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A fragment of the originally grayscale cover of Herman Hertzberger's printed book 'Lessons for Students in Architecture'. Designed by Piet Gerards, digitised by a smartphone, colourised through a 'neural filter' and pixelated through a 'texture' filter in Photoshop by the author.

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From Structured Spaces to Unstructured Data.: Herman Hertzberger from a Computer Vision Perspective

Herman Hertzberger commented in his recent book that architect's 'thought-space' has shrunk compared to its original capacity.¹ As he explained, this is because architects are trained to satisfy the specific 'short-lived' requirements prescribed by the design brief. In his view, designing for the increasingly more 'dynamic and uncertain' world requires a change of approach.² What we should really be after is a 'programme for the *programmeless building*', where forms and spaces would be as free as possible from 'overly explicit meanings'.³ This approach requires architects to 'no longer think in terms of *functions* but exclusively in terms of *conditions* – that is, in terms of space's capacity to fulfil more than one duty'.⁴ In this paper, I will argue that, in the 21st century, due to the digital transformation of disciplinary memory, architect's 'thought-space' has not shrunk, but it has actually expanded, to such an extent that it has become increasingly challenging to navigate, and consequently to utilise for the design of (adaptable) buildings. Through a practical thought experiment, using Hertzberger's ideas as starting points, I intend to reveal the potential of *computer vision* for future design practice and raise awareness of the increasing interdependence between digital technologies and design thoughts that will shape the future of the built environment.⁵

ARCHITECT'S MEMORY

In his book *Lessons for Students in Architecture*, referring to the collection of ideas stored in an architect's memory, Hertzberger wrote: 'the more you have *seen, experienced and absorbed*, the more points of reference you will have to help you decide which direction to take'.⁶ Hertzberger described the record of ideas in an architect's memory as a 'vast collection of images, something of a *library* of images from everywhere and of all times' that the architect can

1 Herman Hertzberger, *Architecture and Structuralism: The Ordering of Space*, trans. John Kirkpatrick (Rotterdam: nai010 publishers, 2015), 130.

2 Ibid., 126–30.

3 Ibid., 100, 144. Emphasis added.

4 Ibid., 109. Emphasis added.

5 This paper is a part of an ongoing PhD research at the intersection of architecture, computer vision and media studies, exploring interfaces between vision, memory, design thinking and the digitalisation of cultural techniques in the context of new emerging technologies resulting from the abundance of data.

6 Herman Hertzberger, foreword to *Lessons for Students in Architecture*, trans. Ina Rike, 6th ed. (Rotterdam: 010 publishers, 2009). Emphasis added.

‘consult whenever a problem arises’.⁷ The capacity to find a ‘fundamentally different solution to a problem’, he argued, depends entirely on the wealth of one’s experience.⁸ Discovering what the images have in common, by looking at their ‘fundamentally unchangeable ingredients’, would enable architects to find ‘the “cross section of the collection”, the unchangeable, underlying element of all the examples, which...can be an evocative form-starting-point’.⁹ In other words, history keeps uncovering ‘different aspects of an *unchanging structure* under changing conditions’,¹⁰ through the medium of memory.

Memory, as defined by the field of psychology, is the capability of encoding, storing, and retrieving information, where *encoding* refers to the initial learning of information by perceiving, *storage* refers to maintaining information over a period of time and *retrieval* is the ability to access information when needed.¹¹ Looking at these definitions, it becomes apparent that Hertzberger’s original terms ‘*seeing, experiencing and absorbing*’ could be translated into *encoding*, ‘*library*’ could be translated into *storage*, and ‘*consulting*’ could be translated into retrieval. This analogy enables us to investigate how memory transformed in the 21st century.

