Improving the Super-Paging Swapping Algorithm

Yair Wiseman
Computer Science Department
Bar-Ilan University
Ramat-Gan 52900
Israel
wiseman@cs.biu.ac.il

Abstract

The contemporary algorithms used by paging swapping systems are quite old and they usually do not take into account the possibility of super-paging. We suggest incorporating an uncommon page replacement algorithm so as to enhance the traditional swapping algorithms. This enhanced approach can efficiently handle the different size of pages and achieve better results.

Keywords: Super-Pages, Virtual Memory, Page Replacement Algorithms.

1. Background

Recently, a new page replacement policy has been proposed by Megiddo and Modha named ARC (Stands for Adaptive Replacement Cache) [1,2,3]. The new policy outperforms the traditional LRU used by many paging systems. Actually, the authors claim their policy outperforms also the LRU of many other systems e.g. web browsers or RIAD controller.

The main concept of ARC is to have two lists of active pages (one for the frequently used pages and one for the most recent pages) and to endow the list that is performing the best with a larger memory space. ARC is about 10%-15% more time consuming than LRU, but the hit ratio is in average about as twice as LRU. Small space overhead, however, is needed. The main advantage over the “Least Frequently Used” (LFU) [4] policy is that stale pages do not retain in the memory.

This paper inquires whether the ARC can also outperform the LRU when using SuperPaging systems [5]. SuperPages are larger pages that are pointed by the TLB. The internal memory of modern computers has been significantly increased during the last decade. However, the TLB coverage (i.e. the size of the memory that can be pointed directly by the TLB) has been increased by a much lower factor during the same period [6,7]. Therefore, several new architectures like Itanium, MIPS R4x00, Alpha, SPARC and HP PA RISC support multiple page size of the frames pointed by the TLB. In that way the memory size pointed directly by the TLB is higher and the overhead of the page table access time is reduced. In addition, many modern operating systems support superpaging e.g. some versions of Linux [8] or HP-UX [9]

2. The ARC Algorithm

ARC is defined as follow: Let *c* be the number of pages in the memory and let L_1 and L_2 be two linked lists. L_1 contains the pages that have been accessed just once, while L_2 contains the pages that have been accessed at least twice. The allowed operations on L_1 and L_2 are the same operations that are allowed on an LRU linked list. $|L_1|+|L_2|$ is a not negative number and not bigger than $2c$. L_1 is a not negative number and not bigger than *c*, but L_2 can be bigger than *c*.

When a page is accessed; if the page is in L_1 or L_2, it will be moved to the MRU of L_2; otherwise it will be moved to the MRU of L_1. If adding the new page makes $|L_1|+|L_2| > 2c$ or $|L_1|>c$, then if L_1 (before the addition) contains less than *c* pages, the LRU of L_2 will be taken out; otherwise the LRU of L_1 will be taken out.

$|L_1|+|L_2|$ is not bigger than $2c$, but the size of the memory is just *c*. This leads to the following partition: Let T_1 be the most recent pages in the memory and B_1 be the least recent pages in the memory. Similarly, L_2 is partitioned into T_2 and B_2. Therefore, T_1 and T_2 contain the pages that are actually in the memory. When a page is moved from a "T" list to a "B" list, it will be taken out of the memory.

Let the threshold *p* be the current target size for the list T_1.

- If $|T_1|>p$, move the LRU of T_1 to be the MRU of B_1.
- If $|T_1|<p$, move the LRU of T_2 to be the MRU of B_2 .
- If $|T_1|=p$, if the accessed page has been in B_2, move the LRU of T_1 to be the MRU of B_1. (Because *p* is going to be decremented). If the accessed page has been in B_1 or has not been in the memory, move the LRU of T_2 to be the MRU of B_2.

- If there is a hit in T_1 or T_2, do nothing.
- If there is a hit in B_1, if the size of B_1 is at least the size of B_2, increment the threshold *p* by 1; otherwise, increment *p* by $|B_2|-|B_1|$.
- If there is a hit in B_2, if the size of B_2 is at least the size of B_1, decrement the threshold *p* by 1; otherwise, decrement *p* by $|B_1|-|B_2|$.

