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ARTIFICIAL INTELLIGENCE IN LOGISTICS APPLICATIONS AND ALGORITHMS

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Abstract: The artificial intelligence undergoes an enormous development since its appearance in the fifties. The computing power has grown exponentially since then, enabling the use of artificial intelligence applications in different areas. Since then, artificial intelligence applications are not only present in the industry, but they have slowly conquered households as well. Their use in logistics is becoming more and more widespread, just think of self-driving cars and trucks. In this paper, the author attempts to summarize and present the artificial intelligence logistical applications, its development from the beginnings and impact on logistics and share some thoughts about the future.
Keywords: artificial intelligence, AI logistical applications, neural nets, robots, self-driving vehicles, augmented reality, optimization algorithms

1. INTRODUCTION

The term "Artificial Intelligence" was created by John McCarthy, who is known as the father of the artificial intelligence, he mentioned it firstly at a conference at Darthmouth in 1956 [1]. This was the first conference on this topic. The first testing method of the artificial intelligence was created by Alan Turing in 1950. One of the earliest testing methods, according to this, if an interrogator gives written questions to another person and a machine behind a screen and they will answer in writing, if the interrogator cannot decide in 5 minutes which one is a person and which one is a computer then the artificial intelligence passed the test. [2]. Of course, the Turing test got a lot of criticism, mainly because the simulation of the dialogue is only a small part of the intelligence. A Loebner prize was established in 1990 for an artificial intelligence which can pass the test, but no program passed it in a convincing way ever, however a smaller prize is awarded annually for the program which is the closest. [3]

2. NEURAL NETS

The first artificial neural network was created by Frank Rosenblatt in 1958. This modelled the functioning of the human brain with artificial neurons, how it is processing the visual information and how it can identify various objects [4]. The first practical application was the optical handwriting recognition, this quickly became industrially applicable and quickly spread among the postal companies.

After the USA (1965) and then Japan (1968) [5], in Hungary (1978) the optical recognition of the handwritten postal codes was introduced [6], this system was based on a neural network character recognition application (Fig. 1). Later, the systems were able to identify whole handwritten addresses with great precision. The neural networks have been extensively used since then in almost all segments of the artificial intelligence, including the field of self-driving cars, to identify and classify visual information.

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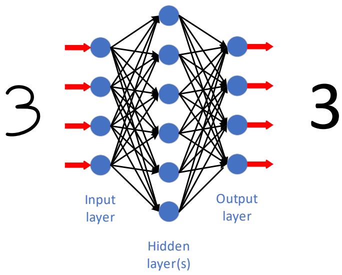

Figure 1. Character recognition using neural network

3. CONSUMER SEGMENT

The forerunner of artificial intelligence in the consumer segment was the data mining on the extensively collected data related to loyalty cards in the eighties. Companies launched loyalty programs, issued point-collecting cards, so they were able to connect the consumers to the purchased products, and they built huge databases that were analyzed using various data mining techniques [7]. Later, the extensive online data collection was appeared, and the deeper analysis of consumer behavior began.

The software solutions use machine learning methods to analyze our consumption patterns, considering our orders, searches, the web pages visited, the contents of our emails, even our spoken words for effective profiling. They offer products for purchase based on this. This product recommendation method is very effective. Amazon experienced a 29% increase in sales after implemented his product recommendation system. At present, products sold on product recommendation account for 35% of Amazon's turnover [8].

Household and personal assistants appeared whose can communicate in natural language, they can even order online, which instantly lead to serious security problems [9], but these home assistants also collect data on user habits too. These applications can, on the one hand, make life easier and, on the other, raise a lot of privacy and data handling problems.

Automatic ordering applications have been released, that are able to order the product at the push of a button (Fig. 2). Analyzing their usage, a big part of the inventory can be calculated effectively.

Figure 2. Amazon Dash, Order products with a push of a button, source: Amazon

It is estimated that the volume of data generated by the world will increase by 40% over the previous year (Fig. 3) [10].

To analyze this huge data volume in the late 90's appeared the big data techniques and then the machine learning. These systems are able to determine relationships and regularities based on the data [12].