In his 1999 article ‘The Seven Sins of Memory’, psychologist Daniel Schacter described seven memory failures that can undermine thinking, indicating that human memory, although often reliable, is also fallible.¹² The fallibility of human memory and the potential way of dealing with its limitations was also insightfully discussed in Vannevar Bush’s visionary essay from 1945 called ‘As We May Think’. With great foresight, Bush spoke of a future device called ‘memex’ that would serve as ‘an enlarged intimate supplement’ to one’s memory, enabling individuals to store all their ‘books, records, and communications’ and consult them ‘with exceeding speed and flexibility’.¹³ Bush advocated the development of instruments that would enable mankind to access their collectively accumulated knowledge. He believed that access and engagement with the collective ‘record of ideas’ would enable knowledge to evolve and endure ‘throughout the life of a race rather than that of an individual’.¹⁴ Evidently, technology has both extended and perpetuated human memory. Most notably, technology has escalated the externalisation of human memory.¹⁵ And although people have long externalised their memories by ‘creating representations that exist outside of their minds’ (through writing, drawing and photography), the frequency of externalising memory

7 Hertzberger, *Architecture and Structuralism*, 118; foreword to *Lessons*. Emphasis added.
8 Ibid.
9 Hertzberger, *Architecture and Structuralism*, 118–19.
10 Ibid., 119. Emphasis added.
11 Kathleen B. McDermott and Henry L. Roediger, *Memory: Encoding, Storage, Retrieval*, Noba Textbook Series: Psychology, ed. R. Biswas-Diener and E. Diener (Champaign, IL: DEF Publishers, 2014), 9. Encoding techniques include: relating new information to the existing knowledge, forming mental images, and creating associations between information that needs to be remembered.
12 Daniel L. Schacter, “The Seven Sins of Memory: Insights From Psychology and Cognitive Neuroscience,” *American Psychologist* 54, no. 3 (March 1999): 182. According to Schacter, the seven memory errors are: transience, absent-mindedness, blocking, misattribution, suggestibility, bias and persistence.
13 Vannevar Bush, “As We May Think,” *The Atlantic Monthly* 176, no. 1 (July 1945): 101–08. Section 6.
14 Ibid. Section 1.
15 Emmaline Drew Eliseev and Elizabeth J. Marsh, “Externalizing Autobiographical Memories in the Digital Age,” *Trends in Cognitive Sciences* 25, no. 12 (December 2021): 1072–81.

significantly increased with the arrival of personal digital devices, which on the one hand, extended autobiographical memory, and on the other hand, enabled individual memory records to be collectively ‘observed’.¹⁶

In his book *Building Knowledge in Architecture*, Richard Foqué argued that most of the knowledge in architecture is ‘generated and legitimised pragmatically instead of being logically derived from theory’.¹⁷ If we adopt Foqué argument, we will be inclined to investigate how architectural memory records emerge in practice today, which can be illustrated through the following sequence of events: an architect takes a photo with a smartphone of a sketch that they made on top of a floor plan that was extracted from a digital 3D model, simulating the envisioned spatial situation; they then instantly send this *visual*¹⁸ to a colleague who opens it on a tablet, ‘zooms in’ on a specific part of the floorplan, takes a screenshot, draws the proposed changes with a digital pen and sends it to a third colleague, accompanied by a link to a website which contains information about a project with similar characteristics;¹⁹ the third colleague then proceeds to implement these changes in the original 3D model on a computer, and stores the record of the new solution in a form of a digital *image*²⁰, thereby making it a permanent item in the digital archive of that particular office.

This example reveals that in the 21st century architect’s memory became more externalised, dynamic, collaborative, extensive and permanent, raising the following questions: How significant is this particular memory record compared to its previous versions? How can a colleague working on a ‘similar’ project in five years retrieve this memory record? Based on which characteristics was this design solution ‘similar’ to the one on the website and why is this relevant? And finally, how can this memory record, together with millions of other such records produced in practice daily, contribute to the evolution of the collective architectural knowledge base? In order to explore these questions, it is necessary to first reflect on the *visual* nature of architectural memory, and to examine the processes that underlie the organisation of knowledge.