The increments and the decrements are subject to the stipulation $0 \leq p \leq c$

ARC is better than LRU because if a process scans a large database, there will be no hits; hence the threshold *p* will not be modified and the pages in T2 will remain in the memory. ARC is better than LFU, because stale pages do not remain in the memory.

3. SuperPages and ARC

When adapting ARC for superpaging, some considerations should be taken into account. In this section, we would like to discuss these considerations and to see how they can affect the ARC algorithm.

3.1 Larger Pages

When using superpages the pages are occasionally larger. In such a case the recency is less important that the frequency. If a page is touched frequently, it can hint the operating systems that this page is important, even if the page is very large, while the importance of a touch of a larger page is less weighty.

3.2 Fragmentation

ARC and LRU do not take into their considerations the location of the “victim” that is chosen to be swapped out; hence they can leave many holes within a superpage, because some of the base pages that the superpage consist of can be in the memory while the others can be out of memory. When not all of the base pages are in the memory, a promotion can be costly. A better replacement algorithm must check the “neighborhood” of the victim page. A similar scheme was suggest by Romer et al. [10], but they preferred to use LRU.

3.3 Thrashing

Usually supperpages supported systems are less thrashing-proof than the old traditional paging systems. Obviously, when the memory is very large this deficiency is not critical. However, one of the importance advantages of the ARC over the “recency” algorithms is the thrashing-proof feature; hence the thrashing argument is clearly in favor of the use of ARC.

3.4 Coarse Granularity

The use of superpages causes all of the superpage’s base pages to be considered as important (or unimportant) ones, while just a few base pages are important or even just a single base page is important. In such cases the LRU gives bad results, because it has no mechanism to distinguish between the superpages that contains a lot of important base pages and the superpages that contains just a small number of important base pages. “Recency” algorithms cannot distinguish this difference; therefore LRU will not be a good choice. ARC, however, takes into account the “frequency”; thus ARC can be a better choice.

3.5 Gathering of the Accesses

When the page is small a look of the specific location of the readings/writings is not significant. However, one can think that a gather can imply an important page, while scattered readings/writings will mean arbitrary accesses. However, practically this assumption is not proved as correct.

4. Evaluation

ARC stipulates that the threshold of the “recency” list is *p* which can be equal or less than the memory size. The outcome of the previous section is that this threshold is too high. The coarse granularity of the larger pages can be misleading and biased towards to the “recency” and against the “frequency”.

Reducing this threshold and put it on a lower value can do better. The results are changed from one benchmark to another and it depends on the memory size. It appears that in some cases the value can be reduced in order to give a better performance. Such a reduced threshold can be more reasonable threshold for superpages systems, because it does not permit too much endowment in the “recency” list and enforce more weighty portion for the “frequency” list.

5. Conclusions

ARC gives quite remarkable results for many systems that have been used the traditionally LRU policy. In this paper we show that ARC is suitable for superpaging systems as well. Yet, an adjustment of the threshold can yield much better performance.

6. References

[1] N. Megiddo and D. S. Modha, "ARC: A Self-Tuning, Low Overhead Replacement Cache," Proc. of the 2nd USENIX Conference on File and Storage Technologies (FAST'2003), San Francisco, pp. 115-130, March 31 - April 2, 2003.

[2] N. Megiddo and D. S. Modha, "One Up on LRU" ;login: - The Magazine of the USENIX Association, vol. 28, no. 4, pp. 7-11, August 2003.

[3] N. Megiddo and D. S. Modha, "Outperforming LRU with an Adaptive Replacement Cache Algorithm," IEEE Computer, pp. 4-11, April 2004.

[4] D. Lee, J. Choi, J.-H. Kim, S. H. Noh, S. L. Min, Y. Cho, and C. S. Kim, "LRFU: A spectrum of policies that subsumes the least recently used and least frequently used policies," IEEE Trans. Computers, vol. 50, no. 12, pp. 1352-1360, 2001.

[5] N. Ganapathy and C. Schimmel, General Purpose Operating System Support for Multiple Page Sizes, In Proceedings of the USENIX, New Orleans, Louisiana, June 15-19, 1998.

