NCN Grant Number 2019/33/B/HS4/00072. ***Utilization of Hybrid Artificial Intelligence Systems in Automated Valuation Models (AVM) for Limited Real Estate Markets with Insufficient Data Sets.***

Emotional Real Estate Market

the Potential of Applying New Technologies in the Real Estate Market

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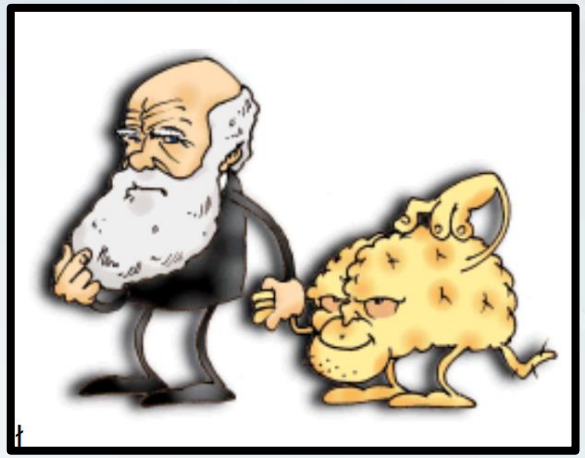
INSPIRATION

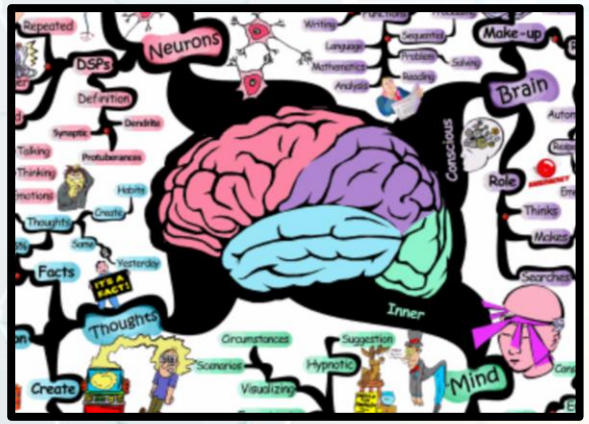
According to classical decision theory, an economic entity (**homo economicus**) has **access to complete and perfect information,** which they process optimally to achieve maximum benefits.

Stiglitz pointed out that in markets with imperfect information, **specific decision-makers' behaviors contain** the "missing" information, making it impossible to obtain full and perfect information (in the classical sense).



Cognitive science explores the human mind, senses, and brain function, seeking to understand what the mind is and how it operates.

Soft computing is an approach to computer science that considers the human mind's ability to reason and learn. Unlike hard computing, soft computing tolerates inaccuracies, uncertainties, partial truths, and approximations.



The application of hybrid solutions based on cutting-edge technologies, **including artificial intelligence**, aims to demonstrate that **behavioral factors** are not just a **component of the real estate market** but **constitute and define it**, and there is a **possibility of understanding** their implications.

*This allows for providing adequate knowledge about its functioning, as the essence of modeling is a compromise between the reality shaped by an **'imperfect' and numerically ambiguous emotional human** and the **science represented by 'perfect' and precise mathematical relationships**."*

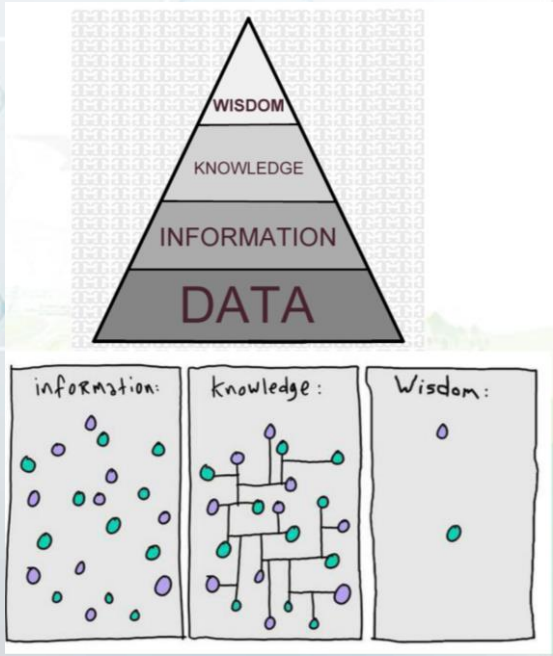
The dichotomy of the heart and mind is usually left unarticulated in science

Source: https://favim.com/image/3486838/

SIGNIFICANCE ASSESSMENT OF PROPERTY ATTRIBUTES – rules and problems

The main (well-known) problems in property attribute significance analyses are as follows:

- selection of the suitable features for representation in the analyses,
- avoiding stereotypes in features assessment (e.g., location is the most important),
- human (analyst) subjectivity,
- lack of sufficient analytical systems that are practical and user-friendly,
- common use of statistical methods that are often unreliable,
- **limited data access from a behavioral perspective and methods that enable to analyse it**



Source: https://ggwo.org/beyond-knowledge-into-wisdom/

Determining the weight of market attributes is based on measuring the impact of these characteristics on real estate prices. Their impact can be measured by:

- analysis of databases, real estate prices and features,
- researching the preferences of potential real estate buyers.