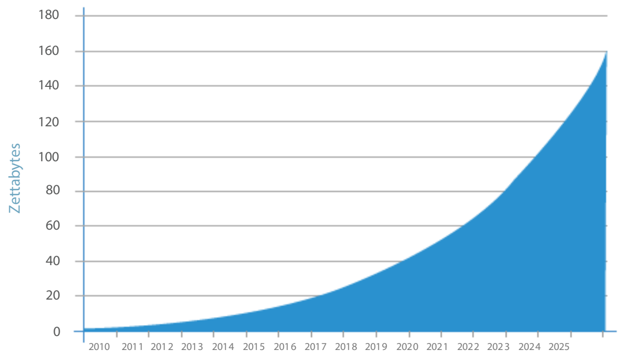

Figure 3. The amount of data created by worldwide [11]

Based on the detected regularities, they are able to make better predictions, reduce inventory levels, increase availability, and increase the safeness of supply of production. The recent research studies extend the machine learning to the entire supply chain, this is the so-called Smart Manufacturing Supply Chain, SMSC [13].

4. ROBOTS

Manufacturing and logistics do not exist without each other [14]. Thus, practically the increase in the automation of the production has led to an increase in logistics automation too. The robots appeared not only in production but also in material handling, transportation, warehousing, etc. With the introduction of Industry 4.0, automation and the need to increase the degree of automation have boosted considerably, and currently the lack of workforce also favors the spread of robotics in production and in logistics also.

In the beginning, the logistical use of robots was held back by the fact that early robots were stationary [15]. They had little intelligence, basically the same procedure was repeated 24/7, but logistics often required movement and more complex operations. With the development of camera systems, laser scanners and sensor systems, various grippers, some of that are modelling the human gripping, robots are now even able to harvest strawberries (Fig. 4).

Figure 4. Strawberry harvester robot [16]

Research has now been carried out in several areas to extend the logistical application of robots, such as container loading and unloading robots (Fig. 5), picking robots, warehouse robots, and collaborative robots.

Figure 5. Container unloader robot [17]

The use of warehouse robots was accelerated by large service providers like Amazon. In Amazon 2016, 45,000 robots (Fig. 6) have been used globally, this number has risen to 100,000 by 2018 [18], but they are not able to completely replace human labor.

Figure 6. Amazon warehouse robots [19]

The present largest developmental step is the use of robots which cooperate with humans, these are the so-called cobots [20]. Current research has shown that they can increase efficiency by up to 50% [21].

The cooperating robots (Fig. 7) raise a lot of security issues, their security-related recommendations are specified in ISO / TS 15066: 2016 [23].

Figure 7. Cobot [22]

5. SELF-DRIVING VEHICLES

The first definition of self-driven vehicles come from the U.S. Department of Transportation: “Self-driving vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode”. You can notice the fact, it is explicitly stated that the driver must be present in the vehicle [24].

Self-driven vehicles use different sensors to measure surrounding traffic, various objects, obstacles, some of these sensors, such as the laser radar, LiDAR (Figure 8), in unlike the human driver, can see in the dark, so they allow even the night driving in totally dark environment. There are 6 levels of automation [25]:

- Level 0: A human driver performs all the operations.
- Level 1: Partial support, the system can accelerate, slow down, can do steering, but not simultaneously.
- Level 2: A driving aid system that can accelerate, slow down and do steering at one time.
- Level 3: The vehicle can drive itself under certain circumstances, but the driver must be able to take control at any time.
- Level 4 Complete driving in certain circumstances, such as in HD mapped areas, other areas require driver intervention.
- Level 5: Full driving, no driver Needed

Figure 8. LiDAR in operation [26]

At the time of the release of this article, Google Waymo is the only one to reach the 4th level of automation and now they got the permit to test fully driverless cars in Mountain View California.

However, not only the passenger transportation, but the freight industry has also started the developments in self-driving. In 2016, Komatsu introduced self-driven dumpers in Australian mines (Fig. 9), which can work continuously 24 hours without human intervention [27]. However, this is a special application without any traffic or with little traffic only. Similar self-driven vehicles have also appeared in agriculture, as there is no traffic expected within the given area.