[6] J. Navarro. Transparent operating system support for superpages, Ph.D. Thesis, Department of Computer Science, Rice University, April 2004.

[7] J. Navarro, S. Iyer, P. Druschel and A. Cox. Practical, Transparent Operating System Support for Superpages, Fifth Symposium on Operating Systems Design and Implementation (OSDI '02), Boston, MA, December 9-11, 2002.

[8] S. Winwood, Y. Shuf, H. Franke, Multiple Page Size Support in the Linux Kernel, Ottawa Linux Symposium, Ottawa, Ont, Canada, June 2002.

[9] I. Subramanian, C. Mather, K. Peterson, and B. Raghunath. Implementation of multiple pagesize support in HP-UX, In Proceedings of the USENIX, New Orleans, Louisiana, June 15-19, 1998.

[10] T. H. Romer, W. H. Ohllrich, A. R. Karlin, and B. N. Bershad, Reducing TLB and memory overhead using online superpage promotion, In Proceedings of the 22nd International Symposium on Computer Architecture (ISCA), pp. 87-176, Santa Margherita Ligure, Italy, June 1995.

[11] Wiseman Y., "Autonomous Vehicles", Encyclopedia of Information Science and Technology, Fifth Edition, Vol. 1, Chapter 1, 2020, pp. 1-11.

[12] Wiseman, Y., (2018), "In an era of autonomous vehicles, rails are obsolete", International Journal of Control and Automation, Vol. 11, No. 2, pp. 151-160.

[13] Wiseman, Y., (2021), "Intelligent Transportation Systems along with the COVID-19 Pandemic will Significantly Change the Transportation Market", The Open Transportation Journal, Vol. 15, No. 1, pp. 11-15.

[14] Wiseman Y., (2018), "Vehicle identification by OCR, RFID and Bluetooth for toll roads", International Journal of Control and Automation, Vol. 11, No. 9, pp. 67-76.

[15] Wiseman Y., (2020), "Conjoint Vehicle License Plate Identification System", The Open Transportation Journal, Vol. 14, No. 1, pp. 164-173.

[16] Wiseman, Y., (2021), "COVID-19 Along with Autonomous Vehicles will Put an End to Rail Systems in Isolated Territories", In IEEE Intelligent Transportation Systems, Vol. 13, No. 3, pp. 6-12, doi: 10.1109/MITS.2021.3049409.

[17] Wiseman, Y. (2019), "Driverless cars will make union stations obsolete", The Open Transportation Journal, Vol. 13, No. 1, pp. 109b 115.

[18] Wiseman Y., (2017, May). "Real-time monitoring of traffic congestions" In proceedings of 2017 IEEE International Conference on Electro Information Technology (EIT-2017, Lincoln, Nebraska, USA, pp. 501-505.

[19] Wiseman, Y., (2017), "Tool for online observing of traffic congestions", International Journal of Control and Automation, Vol. 10, No. 6, pp. 27-34.

[20] Wiseman Y., (2017), "Computerized traffic congestion detection system". International Journal of Transportation and Logistics Management, Vol. 1, No.1, pp. 1-8.

[21] Wiseman Y., (2018)., "Efficient Embedded Computing Component for Anti-Lock Braking System", International Journal of Control and Automation, Vol. 11, No. 12, pp. 1-10.

[22] Wiseman Y., (2018), "Ancillary ultrasonic rangefinder for autonomous vehicles", International Journal of Security and its Applications", Vol. 12, No. 5, pp. 49-58.

[23] Wiseman, Y. (2019), "Driverless cars will make passenger rail obsolete [opinion

[24] Wiseman Y., (2017), "Self-Driving Car - A Computer will Park for You", International Journal of Engineering & Technology for Automobile Security, Vol. 1, No. 1, pp. 9-16.

[25] Wiseman Y., (2017), "Remote Parking for Autonomous Vehicles", International Journal of Hybrid Information Technology, Vol. 10, No. 1, pp. 313-324.

[26] Wiseman Y., (2014), "Device for Detection of Fuselage Defective Parts", Information Journal, Tokyo, Japan, Vol. 17(9(A)), pp. 4189-4194.

