SHORTEST PAHT ROUTING USING HEURISTIC SEARCH

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ABSTRACT

Shortest Path problems are inevitable in road network applications such as city emergency handling and drive guiding system, in where the optimal routings have to be found. To achieve the best path, there are many algorithms which are more or less effective, depending on the particular case. Efficiency depends not only on the time needed for calculation, but also on the reliability of the result. A* algorithm is able to return the best path (if it exists) between two nodes, according to accessibility/orientation and, of course, cost of arcs. In this project A* algorithm was used, to suggest shortest path model between two selected points to find the fastest and shortest route on Malaysia map. This prototype then guides the users according to their interest and work.

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LIST OF ABBREVIATIONS

BFS	Best First Search
UML	Unified Modeling Language
RAD	Rapid Application Development
KL	Kuala Lumpur

CHAPTER 1

INTRODUCTION

The problem of shortest path is a common problem that arises in many fields, such as robotics, games, or web routing. The problem is for finding a path with minimum travel cost from one or more origins to one or more destinations through a connected network. It is an important issue because of its wide range of applications in transportations. Many of the shortest path algorithms use a heuristic to compute a path on an ad hoc basis. This project will focus on shortest road (basically shortest path) on road network represented as Malaysia map. Following shortest path model presented will find the most economical road. Therefore, the efficiency of the algorithm is very important. For instance, in order to improve the effectiveness of travel information provision, there is a need to provide some rational alternative paths for road users driving in road network, to meet it, A* algorithm use in general.

The literature describes many algorithms for finding the shortest path between two points, one of the earliest solutions proposed was Dijkstra's algorithm first published in (1959). The problem with Dijkstra's algorithm is that it finds the shortest paths to all other nodes in the search space as opposed to finding the shortest path to a single goal node. Dijktra's algorithm always visits the closest unvisited node from the

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REFERENCES

Alber, J., Fernau, H., & Niedermeier, R. (2003), Graph Separators: a Parameterized View, *Journal of Computer and System Sciences* 67, 808–832.

Azaron, A., & Kianfar, F. (2003). Dynamic Shortest Path in Stochastic Dynamic Networks: Ship routing problem, *European Journal of Operational Research* 144, 138–156

Ba˜n os, R., Gil C., Ortega J., & Montoya F.G. (2004), A Parallel Multilevel Metaheuristic for Graph Partitioning, *Journal of Heuristics* 10, 315–336

Bellman, R. (1958). On a Routing Problem, *Quarterly of Applied Mathematics* 16, 87–90

Bertsekas, D. P. (1998). *Network Optimization: Continuous and Discrete Models*, Athena Scientific, Nashua, New Hampshire, United States.

Bollob´as, B., & Scott, A.D. (2004), Judicious Partitions of Bounded-Degree Graphs, *Journal of Graph Theory* 46, 131–143.

Car, A., Mehner, H., & Taylor G. [1999], *Experimenting with Hierarchical Wayfinding*, Technical report 011999, University of Newcastle upon Tyne, Department of Geomatics, Newcastle upon Tyne, United Kingdom.

Chabini, I. (2002). Algorithms for K-Shortest Paths and other Routing Problems in Time Dependent Networks, *Accepted for publication in Transportation Research Part B: Methodological.*

Chan, E. P.F., & Zhang, N. (2001) Finding Shortest Paths in Large Network Systems, in: Walid G. Aref (ed.), *Proceedings of the ninth ACM International Symposium on Advances in Geographic Information Systems*, Atlanta, Georgia, United States, ACM Press, 160–166.

Chen, D. Z., Daescu O., Xiaobo (Sharon) HU., & Jinhui XU. (2003). Finding an Optimal Path without Growing the Tree, *Journal of Algorithms* 49, 13–41

Chen, D. Z., & Xu, J. (2000), Shortest Path Queries in Planar Graphs, *Proceedings of the thirty-second Annual ACM Symposium on Theory of Computing*, Portland, Oregon, United States, ACM Press, 469–478.

Cordone, R., & Maffioli, F. (2004), On the Complexity of Graph Tree Partition Problems, *Discrete Applied Mathematics* 134, 51–65.

Cunha, C. B. DA., & Swait, J. (2000). New Dominance Criteria for the Generalized Permanent Labelling Algorithm for the Shortest Path Problem with Time

Windows on Dense Graphs, *International Transactions in Operational Research* 7, 139–157

Dai, L., & Maheshwari, A. (2005) Fast Shortest Path Algorithm for Road Network and Implementation, HONOURS PROJECT, Carleton University School of Computer Science, COMP 4905Dijkstra, E.W. (1959). A Note on Two Problems in Connexion with Graphs, *Numerische Mathematik* 1, 269–271

Dijkstra, E.W. (1959). A Note on Two Problems in Connexion with Graphs, *Numerische Mathematik* 1, 269–271

Donoso, Y., Fabregat, R., Solano, F., Marzo, J.L., & Baran, B. (2005) GMM-model for Dynamic Multicast Groups using a probabilistic BFS Algorithm. *Proceedings of IEEE IPOM.* (Short Paper). Barcelona 26-28.

