Journal of Systemics, Cybernetics and Informatics (2024) 22(7), 85-92
https://doi.org/10.54808/JSCI.22.07.85

Image Processing, Computer Vision, Data Visualization, and Data Mining for Transdisciplinary Visual Communication: What are the differences and which should or could you use?

Richard S. SEGALL
Department of Information Systems & Business Analytics
Neil Griffin College of Business
Arkansas State University, State University 72467. USA
E-mail: rsegall@astate.edu

ABSTRACT

Data can be for any discipline, and is only useful if presented, processed, or analyzed in meaningful ways. There are many formats for data such as text, numerical, image and ultrasound. Data can be disciple specific and instrument specific. Applications can be for medical, data communication, remote sensing, astronomical, geospatial and other. This paper discusses what are the differences in purposes, inputs and performing certain operations to get some useful information from its outputs, and applications between: (1.) Image Processing, (2.) Computer Vision, (3.) Data Visualization and (4.) Data Mining. What are these different techniques, and how would you determine which to use for your available data or circumstances? Illustrations of recent studies for each are presented.

Keywords: Computer Vision, Data Mining, Data Visualization, Image Processing, Transdisciplinary Visual Communication

1. INTRODUCTION

The purpose of this paper is that based on my 2024 Plenary Keynote address that was presented virtually at the 28th World Multi-Conference on Systemics, Cybernetics and Informatics: (WMSCI 2024) that was held on September 10 - 13, 2024 as a Virtual Conference. This Plenary Keynote explained the meanings of and differences between four important data processing techniques that are essential for transdisciplinary visual communications in our modern age in which computers are essential for our everyday activities. These techniques are: (1.) Image processing, (2.) computer vision, (3.) data visualization, and (4.) data mining.

Simply stated, (1.) Image processing is the process of manipulating digital images and performing certain operations to get some useful information from it (Kundu, 2024) [12],

(2.) Computer vision is a field of artificial intelligence (AI) that uses machine learning and neural networks to teach computers and systems to derive meaningful information from digital images, videos and other visual inputs. (IBM, 2024a) [7]

(3.) Data visualization is the representation of data through use of common graphics, such as charts, plots, infographics and even animations. (IBM, 2024b) [8]

(4.) Data mining is the process of using computers and advanced analytical tools to find patterns and relationships in large data sets. (IBM, 2024c) [9]

The above technologies can be applied to different types of data, and according to Research Data Services (2024) [17] of Oregon State University, there are five categories of Data Types: (1.) Observational (such as sensor readings) (2.) Experimental (such as spectroscopy), (3.) Derived or complied (such as text and data mining), (4.) Simulation (such as climate models), and (5.) Reference or cantorial (such as gene sequence databanks).

2. WHAT IS IMAGE PROCESSING?

According to Britannica (2024) [5], image processing is set of computational techniques for analyzing, enhancing, compressing, and reconstructing images. Its main components are (1.) importing, in which an image is captured through scanning or digital photography; (2.) analysis and manipulation of the image, accomplished using various specialized software applications; and (3.) output (e.g., to a printer or monitor). Image processing has extensive applications in many areas, including astronomy, medicine, industrial robotics, and remote sensing by satellites.

The interdisciplinary applications of image processing is the theme of an entire book written by Tanimoto [31] titled "An Interdisciplinary Introduction to Image Processing" published by MIT Press.

2.1 Background of Image Processing

Figure 1 below show a remote sensor (RS) in orbit above the earth that takes images that can accessed in some form of data that can be extracted and processed or transformed into a thematic map for inclusion into a cloud-spatial database.