ARCHITECT’S VISION

Considering that all production and absorption of the material recorded in human memory fundamentally proceeds through one of the senses,²¹ we can

16 Ibid.
17 Richard Foqué, *Building Knowledge in Architecture* (Antwerp: UPA, 2010), 146–50. Foqué refers to Putnam’s definition of pragmatic thinking, emphasising the significance of ‘unity in learning and experience, and in conceptual thought and situational consciousness’.
18 A *visual* can be any sketch, drawing, diagram, picture, photo etc, used to show or explain something.
19 Besides the textual description (computationally translatable to any language) and the selection of drawings, renderings and photographs of the reference project, the website might even contain a link to the video clip in which the project architect explains the reasoning process that generated that particular spatial situation.
20 A digital *image* is any *visual* (see above), either born-digital (produced in digital form) or digitised (converted to digital form), eg a *drawing* made by hand is a *visual* that can be digitised (scanned) becoming an *image*.
21 Bush, “As We May Think,” Section 8. Senses are: sight, hearing, smell, taste and touch.

certainly acknowledge that architectural design is dominated by the sense of sight, i.e. *vision*.²² Architectural design can be seen as the realisation of an idea, or the resolution of requirements by means of visual communication,²³ which are used to enable spatial structures to be created or spatial issues to be resolved.²⁴ The ability to read graphic information is therefore a prerequisite for interpreting architectural memory records while processing digital records in large quantities requires employment of computational techniques. Therefore, it could be argued that the success of exploiting the growing architectural knowledge base essentially depends on the computer's ability to read various architectural *visuals*.²⁵ Recent evidence suggests that computers have become surprisingly good at extracting information from *visual data*,²⁶ as a result of advancements in the field of computer vision whose primary goal is to enable computers to perceive and understand the visual world as humans do. *Computer vision* research fundamentally derives from the fact that the human mind is a 'categorising machine' constantly processing and categorising sensory information.²⁷ Psychologically, the purpose of *categorisation* is to simplify the complexity of sensory inputs. By dividing our experience into 'groups or categories whose members share some perceptible similarity within a given context',²⁸ the process of categorisation establishes order in our memory, thereby enabling us to store and retrieve information efficiently. Language, to a great extent, helps us navigate our memories and enables us to communicate about what we perceive. Interestingly, Hertzberger argued that 'an idea can only be said to exist in so far as it permits formulation in words'.²⁹ This assumption, when observed from a (computer) vision perspective, is arguable since categories are *not* exclusively defined by language.³⁰ When it comes to recognition of visual features, people are able to group objects (and colours) based on their similarity even when they cannot verbally describe them. *Vision* allows us to register many distinct aspects and delicate nuances within images, e.g. distinctions between numerous geometric shapes, their ratios and relationships, visual rhythms and hierarchies, alignments, colours, textures, transparency, types of surfaces etc. These aspects are particularly characteristic of aesthetic artefacts, including architectural artefacts.³¹ A

22 Written and verbally transmitted information is usually seen as supplementary to the graphic information in practice. Senses of *hearing*, *touch* and *smell* are also employed through eg site visits and material sampling.
 23 Eg drawings, models, diagrams, renderings and photographs.
 24 This definition is a partial adaptation and extension of the definition found on the construction wiki. See "Design," Designing Buildings, last modified July 27, 2021, <https://www.designingbuildings.co.uk/wiki/Design>.
 25 Interpreting visual information is a complex task for a computer. When looking at an image, humans can immediately detect shapes (rectangles), separate them from the background (urban setting), understand what does each shape depict (residential tower), interpret the implicit information (competition render) etc, while computer can initially only 'see' the numbers that make up the image.
 26 For example, in the field of medical image analysis computers have been able to exceed human capabilities in recognising visual patterns, leading to faster and more precise medical diagnostics. Visual *data* is un-interpreted visual information in digital format that can be processed by a computer.
 27 Lev Manovich, *Cultural Analytics* (Cambridge, MA: MIT Press, 2020), 251.
 28 Elin K. Jacob, "Classification and Categorization: A Difference that Makes a Difference," *Library Trends* 52, no. 3 (Winter 2004): 515–40.
 29 Hertzberger, *Architecture and Structuralism*, 34.
 30 John Paul Minda, *The Psychology of Thinking: Reasoning, Decision-Making & Problem-Solving* (Los Angeles: SAGE, 2021), 108–11. Minda mentions several experiments which studied colour and shape recognition across different languages and cultures, arguing against linguistic determinism theory.
 31 Architectural artefacts include physical buildings but also their various 2D and 3D representations.