Figure 9. 416 tons Komatsu dumper [26]

The self-driving is spreading in the field of commercial transportation also. Currently, most of the major carmakers are conducting research projects in this field. According to the promises, in 2019, Tesla Semi, which is an electric powered self-driving truck (Fig. 10) will be presented to the public. Tesla promises full self-driving, but according to the current situation, the vehicle is probably reaching level 3 or 4, which can be upgraded later with software updates. It is estimated that around 2030 we will reach level 5 [28].

Figure 10. Tesla Semi, self-driving fully electric truck, source: Wikipedia

6. AUGMENTED REALITY

Augmented Reality or Mixed Reality is a kind of expansion of the reality when virtual elements are projected into the real environment. For example, a virtualized image can be seen with a mobile phone or special glasses.

One of the most recent definitions of the extended reality is Milgram's Reality-Virtuality Continuum (Fig. 11) [29]. From the graph, it can be seen that, starting with the real environment on the left, adding more and more virtual environment objects, we get to a completely virtual, simulated environment that has no real elements. Practically leaving the two extreme states we are in the augmented reality or mixed reality.

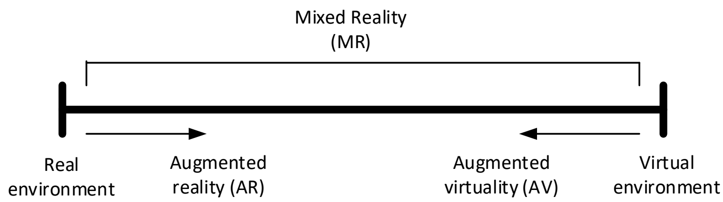

Figure 11. Milgram's Reality-Virtuality (RV) continuum

The first VR system (Fig. 12) was made by Ivan Sutherland in 1968, but it was so heavy, it must be suspended on the ceiling, portability was not a question [30].

Figure 12. First head mounted VR system, 1968

The creation of augmented and virtual reality applications started with computing performance increase in the early 1990s. The first ever augmented reality system, the Virtual Fixtures (Fig. 13), developed by Louis Rosenberg in the US Air Force Armstrong Laboratory, was used mainly by robot aided remote controlling, he was using several procedures to eliminate the shortcomings of the primitive 3D graphics of that time [31].

Figure 13. Virtual Fixtures, first AR system, 1992

Computing needs of these types of applications were not available at this time, especially in small sizes, large computers were expensive, graphics were very primitive and low resolution, so the applications were limited, does not look real and did not spread. Over the next 15 to 20 years, augmented reality research was funded by industry giants and military research laboratories, then the augmented reality slowly spread in computer games, industrial applications are not yet available at this time.

The first major breakthrough was the launch of Google Glass in 2013, which has been sold in limited numbers [32]. This can be worn as a voice-controlled device, it was already suitable for augmented reality applications. Research has accelerated, with more companies appearing with their own products such as Lenovo C1 or Microsoft Hololens (Fig. 14).

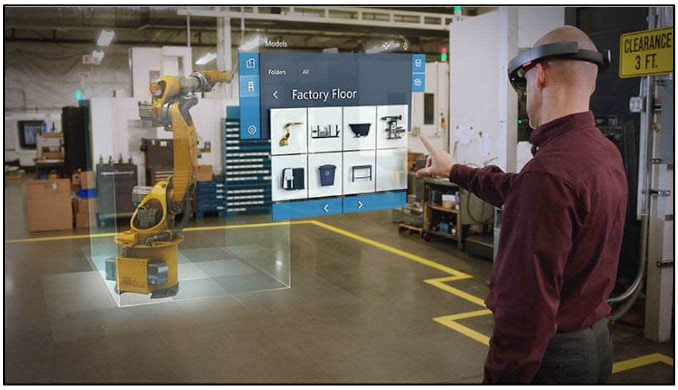

Figure 14. Microsoft Hololens, source: Microsoft

With the development of hardware, industrial applications have begun. Logistics research first started at the DHL and SAP research laboratories, and later, as hardware became cheaper, more and more companies began to develop applications. One of these is the KNAPP AG Pick-by-Vision system (Fig. 15) [33]. Which guides the picking person with visual aids for the specified goods, increasing order picking speed and minimizing errors.