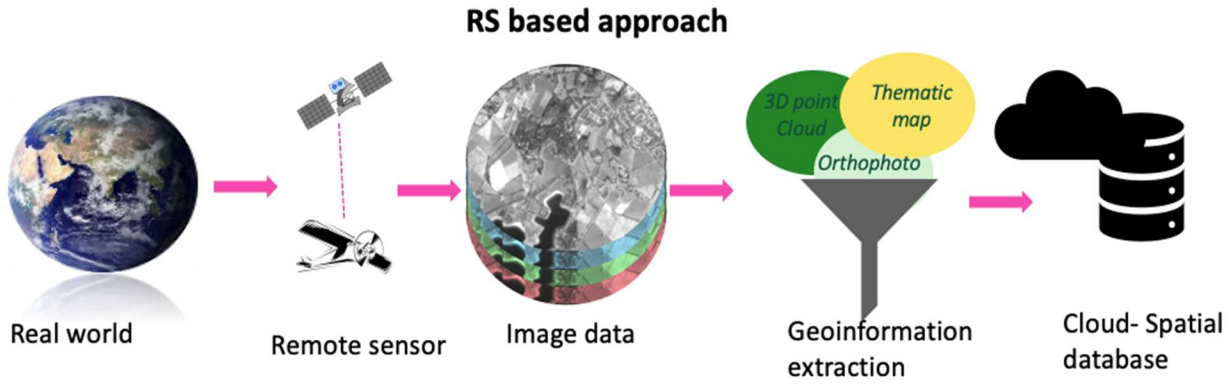


Figure 1: Remote sensing and digital image processing
Source: University of Twente (2024) in Netherlands at https://www.itc.nl/education/study-finder/remote-sensing-and-digital-image-processing/#programme-overview

2.2 Applications of Image Processing

Applications of image processing include image restoration, computer vision as described in next section, medical imaging, color processing, object recognition, segmentation, image acquisition and pattern recognition. Google (2024[6]). Other applications of image processing are discussed in Bergmark (2023[2] for OpenCV, Loncova et al. (2017) [13] for biomedical image processing, and Segall & Rajbhandari (2024 [24]).

3. WHAT IS COMPUTER VISION?

According to Blicker (2023) [3], "Computer Vision" is a field of artificial intelligence that allows computers to obtain structured and meaningful information from digital images, videos, and other visuals. Based on this information, actions or recommendations can be given.

Computer vision allows self-driving cars to identify and distinguish objects such as traffic lights, pedestrians and road signs, identifies specific facial features and use this information to determine whether a face is present, and segments medical images into different regions of interest, such as organs or tissues. (Augmented A.I. (2023) [1.])

Foundations of computer vision was presented in an entire book by Torralba et al. (2024) [34] published by MIT Press. Boesch (2023) [4] presented the 100 most popular computer applications in 2024. An entire book authored by Nixon and Aguado (2020) [15] discussed the applications of feature extraction and image processing for computer vision.

According to Sharma (2024) [27] some of the applications of computer vision include artificial intelligence driven automated cell counting, applications on store shelves can help keep real-time track of inventory, smart farming to identify weeds in crops for spraying with herbicides, identify the best route through crops, the use of drones and robots with computer vision for locating disaster survivors, use in driverless vehicles, and use of AI-enabled cameras for monitoring and understanding the behavior and attitudes of students.

Others who have discussed computer vision include Rouse (2023) [18], Sawtell-Rickson [2022] [20], and Sharma (2021) [26].

Figure 2 shows the potential of "Trans-disciplinary" uses of computer vision in areas of biology, psychology, computer science, mathematics, engineering and physics. The applications of computer vision shown in Figure 2 range from neuroscience to computer graphics to robotics and machine learning.