Edelkamp, S., Lafuente, A. L., & Leue, S. (2001). Directed Explicit Model Checking with hsf-spin. In *Proceedings of the 2001 SPIN Workshop*, volume 2057 of *Lecture Notes in Computer Science*, pages 57–79

Ertl, G. (1998), Shortest Path Calculation in Large Road Networks, *OR Spektrum* **20**, 15–20.

Faramroze, E. (2001) Fast Shortest Path Algorithms for Large Road Networks, Department of Engineering Science. University of Auckland, New Zealand.

Falkner, Julie, Rendl, F., & Wolkowicz, H. (1994) A Computational Study of Graph Partitioning, *Mathematical Programming* 66, 211–239.

Fern´andez-Madriagl, J.-A., & Gonz´alez J. (2002), Multihierarchical Graph Search, *IEEE Transactions on Pattern Analysis and Machine Intelligence* **24**, 103–113.

Floyd, R. W. (1962), Algorithm 97 Shortest Path, *Communications of the ACM* 5, 345

Ford JR., L.R., & Fulkerson, D.R. (1962). *Flows in Networks*, Princeton University Press, Princeton, New Jersey, United States

Fu, L. (2001). An Adaptive Routing Algorithm for In-Vehicle Route Guidance Systems with Real-Time Information, *Transportation Research Part B: Methodological* 35, 749–765.

Frigioni, D. (1998), Semidynamic Algorithms for Maintaining Single-Source Shortest Path Trees, *Algorithmica* **22**, 250–274.

Gelperin, D. (1977). On the Optimality of A*w, *Artificial Intelligence* 8, 69–76

Ghiani, G., Guerriero, F., Laporte, G., & Musmanno, R (2003). Real-Time Vehicle Routing: Solution Concepts, Algorithms and Parallel Computing Strategies, *European Journal of Operational Research* 151, 1–11

Goldberg, A., Kaplan, H., & Werneck, R. F. (2006). Reach for A*: Efficient Point-To-Point Shortest Path Algorithms. In *Proceedings of the Eighth Workshop on Algorithm Engineering and Experiments (ALENEX06)*. SIAM

Golshani, F., Cortes-Rello E., & Howell, T.H. (1996). Dynamic Route Pplanning with Uncertain Information, *Knowledge-Based Systems* 9, 223–232

Granat, J., & Guerriero, F. (2003). The Interactive Analysis of the Multicriteria Shortest Ppath Problem by the Reference Point Method, *European Journal of Operational Research* 151, 103–118

Gutman, R. (2004). Reach-Based Routing: A New Approach to Shortest Path Algorithms Optimized for Road Networks, *In Proc. 6th International Workshop on Algorithm Engineering and Experiments*, pages 100-111, 2004.

Hart, P. E., Nilsson N. J., & Raphael, B. (1968). A Formal Basis for the Heuristic Determination of Minimum Cost Paths, *IEEE Transactions of Systems Science and Cybernetics* 4, 100–107

Henzinger, M. R., Klein, P., Rao, S., & Subramnian, S. (1997), Faster Shortest-Path Algorithms for Planar Graphs, *Journal of Computer and System Sciences* **55**, 3–23.

Hiraishi, H., Ohwada, H., and Mizoguchi, F. (1999), Intercommunicating Car Navigation System with Dynamic Route Finding, *Proceedings 1999 IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems*, Tokyo, Japan, IEEE, 284–289.

Horn, M. E. T. (2000), Efficient Modeling of Travel in Networks with Timevarying Link Speeds, *Networks* 36, 80–90.

Huang, Y-W., Jing, N., & Rundensteiner, E. A (1996), Path Queries for Transportation Networks: Dynamic Reordering and Sliding Window Paging Techniques, *Proceedings of the fourth ACM Workshop on Advances in Geographic Information Systems*, Rockville, Maryland, United States, ACM Press, 9–16.

Huang, Y-W., Jing, N., & Rundensteiner, E. A (1997) A Hierarchical Path View Model for Path Finding in Intelligent Transportation Systems, *GeoInformatica* **1**, 125–159.

Huang, Y-W., Jing, N., & Rundensteiner, E. A. (2000), Optimizing Path Query Performance: Graph Clustering Strategies, *Transportation Research Part C: Emerging Technologies* 8, 381–408.

Jung, S., & Pramanik, S. (2002), An Efficient Path Computation Model for Hierarchically Structured Topographical Road Maps, *IEEE Transactions on Knowledge and Data Engineering* **14**, 1029–1046.

Kanai, T., & Suzuki, H. (2000), Approximate Shortest Path on Polyhedral Surface Based on Selective Refinement of the Discrete Graph and its Applications. *In Geometric Modeling and Processing*, pages 241-250

Kim, K., Yoo, S., & Cha, S. K. (1998), A Partitioning Scheme for Hierarchical Path Finding Robust to Link Cost Update, *Proceedings of the 5th World Congress on ITS*, Seoul, Korea.

Kim, Y.-H., & Moon, B.-R. (2004a), Investigation of the Fitness Landscapes in Graph Bipartitioning: An Empirical Study, *Journal of Heuristics* 10, 111–133.