1

One of the most frequently used analytical methods for determining the market attribute weights:

$$wg_{il} = \left(C_{jl_s} - C_{jl_k}\right) \cdot \left(\max_j C_{ij} - \min_j C_{ij}\right)^{-1} \quad (1)$$

$$wg_j = \left(\sum_{l=1}^{l=z} wg_{il}\right) \cdot z^{-1} \quad (2)$$

C_{jl_s}, C_{jl_k} - real estate prices that differ in only one feature,

$\max_j C_{ij}, \min_j C_{ij}$ - minimum and maximum real estate prices on the local market.

2

Other analytical approaches for determining the weights of market features are methods that are based on a correlation matrix between features and property prices. The determination of the weighting coefficients of real estate features on the basis of variation coefficients that are calculated according to Formula:

$$wg_j = \left(\sum_{i=1}^{n} x_{ij}\right) \cdot \left(n \cdot \sigma_j\right)^{-1} \quad (3)$$

j - designation of a feature,
n - number of properties,

wg_j – weighting coefficients of real estate features,

x_{ij} - value of attribute x for feature j and particular property **i**,

$\left(n \cdot \sigma_j\right)^{-1}$ - variation coefficient of feature **j**.

3

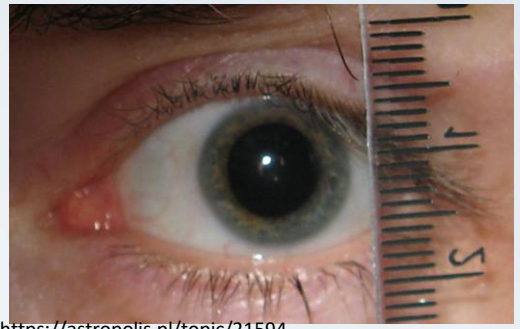
The analysis of potential property buyer's preferences is regarded as an alternative property attribute significance determination method. It is typically used when analytical methods that are based on property prices and features are not applicable due to, for example, lack of data. The structure of buyer preferences reflects a hierarchical arrangement of the possibility of choosing purchases from the market offerings. The consumer assesses which of the purchase options is more suitable for him.

IGPiG

HUMAN EMOTION RECOGNITION

One of the key challenges in collecting and evaluating the significance of real estate market information (data) arises from the fact that decision-making motives are **individual and as diverse** as people themselves. This leads to the formulation of the following question: **How should aspects based on factors expressing human reactions, which are evident in human decisions, be considered**?

There are **different psychological signals that show human emotion**. Due to this fact, **different solutions and tools** must be applied for biometric research that **supports a wide range of biosensors.**



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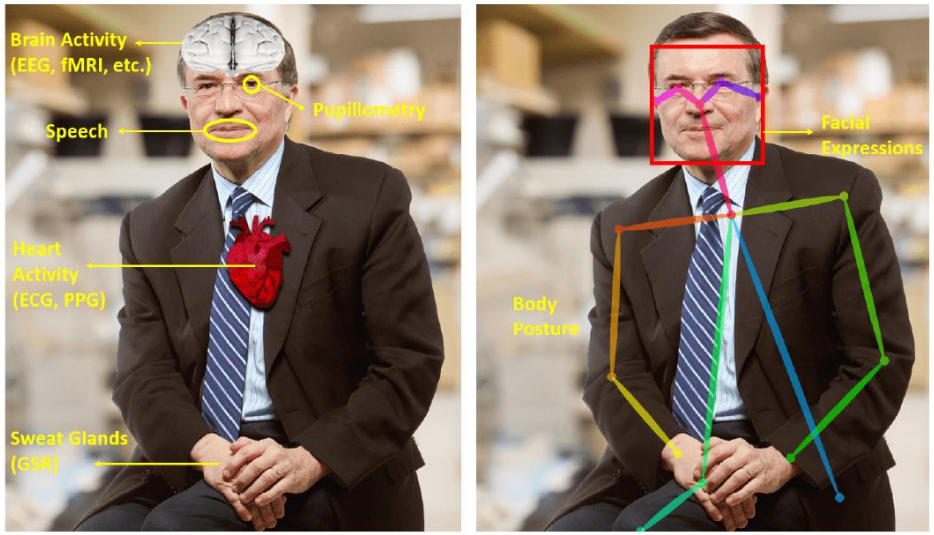
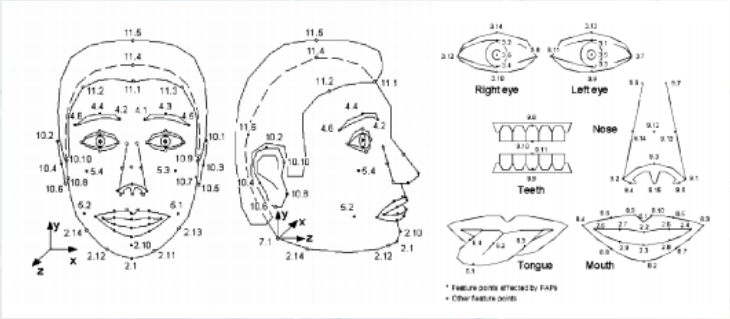