pattern we may observe by looking at sensory data, as Lev Manovich points out, is like 'constructing a new category: a recognition that some things or some aspects of these things have something in common'.³² For this reason, images in their raw form, before having been assigned any semantic meaning through verbal *tags* or *metadata* in the digital environment, are considered 'unstructured'.³³ Artificial classification³⁴ systems, which are meant to organise our knowledge and enable us to efficiently access and retrieve digital memory records, impose a fixed knowledge structure, which often fails to 'reflect the way individual users structure experiential knowledge of the real world'.³⁵ Bush had already anticipated that the key obstacle to exploiting the collective knowledge base will be the artificial 'systems of indexing' that won't be able to replicate mechanisms of the human mind, which operates 'by association'.³⁶ The following examples will illustrate the nature of architectural associations and elucidate why *computer vision* technology opens promising perspectives for utilising architectural archives.

ARCHITECT'S 'THOUGHT-SPACE'

Comparing Stefan Wewerka's Ruhwald project and Aldo van Eyck's Sonsbeek Pavillion, Hertzberger indicated that 'although the differences between the two are obviously more profuse than the similarities, certain characteristics of their ground plans...bear strong resemblances'.³⁷ He described Wewerka's project as a 'grid' of 'rectilinear residential streets' separated by 'wall-like building blocks' with 'openings' that give the plan 'its permeability and...spatial openness', and he described van Eyck's project as 'parallel walls', 'of equal height', forming 'parallel streets', in which 'curves, hollows, shiftings...constantly narrow and widen one's field of vision', resulting in an 'alternate openness and enclosure'.³⁸ Looking closer, we can see that Hertzberger is trying to describe the underlying structure of similarities between the two projects primarily through their geometric aspects such as properties and relations (rectilinear, parallel, equal), rhythms (alternating open-closed, narrow-wide) etc, without focusing on their specific functions. Looking back at Manovich's definition of category construction, it is evident that Hertzberger is proposing a category of 'wall-like' projects

32 Manovich, *Cultural analytics*, 251. Manovich uses the term 'analog' for what is here called 'sensory data'.
 33 'Unstructured' means that they cannot be organised according to a predefined model (eg a spreadsheet). On the example of a digital *photo*, the image itself is 'unstructured', but once digitally stored, it becomes associated with other 'structured' data (eg date, time, geolocation and other potential *tags* such as 'home' or 'office').
 34 Jacob highlights the difference between categorisation and classification, explaining that *categorisation* is more flexible and creative while *classification* is more rigorous and exclusive. See Jacob, "Classification," 14.
 35 Pat Molholt, "Research issues in information access," in *Rethinking the library in the information age: Vol. II*, ed. A.J. Matthews (Washington, DC: U.S. Department of Education, 1988), 93–113.
 36 Bush, "As We May Think," Section 6. Bush indicates that any data placed in storage is filed alphabetically or numerically and one can find it by 'tracing it down from subclass to subclass'. In contrast, the human mind, 'with one item in its grasp, snaps instantly to the next that is suggested by the association of thoughts'.
 37 Hertzberger, *Architecture and Structuralism*, 47.
 38 *Ibid.*, 44–48.