[27] Wiseman Y., (2013), "Fuselage Damage Locator System", Advanced Science and Technology Letters, Vol. 37, pp. 1-4.

[28] Wiseman Y., (2010), "Take a Picture of Your Tire!", Proc. IEEE Conference on Vehicular Electronics and Safety (IEEE ICVES-2010) Qingdao, ShanDong, China, pp. 151-156.

[29] Wiseman Y., (2013), "The Effectiveness of JPEG Images Produced By a Standard Digital Camera to Detect Damaged Tyres", World Review of Intermodal Transportation Research, Vol. 4, No. 1, pp. 23-36.

[30] Wiseman Y., (2013), "Camera That Takes Pictures of Aircraft and Ground Vehicle Tires Can Save Lives", Journal of Electronic Imaging, Vol. 22, No. 4, 041104.

[31] Wiseman Y., (2017), "Safety Mechanism for SkyTran Tracks", International Journal of Control and Automation, Vol. 10, No. 7, pp. 51-60.

[32] Wiseman Y., (2017), "Automatic Persistent Inspection of SkyTran Track System", http://u.cs.biu.ac.il/~wiseman/skytran1.pdf .

[33] Grinberg I. and Wiseman Y., (2007), "Scalable Parallel Collision Detection Simulation", In Proceedings of Signal and Image Processing, Honolulu, Hawaii, pp. 380-385.

[34] Grinberg I. and Wiseman Y., (2013), "Scalable Parallel Simulator for Vehicular Collision Detection", International Journal of Vehicle Systems Modelling and Testing, Inderscience Publication, Vol. 8, No. 2, pp. 119-144.

[35] Wiseman Y., K. Schwan and P. Widener, (2004), "Efficient End to End Data Exchange Using Configurable Compression", Proceedings of The 24th IEEE Conference on Distributed Computing Systems (ICDCS 2004), Tokyo, Japan, pp. 228-235.

[36] P. Weisberg and Wiseman Y., (2009), "Using 4KB Page Size for Virtual Memory is Obsolete", Proc. IEEE Conference on Information Reuse and Integration (IEEE IRI-2009), Las Vegas, Nevada, pp. 262-265.

[37] P. Weisberg and Wiseman Y., (2015), "Virtual Memory Systems Should Use Larger Pages rather than the Traditional 4KB Pages", International Journal of Hybrid Information Technology, Vol. 8(8), pp. 57-68.

[38] Wiseman Y., (2017), "Automatic Alert System for Worn Out Pipes in Autonomous Vehicles", International Journal of Advanced Science and Technology, Vol. 107, pp. 73-84.

[39] Wiseman Y. and Grinberg I., (2016), "When an Inescapable Accident of Autonomous Vehicles is Looming", International Journal of Control and Automation, Vol. 9 No. 6, pp. 297-308.

[40] Wiseman Y. and Grinberg I., (2016), "Autonomous Vehicles Should Not Collide Carelessly", Advanced Science and Technology Letters, Vol. 133, pp. 223-228.

[41] Wiseman Y. and Grinberg I., (2016), "Circumspectly Crash of Autonomous Vehicles", Proceedings of IEEE International Conference on Electro Information Technology (EIT 2016), Grand Forks, North Dakota, USA, pp. 382-386.

[42] Y. Wiseman, "Diminution of JPEG Error Effects", The Seventh International Conference on Future Generation Information Technology, Vol. 117, pp. 6-9, (2015).

[43] Y. Wiseman, "Alleviation of JPEG Inaccuracy Appearance", International Journal of Multimedia and Ubiquitous Engineering, Vol. 11(3), pp. 133-142, (2016).

[44] Y. Wiseman, "Enhancement of JPEG compression for GPS images", International Journal of Multimedia and Ubiquitous Engineering, Vol. 10, No. 7, pp. 255-264, (2015).

[45] Y. Wiseman, "Improved JPEG Based GPS Picture Compression", Advanced Science and Technology Letters, (2015).

[46] Y. Wiseman, "The still image lossy compression standard - JPEG", Encyclopedia of Information Science and Technology, Third Edition, Vol. 1, Chapter 28, (2014).