Source: Siddharth, Siddharth. *Utilizing Multi-modal Bio-sensing Toward Affective Computing in Real-world Scenarios*. University of California, San Diego, 2020.



Characteristic points for describing the appearance of the face defined in MPEG-4 FAP standard

Pupillometry is a field of oculography that measures the width of the pupil in response to psychophysiological stimuli. Degree of pupil dilation when performing cognitive tasks is a psychophysiological measure of information processing.

Facial emotion recognition systems a method for measuring facial expressions in terms of changes in the appearance of the face that are caused by individual emotions.

USES OF EMOTION AI TECHNOLOGIES

In the past two years, emotion AI vendors have moved into completely new areas and industries, helping organizations to create a better customer experience.

1. **Video gaming.** Using computer vision, the game console/video game detects emotions via facial expressions and adapts to it.
2. **Medical diagnosis**. Software can help doctors with the diagnosis of diseases such as depression and dementia by using voice analysis.
3. **Education.** Learning software prototypes have been developed to adapt to kids' emotions.
4. **Employee safety.** Emotion AI can help to analyze the stress and anxiety levels of employees who have very demanding jobs.
5. **Patient care.** A 'nurse bot' not only reminds older patients on long-term medical programs to take their medication.
6. **Car safety.** Automotive vendors can use computer vision technology to monitor the driver's emotional state.
7. **Autonomous car.** To understand how users view the driving experience.
8. **Fraud detection.** Insurance companies use voice analysis to detect whether a customer is telling the truth when submitting a claim.
9. **Recruiting.** Software is used during job interviews to understand the credibility of a candidate.
10. **Call center intelligent routing.** An angry customer can be detected from the beginning and can be routed to a well-trained agent.
11. **Public service.** Partnerships between emotion AI technology vendors and surveillance camera providers have emerged.
12. **Retail.** Tn stores to capture demographic information and visitors' mood and reactions.

WHAT ABOUT PROPERTY MARKET ANALYSES ?????

'It's time for us (the appraisers) to really add value in the process. Let the technology deal with the inefficies in our world.'

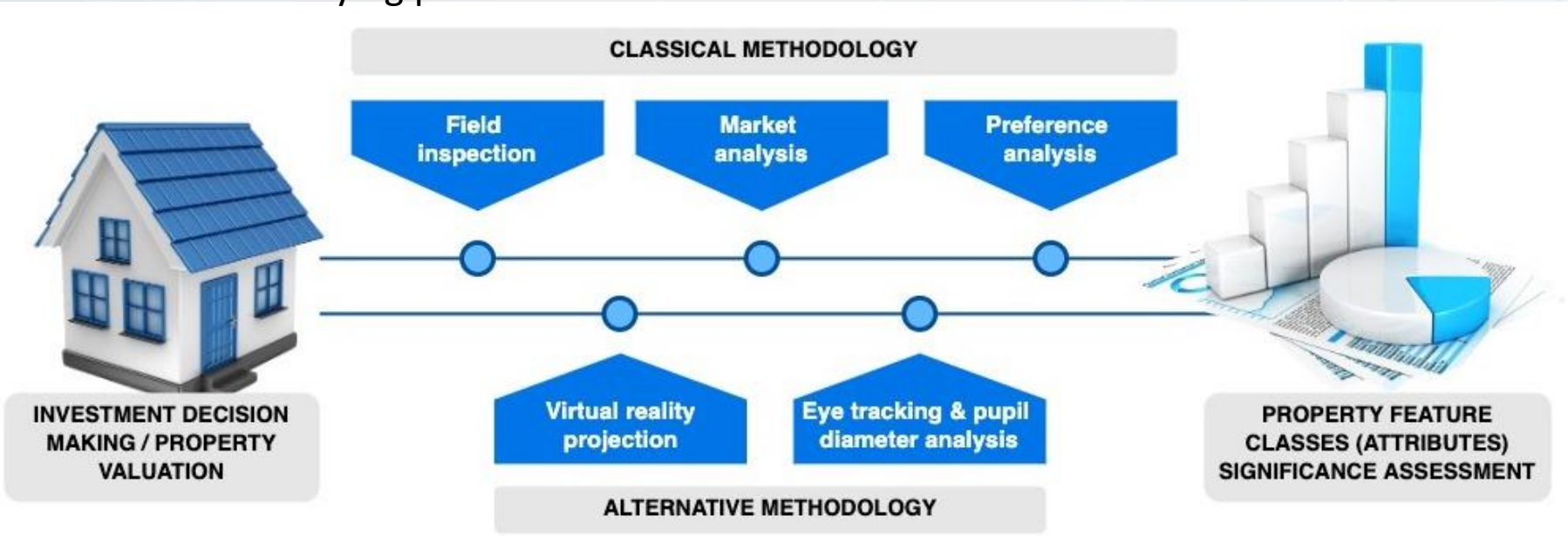
The Royal Institution of Chartered Surveyors (RICS) 2021