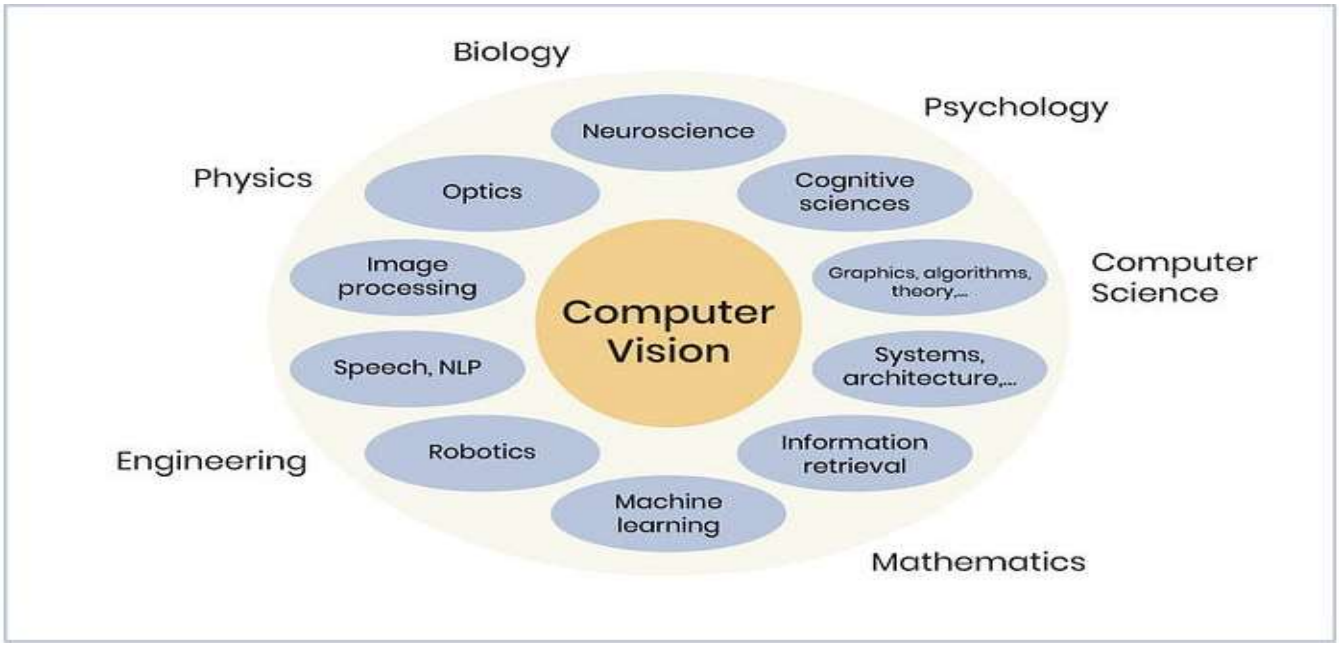
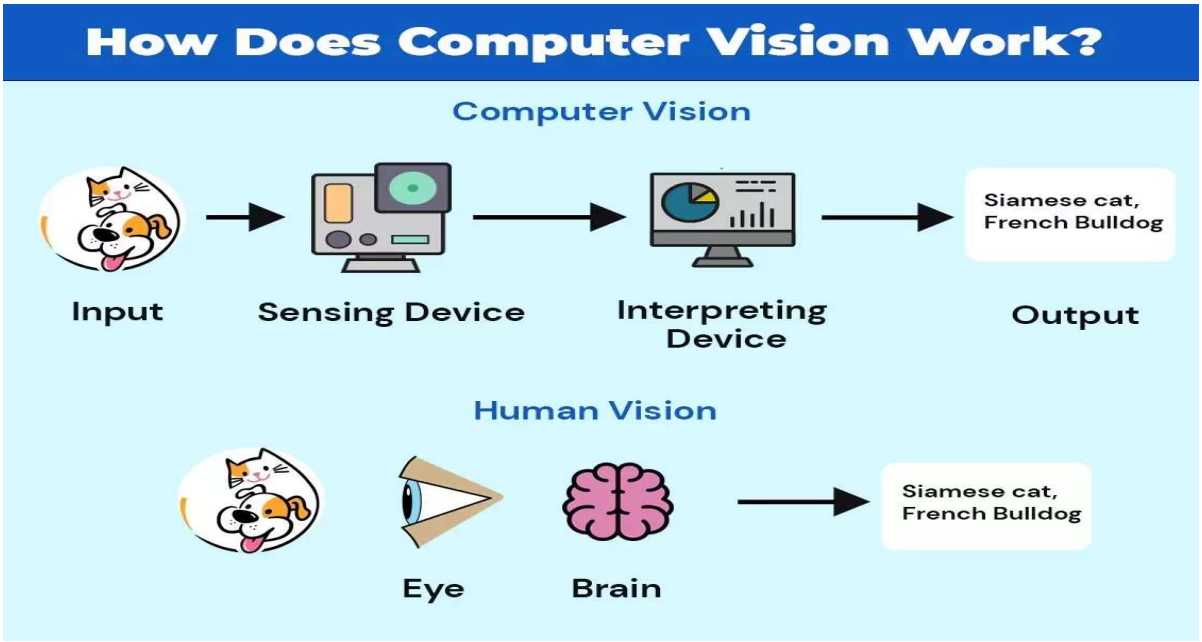