[47] Y. Wiseman, "A Pipeline Chip for Quasi Arithmetic Coding", IEICE Journal - Trans. Fundamentals, Tokyo, Japan, Vol. E84-A No.4, pp. 1034-1041, (2001).

[48] Y. Wiseman, "Burrows-Wheeler Based JPEG", Data Science Journal, Vol. 6, pp. 19-27, (2007).

[49] Y. Wiseman, "Efficient Embedded Images in Portable Document Format (PDF)", International Journal of Advanced Science and Technology, Vol. 124, pp. 129-138, (2019).

[50] Y. Wiseman and E. Fredj, "Contour Extraction of Compressed JPEG Images", ACM - Journal of Graphic Tools, Vol. 6, No. 3, pp. 37-43, (2001).

[51] E. Fredj and Y. Wiseman, "An O(n) Algorithm for Edge Detection in Photos Compressed by JPEG Format", Proc. International Conference on Signal and Image Processing SIP-2001, Honolulu, Hawaii, pp. 304-308, (2001).

[52] Y. Wiseman, "Adjustable and Automatic Flush Toilet", International Journal of Control and Automation, Vol. 13, No. 4, pp. 1-10, (2020).

[53] D. Livshits and Y. Wiseman, "Cache Based Dynamic Memory Management for GPS", Proceedings of IEEE Conference on Industrial Electronics (IEEE ICIT-2011), Auburn, Alabama, pp. 441-446, (2011).

[54] D. Livshits and Y. Wiseman, "The Next Generation GPS Memory Management", International Journal of Vehicle Information and Communication Systems, Vol. 3(1), pp. 58-70, (2013).

[55] R. B. Yehezkael, Y. Wiseman, H. G. Mendelbaum & I. L. Gordin, "Experiments in Separating Computational Algorithm from Program Distribution and Communication", LNCS of Springer Verlag Vol. 1947, pp. 268-278, 2001.

[56] Y. Wiseman, "ARC Based SuperPaging", Operating Systems Review, Vol. 39(2), pp. 74-78, 2005.

[57] Y. Wiseman, "Advanced Non-Distributed Operating Systems Course", ACM - Computer Science Education, Vol. 37(2), pp. 65-69, 2005.

[58] M. Reuven & Y. Wiseman, "Reducing the Thrashing Effect Using Bin Packing", Proc. IASTED Modeling, Simulation, and Optimization Conference, MSO-2005, Oranjestad, Aruba, pp. 5-10, 2005.

[59] M. Reuven & Y. Wiseman, "Medium-Term Scheduler as a Solution for the Thrashing Effect", The Computer Journal, Oxford University Press, Swindon, UK, Vol. 49(3), pp. 297-309, 2006.

[60] Y. Wiseman, "The Relative Efficiency of LZW and LZSS", Data Science Journal, Vol. 6, pp. 1-6, 2007.

[61] Y. Wiseman & I. Gefner, "Conjugation Based Compression for Hebrew Texts", ACM Transactions on Asian Language Information Processing, Vol .6(1), article no. 4, 2007.

[62] I. Grinberg & Y. Wiseman, "Scalable Parallel Collision Detection Simulation", Proc. Signal and Image Processing (SIP-2007), Honolulu, Hawaii, pp. 380-385, 2007.

[63] Y. Wiseman, "ASOSI: Asymmetric Operating System Infrastructure", Proc. 21st Conference on Parallel and Distributed Computing and Communication Systems, (PDCCS 2008), New Orleans, Louisiana, pp. 193-198, 2008.

[64] Y. Wiseman, J. Isaacson & E. Lubovsky, "Eliminating the Threat of Kernel Stack Overflows", Proc. IEEE Conference on Information Reuse and Integration (IEEE IRI-2008), Las Vegas, Nevada, pp. 116-121, 2008.

[65] M. Itshak & Y. Wiseman, "AMSQM: Adaptive Multiple SuperPage Queue Management", Proc. IEEE Conference on Information Reuse and Integration (IEEE IRI-2008), Las Vegas, Nevada, pp. 52-57, 2008.

[66] R. Ben Yehuda & Y. Wiseman, "The Offline Scheduler for Embedded Transportation Systems", Proc. IEEE Conference on Industrial Electronics (IEEE ICIT-2011), Auburn, Alabama, pp. 449-454, 2011.