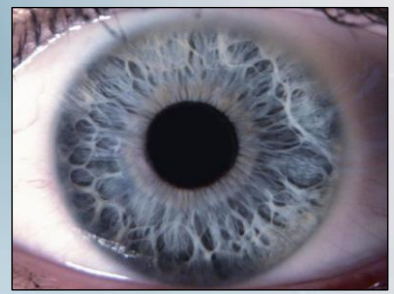
METHODOLOGY

Research Objective: *indication the significance of the "synergy" of property features that elicit specific human reactions.*

Technology fusion *includes: virtual reality with pupil tracking, computer vision technologies, neural network models, to address key substantive and technical issues related to the interpretation of human reactions towards the significance of property feature synergy.*
Feature synergy *implies the co-occurrence of property features eliciting similar reactions.*

Thesis: Multisensory real-time projection (VR with eye tracking and pupil diameter measurement) is a valuable tool for studying potential investors' reactions in the real estate market.





Pupillometry - studying the pupil allows us to leverage the fact that the eye is an extension of the brain. **Human awareness** is not equipped to process multiple external stimuli, hence a portion of **significant information is processed unconsciously**. The extent of pupil dilation during cognitive tasks serves as a psychophysiological measure of information processing - the greater the mental effort and information processing, the larger the pupil diameter.

Source: https://ggwo.org/beyond-knowledge-into-wisdom/

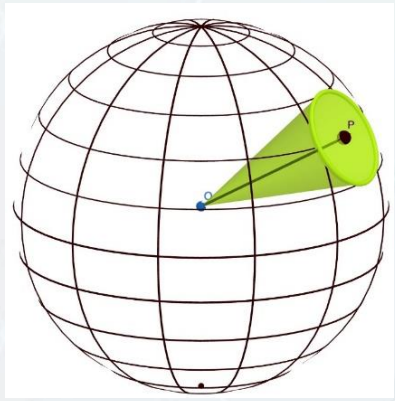
One of the tools that has gained significant traction recently is **Virtual Reality (VR),** which offers computer-generated simulations of three-dimensional images or environments, providing seemingly real interactions. The real estate industry utilizes this solution in various ways: Virtual Property Presentations, Staging and Virtual Visualization, V-Commerce, Virtual Tenant Instructions, Architectural Visualization.

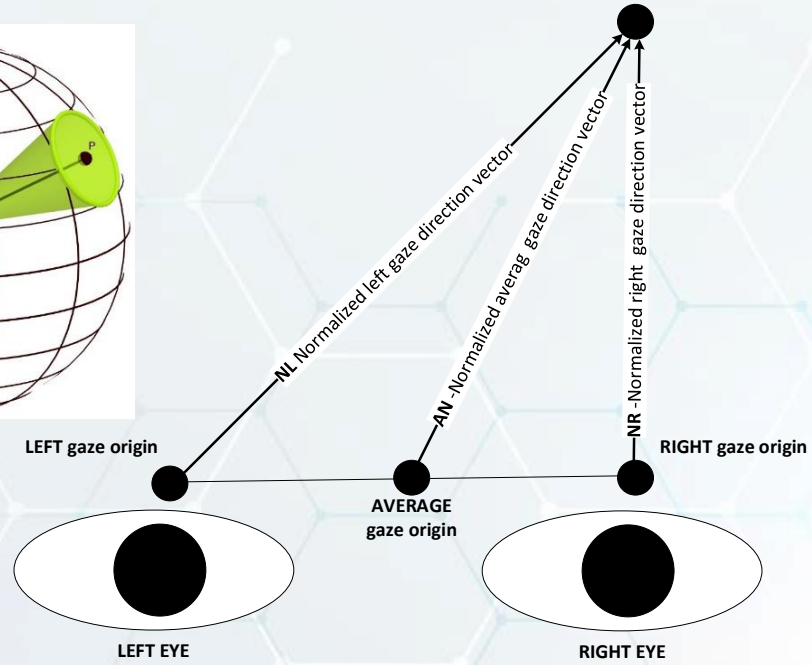
Gogle HTC Vive ProEye o maksymalnej rozdzielczości wizualizacji VR 2880 x 1600px (1440 x 1600 na oko), z akcelerometrem, żyroskopem i śledzeniem laserowym.