Klein, P. N., & Subramanian, S. (1998), A Fully Dynamic Approximation Scheme for Shortest Paths in Planar Graphs, *Algorithmica* **22**, 235–249.

Krishnan, Rajesh, Ramanathan, R., & Steenstrup, M. (1999) Optimization Algorithms for Large Self-Structuring Networks, *Proceedings of the Conference on Computer Communications (IEEE Infocom)*, New York, New York, United States, 71–78

Lipton, R. J., & Tarjan, R. E. (1979) A Separator Theorem for Planar Graphs, *SIAM Journal on Applied Mathematics* **36**, 177–189.

Luger, G. (2002). Artificial Intelligence: Structures and Strategies for Complex Problem Solving. *Pearson Education Limited, Edinburgh Gate, Harlow, Essex CM20 2JE.*

Mandow, L., & Cruz J.L. (2003). Multicriteria Heuristic Search, *European Journal of Operational Research* 150, 253–280

Meyer, U. (2001). Single-Source Shortest-Paths on Arbitrary Directed Graphs in Linear Average-Case Time, *Proceedings of the twelfth Annual ACM-SIAM Symposium on Discrete Algorithms*, Washington, District of Columbia, United States, Society for Industrial and Applied Mathematics, 797–806

Meyer, U. (2002). Buckets Strike Back: Improved Parallel Shortest-Paths, *Proceedings of the 16th International Parallel and Distributed Processing Symposium,* IEEE Computer Society, Fort Lauderdale, Florida, United States

Meyer, U., & Sanders, P. (2003), Δ-Stepping: a Parallelizable Shortest Path Algorithm, *Journal of Algorithms* **49**, 114–152.

Montemanni, R., & Gambardella, L.M. (2004). An Exact Algorithm for the Robust Shortest Path Problem with Interval Data, *Computers & Operations Research* 31, 1667–1680

Narv´a ez, P., SIU, K.-Y., & Tzeng, H.-Y. (2001) New Dynamic SPT Algorithm Based on a Ball-and-String Model. *IEEE/ACM Transactions on Networking* **9**, 706–718.

Orda, A., & Rom, R. (1996), Distributed Shortest-Path Protocols for Time-Dependent Networks, *Distributed Computing* 10, 49–62.

Pape, U. (1974). Implementation and Efficiency of Moore-Algorithms for the Shortest Route Problem, *Mathematical Programming* 7, 212–222

Pearl, J. (1984). Heuristics: Intelligent Search Strategies for Computer Problem Solving. Addison-Wesley, Reading, Massachusetts, United States

Pettie, S. (2002), A Faster all-Pairs Shortest Path Algorithm for Real-Weighted Sparse Graphs, *Proceedings of the 29th International Colloquium on Automata, Languages and Programming*, Lecture Notes in Computer Science 2380, 85– 97.

Russell, & Norvig, P., 1995, *"Artificial Intelligence – A modern approach"*, Best First Search, 94-97

Russell, S., & Norvig, P., 1995, *"Artificial Intelligence – A modern approach"*, 97–101

Schmid, W. (2000), *Berechnung K¨urzester Wege in Straßennetzen mit Wegeverboten*, Dissertation, Universit¨at Stuttgart, Stuttgart, Germany.

Schulz, F., Wagner, D, & Weihe, K. (2000). Dijkstra's Algorithm On-Line: An Empirical Case Study from Public Railroad Transport. *J. Experimental Algorithmics*, 5(12)

Shekhar, S., Fetterer, A., & Goyal, B. (1997), Materialization Trade-offs in Hierarchical Shortest Path Algorithms, *Proceedings of the 5th International Symposium on Large Spatial Databases*, Lecture Notes in Computer Science 1262, Berlin, Germany, Springer-Verlag, 94–111.

Szeider, S. (2003), Finding Paths in Graphs Avoiding Forbidden Transitions, *Discrete Applied Mathematics* **126**, 261–273.

Tanimoto, S. (1995) The Elements of Artificial Intelligence Using Common Lisp, *2nd Edition. Computer Science Press, New York, New York.*

Thorup, M. (1997). Undirected Single Source Shortest Paths in Linear Time, *38th Annual Symposium on Foundations of Computer Science*, Miami Beach, Florida, United States, IEEE, 12–21

Vaishnavi, V. & Kuechler, W. (2004/5). "Design Research in Information Systems", last updated January 18, 2006. URL:http://www.isworld.org/Researchdesign/drisISworld.htm Authors e-mail: vvaishna@gsu.edu kuechler@unr.edu

Wang, J., & Kaempke, T. (2004). Shortest Route Computation in Distributed Systems, *Computers & Operations Research* 31, 1621–1633

Wagner, D., & Willhalm, T. (2003), Geometric Speed-Up Techniques for Finding Shortest Paths in Large Sparse Graphs. In *Proc. 11th European Symposium on Algorithms (ESA)*, volume 2832 of *LNCS*, pages 776-787

Winter, S. (2002), Modeling Costs of Turns in Route Planning, *GeoInformatica* **6**, 345–361.

Yang, CH. (1998). *Prioritized Model Checking*. PhD thesis, Stanford University