Figure 2: Illustration of potential Transdisciplinary uses of Computer Vision
Source: https://medium.com/@pontus.bergmark/intro-to-image-processing-in-opencv-with-python-1c7f94af18a7

Figure 3 illustrates how computer vision works in comparison to human vision in that computer vision uses a sensing device for input image that is inputted into an interpreting device to generate the output. This is in comparison for human vision that uses the human eye as input device and human brain as interpreting device.



Source: https://itechindia.co/wp-content/uploads/2021/11/inner14.jpeg
Figure 3: Illustration of how Computer Vision works with comparison to human vision

4. WHAT IS DATA VISUALIZATION?

Below are two tables derived using reference Tableau (2024a) [29]: Table 1 that describes and compares several different types of visualization tools, and Table 2 that provides more specific data visualization tools as a complete overview of the best data visualization tools.

Table 1: General Types of Visualization

General Types of Visualization	Description
Geospatial	A visualization that shows data in map form using different shapes and colors to show the relationship between pieces of data and specific locations.
Infographic	A combination of visuals and words that represent data. Usually uses charts or diagrams.
Dashboard	A collection of visualizations and data displayed in one place to help with analyzing and presenting data.

Table 2: Specific Data Visualization Tools

Specific Data Visualization Tool	Description
Area map	A form of geospatial visualization, area maps are used to show specific values set over a map of a country, state, county, or any other geographic location. Two common types of area maps are choropleths and isopleths.
Box-and-Whisker Plot	These show a selection of ranges (the box) across a set measure (the bar).
Bullet Graph	A bar marked against a background to show progress or performance against a goal, denoted by a line on the graph.
Heat Map	A type of geospatial visualization in map form which displays specific data values as different colors
Highlight Table	A form of table that uses color to categorize similar data, allowing the viewer to read it more easily and intuitively.
Ribbon Graph (also called 'fat graph')	The thickening or fat version of its skeleton graph in dotted line.

The graph presented in Figure 4 is a Ribbon Graph that displays stacked data for multiple categories (U.S. states) with time-series elements and a wave-like representation. The stacked data in this case is the total number of deaths due to Covid-19 from January 2020 to March 2023. The graph is arranged in the order of California, Texas, Florida, Maine, and New York, with the states with the highest values at the top. The time series analysis reveals that there are still several states with no recorded Covid-19 deaths in 2020, and that these deaths will continue to be reported throughout the United States in 2021, 2022, and beyond.