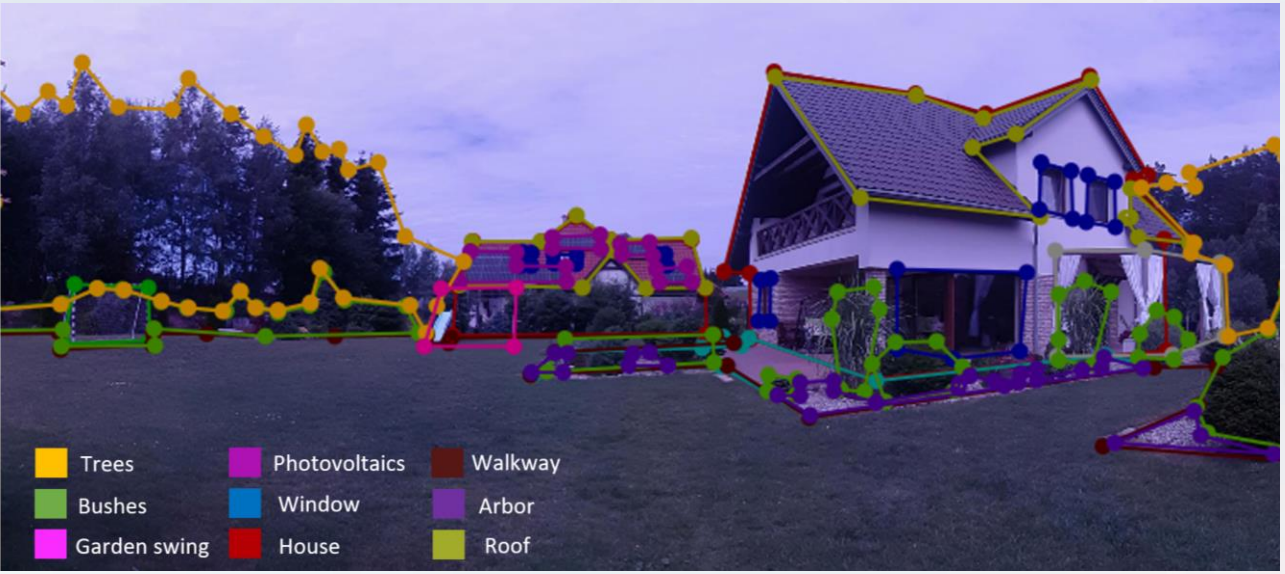
Eye-tracking is a recognized technique employed to investigate the relationship between eye movements and human cognitive abilities.

Experiment - Data

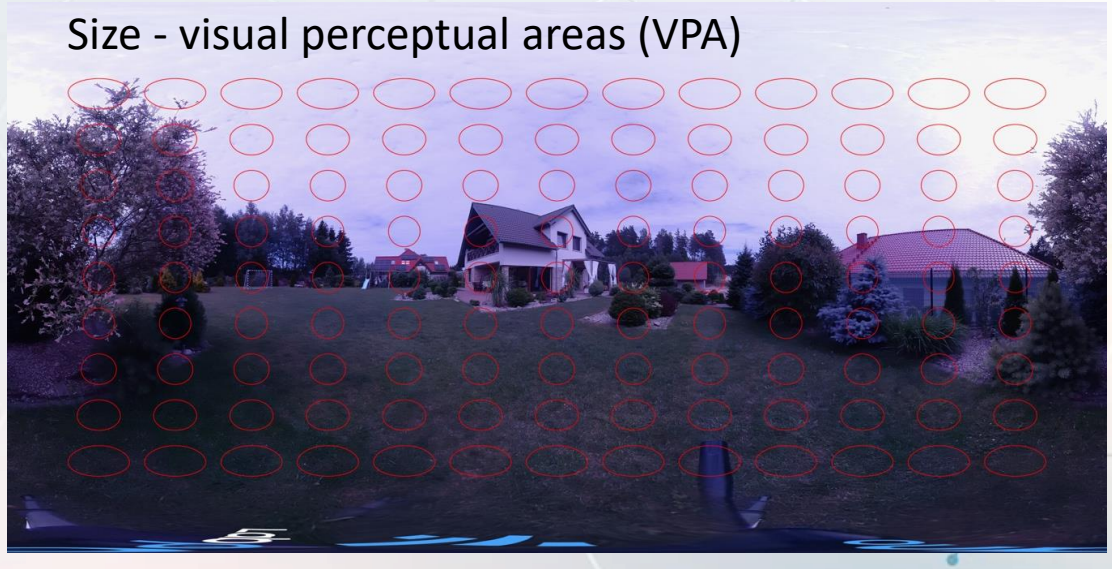
a) 92 respondents without visual impairments, potential real estate market investors,
b) 360-degree spherical raster images,
c) 2D polygon data (for 15 property feature classes),
d) respondent gaze records - left and right pupil diameter; the final dataset consisted of 367,147 records.