Figure 15. KNAPP KiSoft Pick by Vision system, source: KNAPP

7. OPTIMIZATION ALGORITHMS

In the field of artificial intelligence research, many optimization algorithms are used, which can be used to efficiently solve logistics problems. In the field of artificial intelligence, most of the problems can be solved by searching through the problem's state space (Fig. 16) [34].

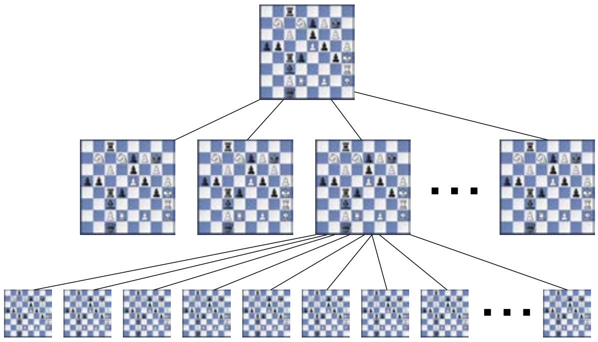

Figure 16. A graph representation of the state space of a chess game [35]

For example, layout design algorithms searching in tree structures, while robots use local searches when using grippers, and the learning algorithms also use optimizations based on searches. [36].

Logistic problems in real life are usually very diverse, with many conditions, often have very high variable count. One of the simplest and most basic logistical problems is to define the shortest path. Although the problem is simple, it did not become outdated over time. Algorithms that solve the shortest path problem are currently widely used, for example, in route planning systems, GPS devices, navigation software, robotic devices. There are several algorithms for this, the most important ones are these:

- Disjkstra algorithm (Fig. 17), 1956
- Bellman-Ford algorithm, 1956
- The A* algorithm, 1968
- Floyd-Warshall algorithm, 1962
- Viterbi algorithm, 1967
- Johnson Algorithm, 1977 [37].

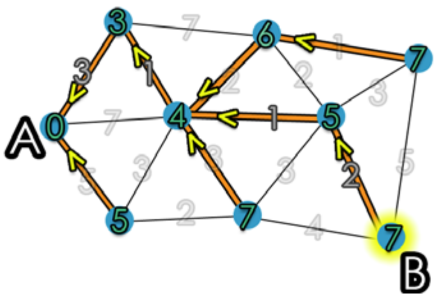

Figure 17. Dijsktra algorithm [38]

Perhaps the most well-known logistic problem, the "holy grail" of logistics optimization, is the Traveling Salesman Problem (TSP) and its variants, such as the Multiple Traveling Salesman Problem (MTSP). Since the TSP problem is NP-hard, so with exhaustive search it can be solved on very small problems in practice. The TSP problem has been solved by the following heuristic algorithms [39]:

- Nearest neighbors' algorithm, 1973
- Christofides algorithm, 1976
- Lin-Kernighan heuristics, 1973
- Genetic algorithm, 1963-1975
- Simulated cooling, 1983
- Taboo search, 1986
- Ant Colony algorithm, 1991
- Particle Methods, 1986

Of course, under real circumstances "clear" TSP problem does not exist. Mostly, the MTSP problem and its variants appear, such as the time window MTSP problem, or MTSP problem with real world conditions (Fig. 18).

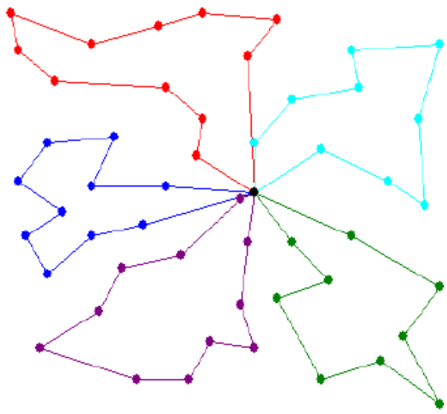

Figure 18. A simple MTSP problem [40]

If we include realistic conditions such as one-way roads, working hours, driving time, and fuel constraints, then complexity can be increased so that the runtime of heuristics often falls outside the foreseeable time range with the current computing capacity. Thus, such problems are solved by metaheuristic methods, directed heuristics.

The multiphase algorithms are popular at present, they include usually two phases - a fast global search and a slower local search. In the first stage, the state space is narrowed by a fast heuristic, for example clustering, second phase use this heuristic method output for a starting point, for example, by initializing a heuristic method with an output of a randomized search [41] or using adaptive methods that modify the heuristic parameters during runtime and generally provide methods for avoiding stuck into local optimum [42].