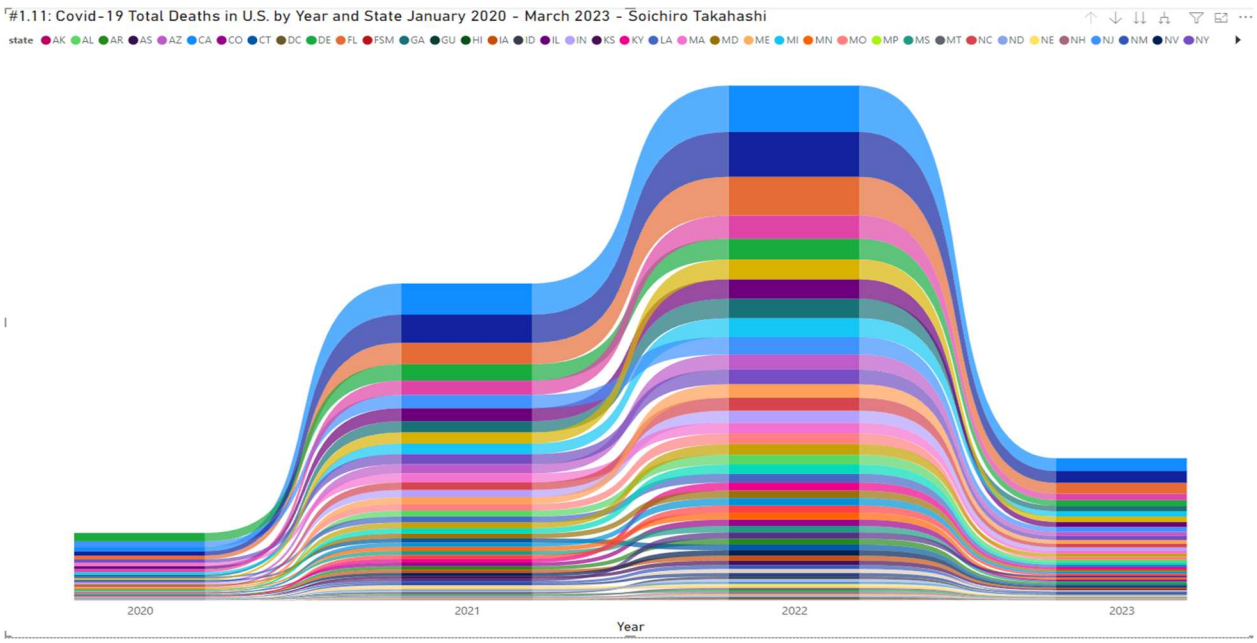


Figure 4: Ribbon Graph for Covid-19 Total Deaths in U.S. by Year and States for January 2020 -March 2023 (Source: Takahashi (2023) [28]).

Figure 5 below shows sixteen types of visualization plots that include Alluvial diagram, Butterfly chart, chord diagram, contour plot, histogram, hyperbolic tree, multi-level pie chart, pareto chart, radial bar chart, Taylor diagram, Treemap and Three-dimensional stream graph.