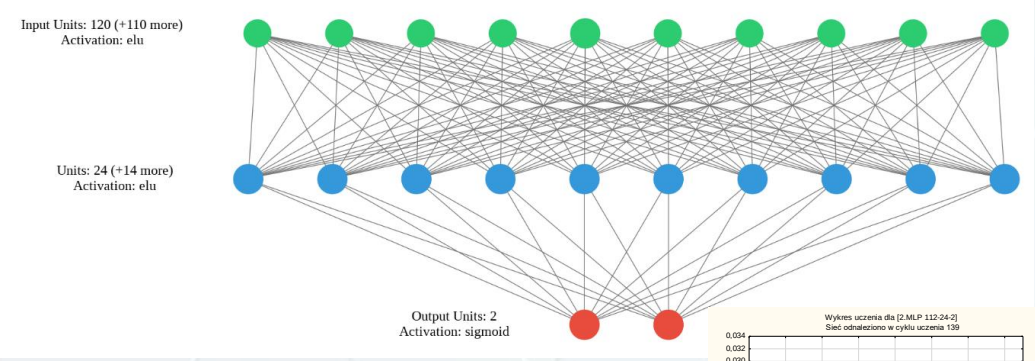
Size - visual perceptual areas (VPA)

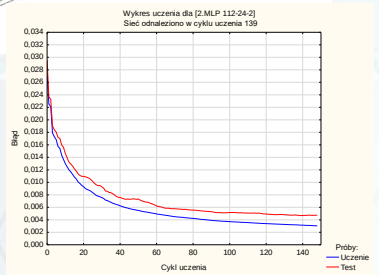


Implementation of Neural Networks

To obtain an optimal model of the effect of feature classes on pupil diameter changes, the analysis was divided into the three stages:

- In the first step, a single model was developed for all combined observed feature categories in all 8 Visual Perceptual Area (VPA) sizes to select an optimal VPA size.
- In the next step, the development of a Neural Network (NN) was assumed for each observed feature class in a specific VPA size separately.
- The development of an optimal NN model for all investigated feature class sizes of VPAs based on 7 feature class sizes was assumed.





NN MLP 15-19-1							
Football gate (VPA-7)	House (VPA-7)	Walkway (VPA-7)	Trees (VPA-7)	Ornament trees (VPA-7)	Photovoltaics (VPA-7)	Bushes (VPA-7)	Window (VPA-7)
9,603315	8,433569	8,210049	8,003390	7,280100	7,111425	6,753621	6,363154
Grass (VPA-7)	Roof (VPA-7)	Garden swing (VPA-7)	Arbor (VPA-7)	Garden pebbles (VPA-7)	Road (VPA-7)	Power line (VPA-7)	
4,441035	4,031572	3,586994	3,403079	3,038563	1,768845	1,047655	

Source: authors' elaboration on the us

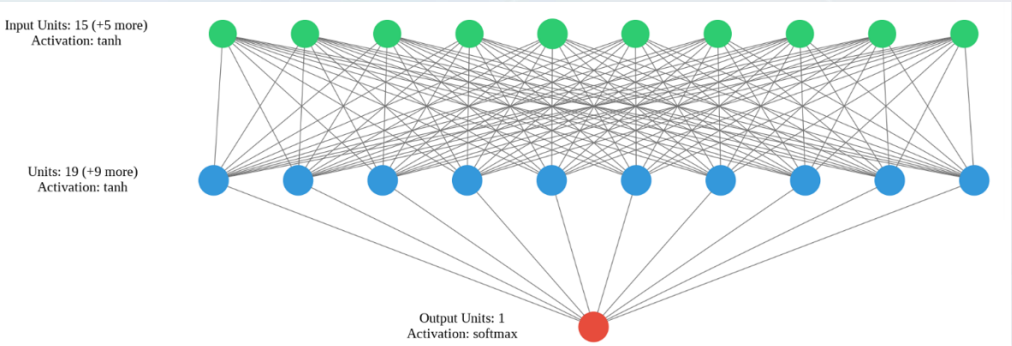


Fig. 9. Neural Network Architecture for 15 input features. Source: authors' elaboration with the use a Keras Visualizer.

Table. 3 NN architecture for 7th sized of VPA.