In addition to these algorithms, artificial intelligence uses a number of other algorithms and methods, such as probability algorithms, fuzzy logic, regression, clustering, pattern recognition, enhanced learning and speech processing that are not closely related to logistics but may be present in logistics applications. The artificial intelligence area growing exponentially nowadays (Fig. 19), the development practically exploded.

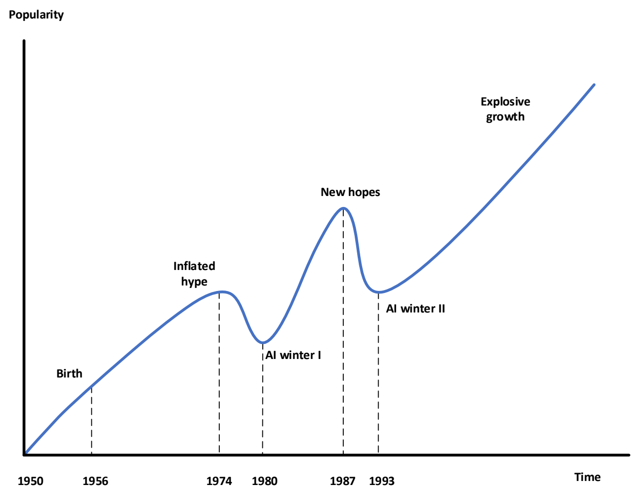

Figure 19. AI timeline [43]

Today, commercially available hardware and software packages exists such as the Intel Nervana NNP - Neural Network Processor (Fig. 20), which is an artificial intelligence accelerator specifically designed to accelerate machine learning. Virtually every day new hardware, new applications and new algorithms are being created.

Figure 20. Intel Nervana NNP
source: ai.intel.com

8. FINAL THOUGHTS

At present we distinguish three types of the artificial intelligence. The first type is the weak artificial intelligence or narrow artificial intelligence which programmed to solve one task only. The second one is the strong artificial intelligence or artificial general intelligence which is close to the human intelligence or it is about the same level. The third and ultimate type is the super artificial intelligence which goes beyond the human intelligence in every aspect [44]. However, we just implemented the narrow AI and use it in special areas, like driverless vehicles or computer vision systems or in chess games. The development of the AI is a rapidly growing area. Researchers, philosophers and futurologists are trying to predict the evolution of the artificial intelligence. The last two types of the artificial intelligence are just fiction now, but it can be changed in the future, the predictions vary [45], [46]. At present maybe due to the current promising results and current predictions a lot of critical voices emerged to warn the potential dangers [45], [46]. It might be dangerous if we can't use them well. We still have a lot to learn about the human robot interactions, machine learning and AI controlled machines. They are not just in the industry but in the homes as well, they will appear in the everyday life in growing numbers, so this is inevitable.

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Literature

[1] Rajaraman, V. & McCarthy, J. (2014). Father of Artificial Intelligence, *Resonance 19*(3), 198-207. https://doi.org/10.1007/s12045-014-0027-9

[2] Turing, A. M. (1950). Computing Machinery and Intelligence. Retrieved from https://www.csee.umbc.edu/courses/471/papers/turing.pdf

[3] Powers, D. M. W. (1998). The total Turing test and the Loebner prize. In *Proceedings of the Joint Conferences on New Methods in Language Processing and Computational Natural Language Learning*, 279-280. ISBN:0-7258-0634-6

[4] Yadav, N., Yadav, A. & Kumar, M. (2015) *An Introduction to Neural Network Methods for Differential Equations, Chapter 2 History of Neural Networks*, Springer, https://doi.org/10.1007/978-94-017-9816-7

[5] Hiromichi, F. (2008) Forty years of research in character and document recognition—An industrial perspective, *Pattern Recognition 41*(8), 2435-2446. https://doi.org/10.1016/j.patcog.2008.03.015

[6] Lovászi, J. (2008). *A gépesített levélfeldolgozás 30 éve konferencia*. Retrieved from http://psze.info/a-gepesitett-levelfeldolgozas-30-eve-budapest-2008-november-26/