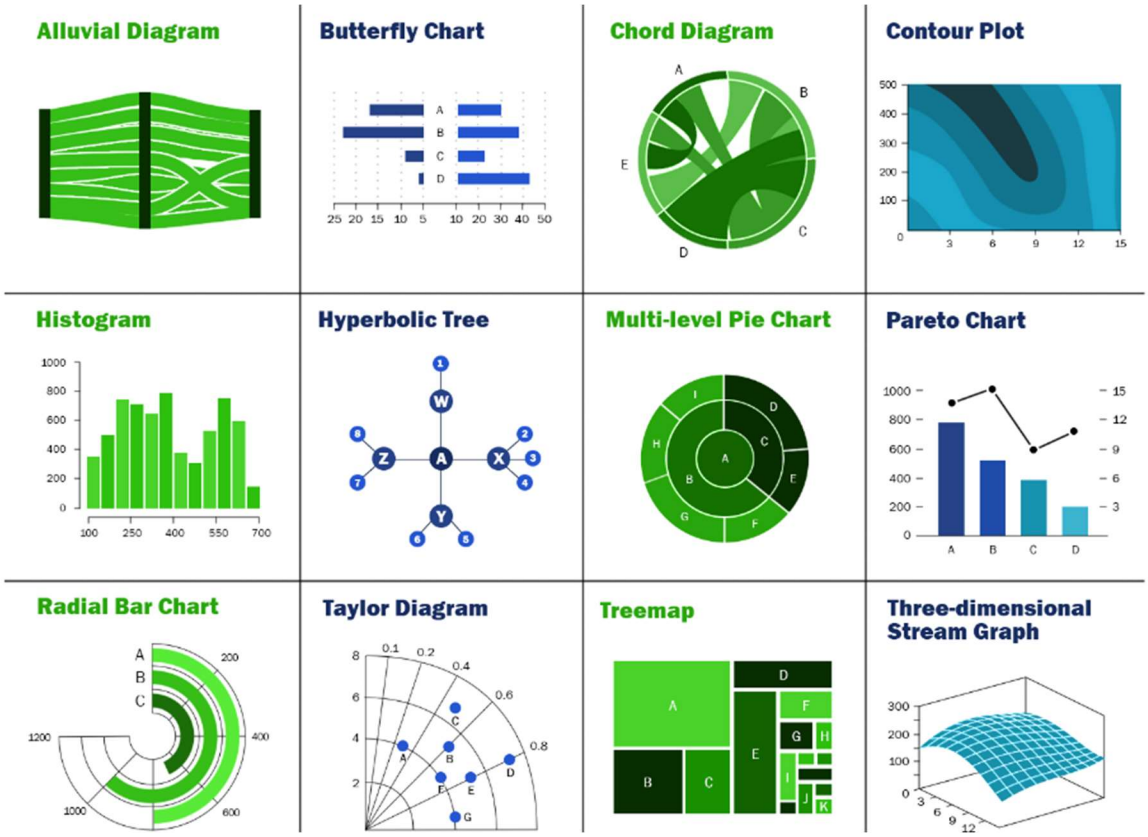


Figure 5: Types of Visualization Plots
Source: Red Nucleus (2020) [16]. https://rednucleus.com/resources/dataviz/

Other research on data visualization and its relationship with big data has been published by Segall & Cook (2018) [21], Segall & Niu (2018[22], 2020[23]) and Segall & Takashashi (2023) [25]. A data visualization guide for business professionals was presented as a book by Knaflic (2015) [11] with objective title of "storytelling with data". Tableau (2024b) [30] presents 12 great books about data visualization. Dashboards are a major visualization method for data visualization and Wexler et al. (2017) [36] presents "The Big Book of Dashboards".

5. WHAT IS DATA MINING?

According to TechTarget (2024) [32], data mining is the process of sorting through large data sets to identify patterns and relationships that can help solve business problems through data analysis. Data mining techniques and tools help enterprises to predict future trends and make more informed business decisions.

Figure 6 below shows sequence of steps in data mining following the acquisition of a significant sized database. The database needs to be preprocessed to ensure that the data has consistent format of data and not have missing data. The data is then transformed or modeled by some processes such as neural network training, data clustering or data segmentation. The mined data is then interpreted and evaluated to create new knowledge.

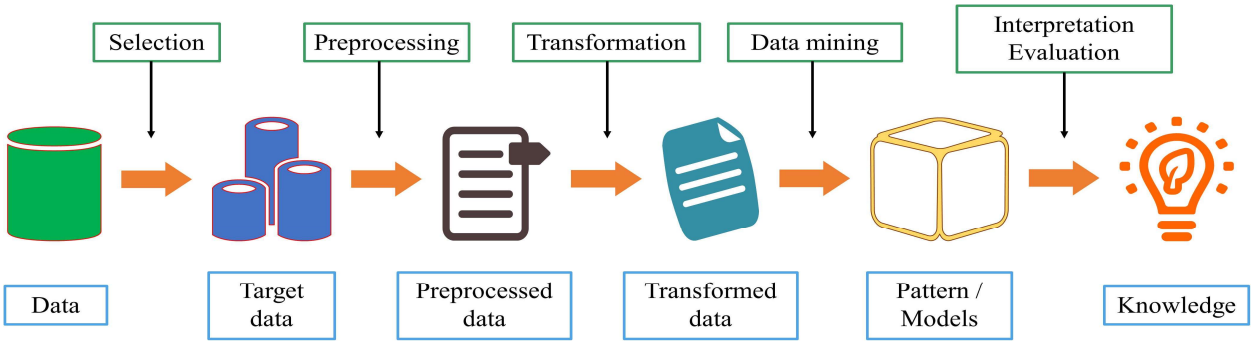


Figure 6: Sequence of Steps in Data Mining
Source: https://jaro-website.s3.ap-south-1.amazonaws.com/2024/04/The-steps-for-data-mining-process.png

Figure 7 below shows the top ten data mining tools in 2024 that are: (1.) SAS Enterprise Miner, (2.) Rapider, (3.) Monkey Learn, (4.) Apache Mahout, (5.) Orange, (6.) H2O, (7.) KNIME, (8.) Weka, (9.) Oracle, and (10.) SPSS Modeler.