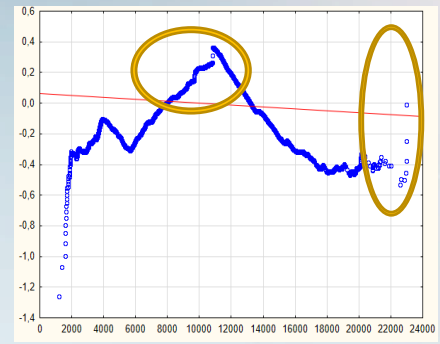
NN	Quality (training)	Quality (validation)	Quality (test)	Learning algorithm	Loss function	Activation (hidden)	Activation (exit)
MLP 15-19-1	0,858043	0,853753	0,842684	BFGS 231	SOS	tangents	logistic

Source: authors' elaboration on the use of the TensorFlow framework

Coefficients of the goodness of fit the model predicted data	Dataset	Coefficient result
Root Mean Squared Error (RMSE)	training	0,0120 mm
Mean Error (ME)	training	-0,0007 mm
Mean Absolute Percentage Error (MAPE)	training	0,08%
The linear correlation coefficient between predicted and observed value - r	training	0,8500
Root Mean Squared Error (RMSE)	validation	0,01100 mm
Mean Error (ME)	validation	-0,0006 mm
Mean Absolute Percentage Error (MAPE)	validation	0,08%
The linear correlation coefficient between predicted and observed value - r	validation	0,8501
Root Mean Squared Error (RMSE)	test	0,0093 mm
Mean Error (ME)	test	-0,0006 mm
Mean Absolute Percentage Error (MAPE)	test	0,07%
The linear correlation coefficient between predicted and observed value - r	test	0,86021

Extraction of Co-occurring Features from Multisensory Data from Real-time Projection (VR)

Pupil Dilation Monitoring Based on Property Feature Class Observations vs. Predictive Approach Using NN



?

1. How the NUMBER of observed property feature classes influenced the quality of pupil diameter prediction.
2. How the DIVERSITY of observed property feature classes affected the quality of pupil diameter prediction.

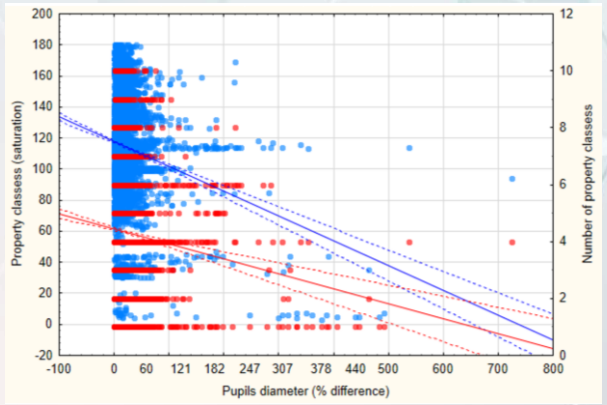
3. IDENTIFYING the components that most stimulate changes in pupil diameter.
4. IDENTIFYING the FACTORS that exhibit the greatest discrepancies in recording/prediction.

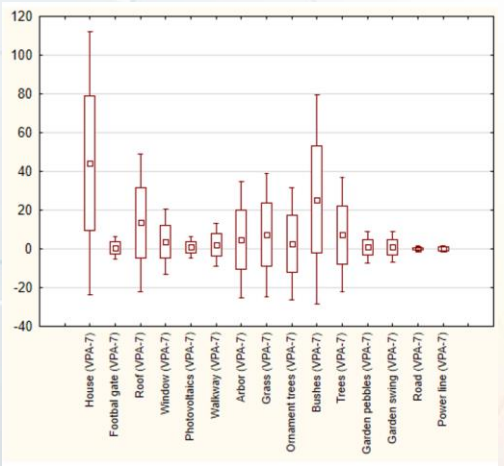
The **most stimulating** changes in pupil diameters were associated with property feature classes that were predominantly perceived as follows:

- House (VPA-7 house): 39%,
- Bushes (VPA-7 bushes): 22%,
- Roof (VPA-7 roof): 12%.

There were also classes that were **barely noticeable** during the total observation time:

- Power line (VPA-7 power line) or
- Road (VPA-7 road)



