as shown by the 'Amsterdam rainproof' installation. The past teaches that rainwater can be collected at the level of individual households as well as via more complex systems (https://copingwithdrought.com/). By developing new buildings with water roofs and balcony gardens, and by designing public space terrains capable of retaining part of the rainwater, it is possible to lessen the negative effects of heavy downpours, while also improving the availability of a resource that climate change will likely make scarcer in the future.

A thematic historical 3D map of Amsterdam. Besides collecting data from the City Archives on the history of the water system in Amsterdam, student assistant Daan Groot of the ATM collaborated with Wietse Balster and other colleagues from the Municipality of Amsterdam at the joint ATM-Municipality contribution the to the exhibition: a water-focused version of the www.3d.amsterdam.nl digital 3D model of the city.

Users can interact with and navigate this thematic version of the 3D 'digital twin' of Amsterdam by selecting one of five different layers, each of them corresponding to a specific aspect of the city's relation with water. Historical 2D maps allow to visualize the physical infrastructure of the waterways superimposed to the present-day city, while a map comparing the taxation on houses in the canal belt in the 17th and 19th century sheds light on the varying economic value of living near waterways. Reference data on the flooding of Kattenburg in 1775 have been extracted from the City Archives records and are visualized on the 3D map with the addition of a time slider. Lastly, buildings in the Oosterdok which are no longer standing, such as the Marinepaleis (demolished in 1968), are reconstructed though 3D models and historical photos and are shown on the map.

For this latter component of the project, a valuable collaboration has been established between the ATM and the Friedrich Schiller University (FSU) of Jena, Germany. Within the Urban History 4D / HistKI project, a research group based at the FSU and lead by Sander Münster has been working since 2015 at the development of a pipeline for the semi-automated creation of 4D city models based on historical images. In addition to applying photogrammetry methods for the identification and orientation of historical photographs, this research project has also resulted in a location-based 4D mobile application. The 4DCity browser application allows users to visualize historical buildings in VR via their phone's camera and to click on the building to access further information linked to it.

At the 'Fluid Matter' exhibit, the collaboration between the ATM and the FSU Jena has materialized in the testing and implementation of a workflow that employs photogrammetry to create 3D virtual replicas of historical buildings, which visitors can visualize on their mobile phones. A QR code gives access to the 4DCity browser application, which allows users to point their phone in the direction of the Oosterdok and to visualize – thanks to a timeslider – buildings such as the Marinepaleis, which once stood in the area but were later demolished. Additional information on these historical buildings can be accessed by clicking on a dedicated icon.



Example of the photogrammetry test case (credit: Daan Groot). More information on the process can be found in this blog post.

In sum, the preliminary results of this pilot project constitute a clear proof of concept of the ATM's approach. The layered maps create visualizations that unlock new knowledge or new (research) questions about the city; semi-automated pipelines make the reconstruction of larger parts of historical Amsterdam feasible; while the reconstructed buildings act as anchors and entry points for heterogeneous data and information

related to that specific location. Taken together, these visualizations serve as a knowledge base for researching and designing sustainable solutions for living with water in the future.