Figure 7: Top 10 Data Mining Tools
Source: https://jaro-website.s3.ap-south-1.amazonaws.com/2024/04/TOP-10-DATA-MINING-TOOLS.jpg

6. CONCLUSIONS

Transdisciplinary applications are feasible for image processing, computer vision, data visualization, and data mining. (1.) Image processing should be used when image data needs to be transformed into meaningful images for specific application(s) such as images from satellites. (2.) Computer vision should be used with artificial intelligence with the available images in order to generate useful outputs such as used in self-driving cares to identify and distinguish objects such as traffic lights and pedestrians. (3.) Data visualization entails the utilization of many different types of tools to generate plots such as graphs, plots, maps, and three-dimensional stream graphs. (4.) Data mining is "knowledge discovery" and is discussed for beginners in Murray (2023) [14] and Rutgers University Bootcamp (2022) [19]. One needs to understand these and other differences to determine which should or could be used for the available data.

7. REFERENCES

[1] Augmented A.I. (2023). 8 Real-World applications of Computer Vision in 2023. Retrieved from https://www.augmentedstartups.com/blog/8-real-world-applications-of-computer-vision-a-comprehensive-guide?srsltid=AfmBOorRCPjinhxoZlDBe9RheEDP3odkj1zWkiGrE_Y6IT5YdETDIgWa

[2] Bergmark, P. (2023) Intro to Image Processing in OpenCV with Python. Retrieved from Intro to Image Processing in OpenCV with Python. Retrieved from https://medium.com/@pontus.bergmark/intro-to-image-processing-in-opencv-with-python-1c7f94af18a7

[3] Blicker (2023). The Future of Computer Vision (9 Applications and Trends in 2023) Retrieved from https://www.blicker.ai/news/the-future-of-computer-vision-9-trends-and-applications-2023

[4] Boesch, G. (2023). The 100 Most Popular Computer Vision Applications in 2024., Retrieved from https://viso.ai/applications/computer-vision-applications/

[5] Britannica (2024). Image Processing. Retrieved from https://www.britannica.com/technology/image-processing

[6] Google (2024). Image processing. Retrieved from https://www.google.com/search?client=firefox-b-1-d&q=applications+of+image+processing

[7] IBM (2024a). What is Computer Vision? Retrieved from https://www.ibm.com/topics/computer-vision

[8] IBM (2024b). What is Data Visualization? Retrieved from https://www.ibm.com/topics/data-visualization

[9] IBM (2024c) What is Data Mining? Retrieved from https://www.ibm.com/topics/data-mining

[10] Jareo education (2024). Top 15+ Data Mining Tools You Need to Know in 2024. Retrieved from https://www.jaroeducation.com/blog/top-15-data-mining-tools-2024/

[11] Knaflic. C.N. (2015). **Storytelling with Data: A Data Visualization Guide for Business Professionals**. Wiley Publishers, New York. ISBN 978-1-1190-0225-3.

[12] Kundu, R. (2024). Image Processing: Techniques, Types, & Applications [2024] Retrieved from https://www.v7labs.com/blog/image-processing-guide

[13] Loncova, A., Koniar, D., Hargas, L., Simonova, A. & Spanikova, G. (2017). Interdisciplinary research in field of biomedical image processing, **Proceedings of the 8th International Multi-Conference on Complexity, Informatics and Cybernetics** (IMCIC 2017), pp. 179-183.

[14] Murray, B. (2023). **Data Mining for Beginners**. Independently Published. ISBN 979-8-3926-5382-9

[15] Nixon, M. & Aguado, A. (2020) **Feature Extraction and Image Processing for Computer Vision**, 4th Edition, Academic Press, ISBN 978-0-1281-4976-8

[16] Red Nucleus (2020). Perspectives on the current data visualization landscape. Retrieved from https://rednucleus.com/resources/dataviz/

[17] Research Data Services, Oregon State University (2024). Lib Guide: Data Types & File Formats. Retrieved from https://guides.library.oregonstate.edu/research-data-services/data-management-types-formats