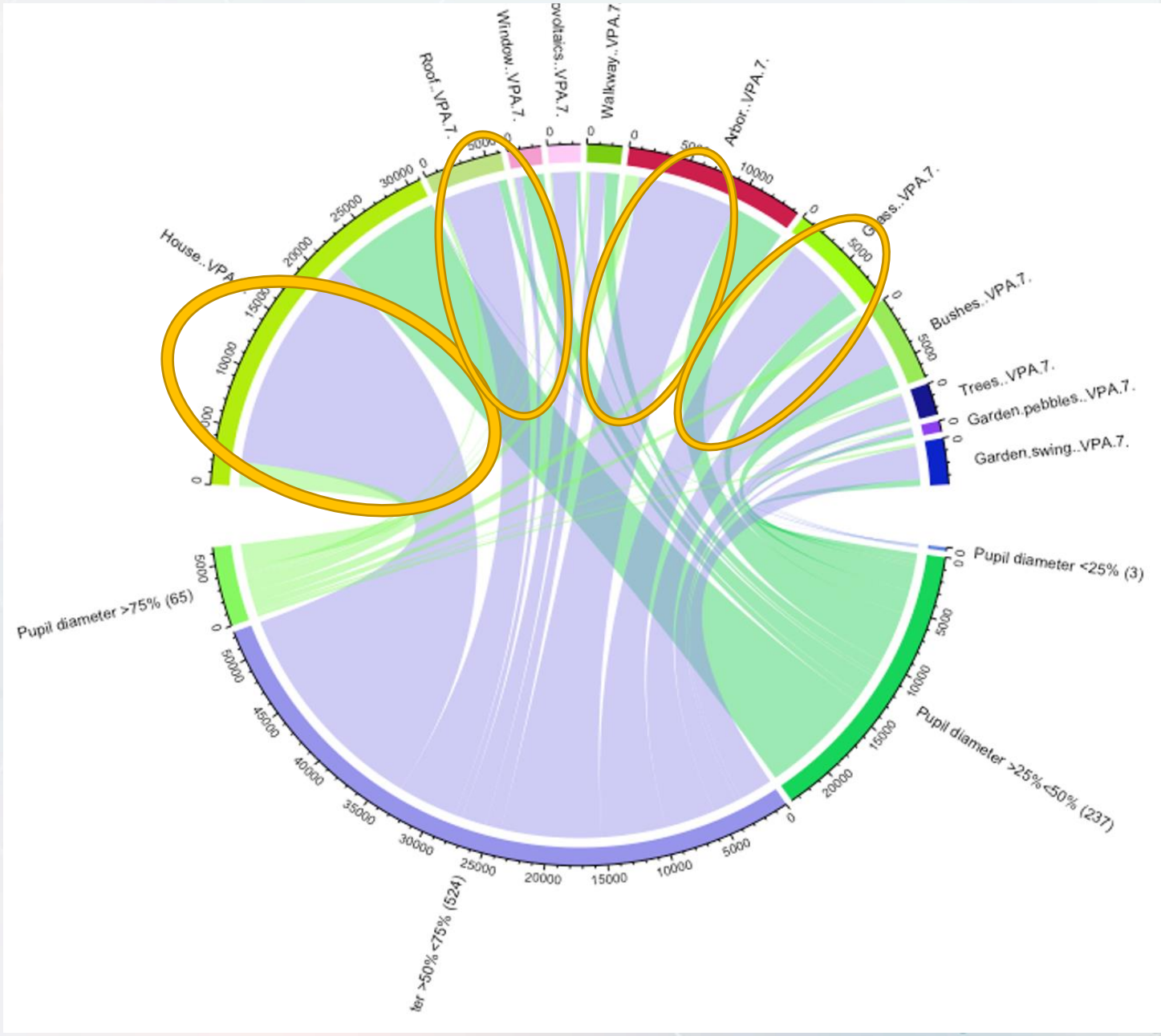


VPA - visual perceptual area

Significant drop in prediction accuracy occurs when the number of observed property feature classes **is less than seven**. The saturation decreased, the prediction precision worsened, especially when the saturation fell below **120 units**.

RESULTS

The greatest "co-dilation" of pupils was induced by the fusion of the following features: **house** (VPA-7), **roof** (VPA-7), **grass** (VPA-7), and **bushes** (VPA-7).
House (VPA-7), Grass (VPA-7), Trees (VPA-7), are the least significant feature fusion in the perceived image.
This suggests that the **most critical elements** were the arranged greenery and residential buildings. These same features, enhanced by the presence of **pedestrian pathways** and **green spaces**, elicited a significant pupil reaction.



Advantages and Disadvantages of the Proposed Solution

Among the most significant **advantages** of the proposed solutions are:

- **Consideration of the most crucial** and complex decision-making component - a **behavioral aspect** to precise decision simulations.
- **VR enables measurement** of property feature significance **in an environment closely resembling reality**.
- **Fusion technology isolates external stimuli** that divert human attention from the most important property attributes.
- The solution allows **interpretation of synergistic feature** perceptions.
- The investigated fusion-based solution enables **understanding the overwhelming complexity** of data sets and challenging **pattern extraction.**

On the other hand, the **drawbacks** encompass:

- **Non-unambiguous interpretation** of pupil changes.
- **Health status limitations for VR usage**: systemic diseases, balance and motor coordination issues, neurological problems, eye conditions like glaucoma, cataracts, retinal disorders.
- Eye tracking **necessitates user gaze calibration**.
- **Technical requirements** such as low hardware latency, high resolution and frame rate, scene lighting rectification, accurate user pose tracking.

CONCLUSIONS

In this study, an attempt was made to **verify the usefulness of one of the most sought-after technologies** today, which enables faithful replication of phenomena and the underlying relationships.

The research provides a **novel** approach to **exploring real estate market data** based on a new indicator (pupil diameter change) that **has not yet been analyzed** in this context.

Their advantage over classical methods lies in the absence of assumptions restricting the variability of expected outcomes and in achieving logical, rational, and close-to-optimal solutions (within acceptable analysis time).

VR APPEARS TO BE MORE VALUABLE THAN IMAGES AND VIDEOS DUE TO MULTISENSORY HUMAN PERCEPTION.