which have certain characteristics (spatial ‘conditions’) in common, that can be visually recognised, but not exclusively associated with any fixed category based on their scale or ‘function’ such as ‘residential area’ (Wewerka) and ‘sculpture pavilion’ (van Eyck).³⁹ From a *computer vision* perspective these visual characteristics are seen as numbers and patterns, which makes them quantifiable.⁴⁰ In other words, a machine could measure to what extent something is ‘wall-like’, compare it with something else and determine how strong the resemblance is through statistical methods. Statistical methods are ‘especially well adapted to represent fuzzy boundaries’.⁴¹ In fact, ‘the whole point of numbers is to handle questions of degree that don’t admit simple yes or no answers’.⁴² Another example of fuzzy boundaries are the ‘in-between spaces’⁴³ which, according to Hertzberger, are characterised by the ‘shifts and overlaps’ occurring at the border between ‘public’ and ‘private’ areas in buildings, introducing the ‘inevitable conflict of responsibilities and a concomitant lack of clarity in interpreting the space’.⁴⁴ Hertzberger basically admits that these spaces belong to multiple categories, which complicates thinking in ‘black-and-white terms’.⁴⁵ However, by naming them ‘in-between spaces’, he formalises a new category which can then be used for communication between the members of the discipline, thereby associating the visually recognizable ‘shifts and overlaps’ with this domain-specific term. It is evident from these examples that language-driven and binary thinking undermines the complexity inherent in visual sensory experiences that are essential to architectural design. The statistical or ‘numbers-driven’ thinking, on the other hand, opens up new possibilities to deal with the global collection of architectural memory records that are imbued with fuzzy boundaries. Looking back at the initially introduced idea of the *programmeless building*, it is now evident that thinking in terms of ‘functions’ reinforces the culturally predetermined categories, while thinking in terms of ‘conditions’ destabilises them. A ‘function’ with its fixed meaning is much easier to ‘look-up’, to communicate about and eventually to construct. A ‘condition’, on the other hand, is considerably more challenging to grasp, describe and associate with temporary cultural values.⁴⁶ Hertzberger was right when he concluded that ‘space, even more than language, has us so

39 Ibid.

40 A digital image is a matrix of pixels, where colour of each pixel is defined by its RGB value (numbers). Computer algorithms can use these values to identify and locate separate objects, identify scenes etc.

41 Ted Underwood, *Understanding Genre in a Collection of a Million Volumes*, Interim Performance Report Digital Humanities Start-up Grant, Award HD5178713, December 29, 2014. chap. 3.4.

42 Ibid.

43 The concept of ‘in-between spaces’ is common in architecture, although different words are used to describe it. For example, Francis D.K. Ching talks about ‘interlocking spaces’ in which ‘a zone of shared space’ emerges as a result of ‘overlapping of two spatial fields’ allowing for ‘a number of interpretations’. See Francis D. K. Ching, *Architecture: Form, Space & Order* (Canada: John Wiley & Sons, 2015), 200.

44 Hertzberger, *Architecture and Structuralism*, 108. Emphasis added. Hertzberger gives an example of *school classrooms* that ‘can be opened up to the adjoining communal corridor...using...partitions or other eliminable forms of separation to create a ‘learning street’.

45 Ibid., 109. The two categories in this case are ‘public’ and ‘private’.

46 Interestingly, referring to the growing lack of interest in professionalism, Hertzberger pointed out in *Architecture and Structuralism* (225) that nowadays people assume they can ‘look-up’ everything. This observation actually implies why thinking in terms of ‘functions’ prevails in the architectural practice today. Designing forms and spaces without strict labels and clear boundaries in the 21st century is extremely challenging since technologically-supported communication and collaboration between clients, consultants and architects essentially depends on categorical agreements.

hemmed in that, like a fish in water, we are unable to step back from it far enough to get at its essence’.⁴⁷

In conclusion, although *computer vision* technology opens up unprecedented opportunities to deal with the scale of global production and participation in architecture, the lack of access to private archives of architectural offices⁴⁸ and the growing language barrier between digital innovators and practising architects prevent data-driven technologies from substantially revolutionising architectural design tools and methods. Enabling computers to recognise disciplinary concepts in digital memory records is one of the key tasks for architects in the 21st century, considering the value of design precedents and prior experiences for design practice.⁴⁹ In order to make use of their overwhelming ‘image collection’, architects must therefore collectively and computationally broaden their vision. This endeavour requires considerable efforts and unconventional methods: opening up private archives and libraries, elaborating on the fuzzy boundaries and retrieving from memory the valuable lessons once learned from Herman Hertzberger.

47 Hertzberger, *Architecture and Structuralism*, 122–23. Emphasis added.

48 Architectural records are especially difficult to access due to *authorship* and *ownership* concerns. Authorship concerns (inherent in all design disciplines) make professional architects reluctant to share their knowledge, while growing data ownership and privacy concerns prevent access to design information of completed projects.

49 This premise is based on the widely acknowledged perspective that the analysis of design precedents is a useful method for transferring knowledge in architecture and an efficient strategy for developing novel designs by means of analogical reasoning.