[18] Rouse, M. (2023) Computer Vision. Retrieved from https://www.techopedia.com/definition/32309/computer-vision

[19] Rutgers University Bootcamp (2022). **What Is Data Mining? A Beginner's Guide**. Retrieved from https://bootcamp.rutgers.edu/blog/what-is-data-mining/

[20] Sawtell-Rickson, J. (2022). What is Computer Vision? Retrieved from https://builtin.com/machine-learning/computer-vision

[21] Segall, R. S. & Cook, J. S. (Eds.). (2018). **Handbook of Research on Big Data Storage and Visualization Techniques** (2 Volumes). IGI Global. https://doi.org/10.4018/978-1-5225-3142-5

[22] Segall, R. S. & Niu, G. (2018). Overview of Big Data and Its Visualization. In R. Segall & J. Cook (Eds.), **Handbook of Research on Big Data Storage and Visualization Techniques** (pp. 1-32). IGI Global. https://doi.org/10.4018/978-1-5225-3142-5.ch001

[23] Segall, R. S. & Niu, G. (2020). Big Data and Its Visualization with Fog Computing. In I. Management Association (Ed.), **Cognitive Analytics: Concepts, Methodologies, Tools, and Applications** (pp. 341-377). IGI Global. https://doi.org/10.4018/978-1-7998-2460-2.ch019

[24] Segall, R. S. & Rajbhandari, P. (2024). Image Processing of Big Data for Plant Diseases of Four Different Plant Categories: Represented by Rice,

Banana, Sunflower, and Potato. **International Journal of Computer Vision and Image Processing** (IJCVIP), 14(1), 1-32. http://doi.org/10.4018/IJCVIP.353913

[25] Segall, R. S. & Takashashi, S. (2023). Data Visualization of Big Data for Predictive and Descriptive Analytics for Stroke, COVID-19, and Diabetes**. International Journal of Big Data and Analytics in Healthcare** (IJBDAH), 8(1), 1-31. http://doi.org/10.4018/IJBDAH.331996

[26] Sharma, S. (2021). 11 Amazing Computer Vision Examples and Applications in 2023. https://blog.gramener.com/computer-vision-examples/

[27] Sharma, Amit, Sharma, Ashutosh, Tselykh, A. & Bozhenyuk, A. (2024). Image and video analysis using graph neural network for Internet of Medical Things and computer vision applications. **CAAI Transactions on Intelligence Technology**, pp. 1–15. https://doi.org/10.1049/cit2.12306

[28] Takahashi, S. (2023). Data Visualization for COVID. Semester Project for ISBA 3423 Data Visualization for Business, Arkansas State University, Neil Griffin College of Business, Jonesboro, AR.72467 USA. Spring 2023.

[29] Tableau (2024a). What Is Data Visualization? Definition, Examples, And Learning Resources. Retrieved from https://www.tableau.com/visualization/what-is-data-visualization

[30] Tableau (2024b). 12 Great Books About Data Visualization. Retrieved from https://www.tableau.com/learn/articles/books-about-data-visualization

[31] Tanimoto, S. L. (2012). **An Interdisciplinary Introduction to Image Processing**: Pixels, Numbers, and Programs. The MIT Press, Cambridge, MA. ISBN 978-0-262-01716-9.

[32] TechTarget. Data Mining. Retrieved from https://www.techtarget.com/searchbusinessanalytics/definition/data-mining

[33] Toptal Designers, LLC. (2024). A Complete Overview of the Best Data Visualization Tools. Retrieved from https://www.toptal.com/designers/data-visualization/data-visualization-tools

[34] Torralba, A., Isola, P. and Freeman, W.T. (2024). **Foundations of Computer Vision**. The MIT Press, Cambridge, MA. ISBN 978-0-262-04897-2.

[35] Yau, T. (2024). **Visualize This: The Flowing Data Guide to Design, Visualization, and Statistics**. 2nd edition. Wiley Press. ISBN-13: 978-1-3942-1486-0.

[36] Wexler, S., Shaffer, J. & Cotgreave, A. (2017). **The Big Book of Dashboards**. Wiley Press. ISBN: 978-1-119-28271-6.