[67] Y. Wiseman & P. Weisberg, "Economical Memory Management for Avionics Systems", IEEE/AIAA 31st Digital Avionics Systems Conference (DASC), 2013.

[68] Y. Wiseman & Alon Barkai, "Diminishing Flight Data Recorder Size", IEEE/AIAA 31st Digital Avionics Systems Conference (DASC), 2013.

[69] R. Ben Yehuda & Y. Wiseman, "The Offline Scheduler for Embedded Vehicular Systems", International Journal of Vehicle Information and Communication Systems, Vol. 3(1), pp. 44-57, 2013.

[70] Y. Wiseman & Alon Barkai, "Smaller Flight Data Recorders", Journal of Aviation Technology and Engineering, Vol. 2(2), pp. 45-55, 2013.

[71] P. Weisberg & Y. Wiseman, "Efficient Memory Control for Avionics and Embedded Systems", International Journal of Embedded Systems, Vol. 5(4), pp. 225-238, 2013.

[72] Y. Wiseman, "Steganography Based Seaport Security Communication System", Advanced Science and Technology Letters, Vol. 46, pp. 302-306, 2014.

[73] P. Weisberg, Y. Wiseman & J. Isaacson, "Enhancing Transportation System Networks Reliability by Securer Operating System", Open Journal of Information Security and Applications, Vol. 1(1), pp. 24-33, 2014.

[74] Y. Wiseman, "Noise Abatement at Ben-Gurion International Airport", Advanced Science and Technology Letters, Vol. 67, pp. 84-87, 2014.

[75] Y. Wiseman, "Protecting Seaport Communication System by Steganography Based Procedures", International Journal of Security and Its Applications, Sandy Bay, Tasmania, Australia, Vol. 8(4), pp. 25-36, 2014.

[76] Y. Wiseman, "Noise Abatement Solutions for Ben-Gurion International Airport", International Journal of U- & E-Service, Science & Technology, Vol. 7(6), pp. 265-272, 2014.

[77] P. Weisberg & Y. Wiseman, "Virtual Memory Systems Should use Larger Pages", Advanced Science and Technology Letters, Vol. 106, pp. 1-4, 2015.

[78] Y. Wiseman & Y. Giat, "Red Sea and Mediterranean Sea Land Bridge via Eilat", World Review of Intermodal Transportation Research, Vol. 5(4), pp. 353-368, 2015.

[79] Y. Wiseman, "Can Flight Data Recorder Memory Be Stored on the Cloud?", Journal of Aviation Technology and Engineering, Vol. 6(1), 16-24, 2016.

[80] Y. Wiseman & Y. Giat, "Multi-modal passenger security in Israel", Multimodal Security in Passenger and Freight Transportation: Frameworks and Policy Applications, Edward Elgar Publishing Limited, Chapter 16, pp. 246-260, 2016.

[81] Y. Wiseman, "Traffic Light with Inductive Detector Loops and Diverse Time Periods", Contemporary Research Trend of IT Convergence Technology, Vol. 4, pp. 166-170, 2016.

[82] Y. Wiseman, "Unlimited and Protected Memory for Flight Data Recorders", Aircraft Engineering and Aerospace Technology, Vol. 88(6), pp. 866-872, 2016.

[83] Y. Wiseman, "Conceptual Design of Intelligent Traffic Light Controller", International Journal of Control and Automation, Vol. 9(7), pp. 251-262, 2016.

[84] Y. Wiseman, "Compression Scheme for RFID Equipment", Proc. IEEE International Conference on Electro Information Technology (EIT 2016), Grand Forks, North Dakota, USA, pp. 382-386, 2016.

[85] Y. Wiseman, "Efficient RFID Devices", Proc. The 42nd Annual Conference of IEEE Industrial Electronics Society (IECON 2016), Firenze (Florence), Italy, pp. 4762-4766, 2016.

[86] Y. Wiseman and I. Grinberg, "The Trolley Problem Version of Autonomous Vehicles", The Open Transportation Journal, Vol. 12, pp. 105-113, 2018.