[7] Sharp, B. (1997) Loyalty programs and their impact on repeat-purchase loyalty patterns. *International Journal of Research in Marketing, 14*(5), 473-486. https://doi.org/10.1016/S0167-8116(97)00022-0

[8] MacKenzie, I., Meyer, C. & Noble, S. (2013). *How retailers can keep up with consumers.* Retrieved from https://www.mckinsey.com/industries/retail/our-insights/how-retailers-can-keep-up-with-consumers

[9] Warren, T. (2017). *South Park trolls Amazon Alexa owners in this week's episode*. Retrieved from https://www.theverge.com/2017/9/16/16318694/south-park-amazon-alexa-google-home

[10] Yaqoob, I. et al. (2016). Big data: From beginning to future, *International Journal of Information Management, 36*(6), Part B, https://doi.org/10.1016/j.ijinfomgt.2016.07.009, 1231-1247

[11] Reinsel, D., Gantz, J. & Rydning, J. (2017). *Data Age 2025: The Evolution of Data to Life-CriticalDon't Focus on Big Data; Focus on the Data That's Big*, Retrieved from https://www.seagate.com/files/www-content/our-story/trends/files/Seagate-WP-DataAge2025-March-2017.pdf

[12] Pyle, D. & San José, C. (2015). An executive's guide to machine learning. McKinsey Quarterly, Retrieved from https://www.mckinsey.com/industries/high-tech/our-insights/an-executives-guide-to-machine-learning

[13] Oh, J. & Jeong, B. (2019). Tactical supply planning in smart manufacturing supply chain. *Robotics and Computer-Integrated Manufacturing, 55*, part B, https://doi.org/10.1016/j.rcim.2018.04.003, 217-233

[14] *Robots in logistics*, Retrieved from https://digitalisgyar.wordpress.com/2018/02/16/robotok-a-logisztikaban

[15] Bonkenburg, T. (2016). *DHL Trend Research: Robotics in Logistics*. Retrieved from http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_trendreport_robotics.pdf

[16] *Agrobot Robotic Harvesters*. Retrieved from www.agrobot.com

[17] *Automation world*. Retrieved from https://www.automationworld.com/article/technologies/robotics/wynright-receives-nextgen-game-changer-award-groundbreaking-robotic

[18] Brown, A. (2018). *Rise of the machines*? Daily Mail. Retrieved from https://www.dailymail.co.uk/sciencetech/article-5808319/Amazon-100-000-warehouse-robots-company-insists-replace-humans.html

[19] *Amazon Robotics*. Retrieved from www.amazonrobotics.com

[20] Kildal, J., Tellaeche, A., Fernández, I. & Maurtua, I. (2018). Potential users' key concerns and expectations for the adoption of cobots, *Procedia CIRP, 72*, 21-26. https://doi.org/10.1016/j.procir.2018.03.104

[21] Mabie, S. (2018). *Collaborative Robots*, Universal Robots USA Inc. Retrieved from https://www.robotics.org/userAssets/riaUploads/file/13-CollaborativeRobotTechnologyandCustomerApplicationsUniversal-ScottMabie.pdf

[22] Techtreak technology blog (2018). *Use of Cobots in Logistics*. Retrieved from http://www.techtreak.com/use-of-cobots-in-logistics/

[23] ISO/TS 15066:2016: *Robots and robotic devices — Collaborative robots*. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:ts:15066:ed-1:v1:en

[24] US Department of Transportation: *Policy on Automated Vehicle Development*. Retrieved from https://www.transportation.gov/briefing-room/us-department-transportation-releases-policy-automated-vehicle-development

[25] US Department of Transportation: *Automated Vehicles for Safety*, Retrieved from https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

[26] Cameron, O. (2017). *An Introduction to LIDAR: The Key Self-Driving Car Sensor*. Retrieved from https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff

[27] Simonite, T. (2016). Mining 24 Hours a Day with Robots, *MIT Technology Reviews*, Retrieved from https://www.technologyreview.com/s/603170/mining-24-hours-a-day-with-robots/

[28] Rehbock, B. (2017). BMW Envisions Level 5 Autonomous Driving in 2030. Retrieved from https://www.motortrend.com/news/bmw-wants-to-build-the-ultimate-self-driving-machine/