[87] Y. Wiseman, "Compaction of RFID Devices using Data Compression", IEEE Journal of Radio Frequency Identification, Vol. 1(3), pp. 202-207, 2018.

[88] Y. Wiseman, "High Occupancy Vehicle Lanes are an Expected Failure", International Journal of Control and Automation, Vol. 12(11), pp. 21-32, 2019.

[89] Y. Wiseman, "Israel Complementary International Airport", International Journal of Control and Automation, Vol. 12(7), pp. 1-10, 2019.

[90] Y. Wiseman, "Adjusted JPEG Quantization Tables in Support of GPS Maps", Journal of Mobile Multimedia, Vol. 17(4), pp. 637-656, 2021.

[91] Y. Wiseman, "Blaumilch Canal on Ayalon Highway", Daaton, 2015, Available online at: http://www.daaton.co.il/Article.aspx?id=3290

[92] Y. Wiseman, "Revisiting the Anti-Lock Braking System", Technical Report, 2021.

[93] Y. Wiseman, "Isolated Territories and Infrastructure development: A case for land transportation investment in Madagascar", Interdisciplinary Approaches to the Future of Africa and Policy Development, IGI Global Publishing, Chapter 5, pp. 78-97, 2022.

[94] Y. Wiseman, J. Isaacson, "Safer Operating System for Vehicle Telematics", technical report, 2010.

[95] Y. Wiseman, J. Isaacson, E. Lubovsky and P. Weisberg, "Kernel Stack Overflows Elimination", Advanced Operating Systems and Kernel Applications: Techniques and Technologies, pp. 1-14, IGI Global, 2010.

[96] Y. Wiseman "Airport in Dothan Valley is Ideal", Technical Report, 2020.

[97] M. Itshak and Y. Wiseman, "Enhancing the Efficiency of Memory Management in a Super-Paging Environment by AMSQM", Advanced Operating Systems and Kernel Applications: Techniques and Technologies, pp. 276-293, IGI Global, 2010.

[98] Y. Wiseman, "Conjoint Reliable Vehicle License Plate Identification System", Technical Report, 2020.

[99] M. Reuven and Y. Wiseman, "Alleviating the Thrashing by Adding Medium-Term Scheduler", Advanced Operating Systems and Kernel Applications: Techniques and Technologies, pp. 118-136, IGI Global, 2010.

[100] Y. Wiseman, "Controlling Dynamic Traffic by Road Expansion Can be Accomplished by Double Decker Roads - Case Study", Technical Report, 2022.

[101] Y. Wiseman, "Rail in Islands is an Expected Failure", Technical Report, 2020.

[102] Y. Wiseman, "Road Planners should not Look Just Right and Left But Rather Should Also Look Up", Technical Report, 2022.

[103] Y. Wiseman "Can a Flight Data Recorder be Situated in a Cloud?", Technical Report, 2016.

[104] Y. Wiseman, "JPEG Quantization Tables for GPS Maps", Automatic Control and Computer Sciences, Vol. 55(6), 2021.

[105] Y. Wiseman, "Intelligent Transportation Systems along with the COVID-19 Guidelines will Significantly Change the Transportation Market", Techical Report, 2021.

[106] Y. Wiseman, "Cracked Pipes Alert System for Autonomous Vehicles", Technical Report, 2017.

[107] Y. Wiseman, "EPC Compression", Technical Report, 2016.

[108] Y. Wiseman, "Warning System for Cracked Pipes in Autonomous Vehicles", Advances of Machine Learning in Clean Energy and Transportation Industry, Chapter 9, pp. 261-276, 2021.

[109] Y. Wiseman, "Madagascar had better invest in a single land transportation infrastructure", Interdisciplinary Approaches to the Future of Africa and Policy Development, IGI Global Publishing, 2021.

[110] Y. Wiseman, "Teaching Research of Operating Systems", Technical Report, 2022.

[111] M. Dreyfuss and Y. Giat, "Optimal spares allocation to an exchangeable-item repair system with tolerable wait", European Journal of Operational Research 261 (2), pp. 584-594, 2017.

[112] Y. Giat, "The effects of output growth on preventive investment policy", American Journal of Operations Research 3 (06), pp. 474-486, 2013.