[29] Milgram, P., Takemura, H., Utsumi, A. & Kishino, F. (1994). *Augmented Reality: A class of displays on the reality-virtuality continuum.* ATR Communication Systems Research Laboratories, Kyoto

[30] Schmalstieg, D. & Hollerer, T. (2016). *Augmented Reality: Principles and Practice*. Boston: Addison-Wesley

[31] Rosenber, L. (1993). Virtual fixtures: Perceptual tools for telerobotic manipulation. In *Proceeding VRAIS '93 Proceedings of the 1993 IEEE Virtual Reality Annual International Symposium*, https://doi.org/10.1109/VRAIS.1993.380795 , 76-82

[32] Strickland, J. (2012). *How Google Glass Works*. Retrieved from https://electronics.howstuffworks.com/gadgets/other-gadgets/project-glass1.htm

[33] Glockner, H., Jannek, K., Mahn, J. & Theis, B. (2014). *Augmented Reality in Logistics, Changing the way we see logistics – a DHL perspective*. Retrieved from https://www.logistics.dhl/content/dam/dhl/global/core/documents/pdf/glo-logistics-insights-augmented-reality.pdf

[34] Luger, G. F. & Stubblefield, W. A. (2004). *Artificial Intelligence Structures and Strategies for Complex Problem Solving (5th ed).* The Benjamin/Cummings Publishing Company, Inc.

[35] Seel, N. (2014). *Three Roads to Artificial Intelligence*. Retrieved from http://interweave-consulting.blogspot.com/2014/01/three-roads-to-artificial-intelligence.html

[36] Chijindu, V. C. (2012). Search in Artificial Intelligence Problem Solving. *African Journal of Computing & ICT, 5*(5), 37-42.

[37] Cherkassky, B. V., Goldberg, A. V. & Radzik, T. (1996). Shortest paths algorithms: Theory and experimental evaluation. *Mathematical Programming, 73*(2), 129–174. https://doi.org/10.1007/BF02592101

[38] Hazzard, E. (2010). *Dijkstra's Algorithm - Shortest Path*. Retrieved from http://vasir.net/blog/game_development/dijkstras_algorithm_shortest_path

[39] Nilsson, C. (2003). *Heuristics for the Traveling Salesman Problem.* Retrieved from https://pdfs.semanticscholar.org/7b80/bfc1c5dd4e10ec807c6f56d0f31f8bf86bc6.pdf

[40] Yousefikhoshbakht, M., Rahmati, F. & Didehvar F. (2013). Modification of the Ant Colony Optimization for Solving the Multiple Traveling Salesman Problem. *Romanian Journal Of Information Science And Technology, 16*(1), 65–80.

[41] Kota, L. & Jármai, K. (2017). Application of multilevel optimization algorithms, In *Advances in Structural and Multidisciplinary Optimization: Proceedings of the 12th World Congress of Structural and Multidisciplinary Optimization (WCSMO12),* 710-715. https://doi.org/10.1007/978-3-319-67988-4_54

[42] Ying, L. & Jun, Z. (2013). Ant colony optimization with adaptive heuristics design. In *GECCO 2013 - Proceedings of the 2013 Genetic and Evolutionary Computation Conference Companion*, https://doi.org/10.1145/2464576.2464587

[43] Lim, M. (2018). *History of AI Winters.* Retrieved from https://www.actuaries.digital/2018/09/05/history-of-ai-winters

[44] Uj, A. (2018). *Understanding Three Types of Artificial Intelligence*, Retrieved from https://www.analyticsinsight.net/understanding-three-types-of-artificial-intelligence

[45] Müller, V. C. & Bostrom, N. (2016). Future Progress in Artificial Intelligence: A Survey of Expert Opinion, In Müller, V. (ed.). *Fundamental Issues of Artificial Intelligence.* 553-571. Berlin: Springer, https://doi.org/10.1007/978-3-319-26485-1_33

[46] Bostrom, N (2014). *Superintelligence: Paths, Dangers, Strategies,* Oxford University Press, ISBN 978-0199678112

[47] Goertzel, B. (2015). Superintelligence: Fears, Promises and Potentials, *Journal of Evolution and Technology, 24*(2), 55-87.