Undergraduate Thesis Prospectus

Machine Learning and Compilers: A Survey of ML Techniques for Enhancing Optimizing Compilers

(technical research project in Computer Science)

The Convenience of Pollution: The Struggle over Gasoline-Powered Leaf Blowers in the United States

(sociotechnical research project)

by

Ryan Steele

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Ryan Steele

Technical advisor:	Briana Morrison, Department of Computer Science
STS advisor:	Peter Norton, Department of Engineering and Society

General Research Problem

How can energy use be reduced in the United States?

In 2021, the United States consumed around 12.16 quadrillion BTUs of energy (EIA, 2022), roughly equivalent to the energy content of 600 million tons of coal (EIA, 2021). Given that only about 12% of this energy came from renewable sources (EIA, 2022), much of this energy use contributed significantly to U.S. greenhouse gas emissions. According to NASA (2022), global climate change due to human greenhouse gas emissions is already negatively impacting the environment, with the effects seemingly irreversible. However, the worst of these effects can probably be mitigated by reducing emissions (NASA, 2022). Success will require a combination of efficiency gains in energy use, further development of renewable energy sources, incentives and other regulatory innovations, and behavior change.

Machine Learning and Compilers: A Survey of ML Techniques for Enhancing Optimizing Compilers

How may machine learning techniques be used to increase the efficiency and practical efficacy of optimizing compilers?

This project will be completed solo as part of the CS4991 seminar under technical advisor Professor Briana Morrison with technical writing instruction provided by Professor Rosanne Vrugtman, both of whom are members of the Computer Science Department.

Optimizing compilers are critical to modern software solutions, as they allow program code written at high levels of abstraction to be automatically transformed into well-performing native machine code. However, this optimization process is inherently uncertain, because the

outcome depends upon the choice and ordering of optimizations in non-obvious ways (Kulkarni et. al., 2006). In practice, modern compilers typically don't try to perform an exhaustive search over the possible optimization parameters due to how computationally expensive this would be, instead opting to use heuristics to determine when optimizations are likely to be helpful (Haj-Ali, 2021; Stephenson et. al., 2003). These heuristics are traditionally designed manually, requiring a significant amount of time and human effort for each target architecture, while also being likely too simple to provide near-optimal solutions (Haj-Ali, 2021; Stephenson et. al., 2003).

One compiler optimization technique known as iterative compilation, which does perform a search over the compilation parameters, has been shown to demonstrate an average program performance increase of 35% over traditional compilation methods (Kisuki et. al., 2000). Unfortunately, methods such as iterative compilation also considerably increase compilation times (Kisuki et. al., 2000). This seems to indicate that traditional heuristics-based compilation methods have room for improvement where program efficiency is concerned.

Given the size of the search space presented by the often large number of available optimization passes and possible orderings, machine learning (ML) techniques may have applications for increasing the practical efficacy of optimizing compilers by providing a means by which to estimate which optimizations are most likely to be beneficial, given the structure of the input program. Using ML in this way also has the benefit that manually designing heuristics for target architectures may no longer be necessary. Once the ML model has been trained, it provides a way for the compiler to very quickly make a good guess about how best to optimize a general program (Haj-Ali, 2021), thus increasing compiler efficiency when compared to an iterative compiler of comparable performance.

The goal of this project is to provide a review of the state of ML in optimizing compilers while also providing an assessment of the overall viability of these methods. This will be accomplished by performing a meta-study of the topic, in which I will review and attempt to provide a summary of the major papers in the field to create a brief yet reasonably comprehensive overview of current and past techniques. Related works with similar goals to this project include the works of Wang and O'Boyle (2018) and Leather and Cummins (2020). Both of these surveys present in-depth summaries of the research surrounding the use of ML in compilers, while the work of Leather and Cummins (2020) also provides a look at the history and possible future directions of research on the topic.

Although several surveys of the field have already been performed, I expect my review to still be of value. Due to the intended brevity of this project compared to the related works described, my review will be able to provide a more concise and general look at the topic, which may be less intimidating for readers unfamiliar with the topic, and will hopefully provide new researchers an easier way to get started navigating the material. Performing a new review also has the benefit of being able to include more recent works, as the field of ML advances rapidly, in addition to possibly picking up important works missed by previous surveys.

The Convenience of Pollution: The Struggle over Gasoline-Powered Leaf Blowers in the United States

How do advocates and critics of gasoline-powered leaf blowers in the U.S. advance their respective agendas?

Leaf blowers are convenient, but they are also noisy emitters of greenhouse gases. According to market research, North America accounts for 30 percent of the market share for leaf blowers, with demand in residential areas expected to increase (MMR, 2021). Many are gasoline-powered, release high amounts of toxic pollutants (Volckens et al., 2008), and produce excessive noise levels that can cause hearing damage (Haron et al., 2015). Nevertheless, gasoline-powered leaf blowers remain ubiquitous in the United States. How have critics acted to oppose the use of these leaf blowers, and how have supporters responded to justify and normalize their use?

Researchers have studied community responses to unwanted local activities, such as “not in my back yard” (NIMBY) movements opposing certain land use practices (Sénécal & Reyburn, 2006). Others have studied how consumers’ environmental values influence their actions. Thieme et al. (2015) conclude that consumers who pay more for an environmentally friendly product are much more likely to do so to save energy than to reduce environmental impact. Peer pressure also affects consumer energy use, as individual decisions to adopt environmentally friendly options have been shown to increase the likelihood that neighbors will do the same (Wolske et al., 2020).

Participants include organized homeowners who oppose gasoline-powered leaf blowers due to air and noise pollution (Quiet Clean NOVA, 2022), as well as less organized homeowners who support these devices on grounds of personal freedom (Feiner, 2019). Many local “Quiet Clean” advocacy groups have sprung up around the country with the goal of banning or restricting gasoline-powered leaf blowers, such as Quiet Clean Nova, Quiet Clean Seattle, Quiet Clean Winchester, and many more (Quiet Clean NOVA, 2022; Quiet Clean Seattle, 2022; Quiet

Clean Winchester, 2022). These organizations present numerous claims about the disadvantages of gasoline-powered leaf blowers on their websites, such as equating the amount of pollution from running a leaf blower for one hour to driving a car over 1,000 miles (Quiet Clean NOVA, 2022, para. 3). These statements are likely intended to be thought-provoking to the general public in an attempt to raise support for their causes. However, some homeowners resist restrictions on gasoline-powered leaf blowers, considering them to be unfair infringements of their rights (Feiner, 2019). In an anonymized email to Greenburgh, NY, Town Supervisor Paul Feiner, one concerned homeowner wrote that "I believe people should have the right … to care for their own property as they see fit" (Feiner, 2019, para. 3), as well as expressing fears of regulatory creep for related gasoline-powered products like lawn mowers and string trimmers.

Further participants include landscaper workers who consider these leaf blowers essential to daily work (Bishop, 2022), landscaping companies organized under professional associations which claim that electric leaf blowers are weaker and less efficient than gasoline-powered counterparts (NALP, n.d.), and landscaping company owners who oppose or are concerned about the use of gasoline-powered leaf blowers. For example, the National Association of Landscape Professionals (NALP) states in their position statement that "leaf blowers are essential for landscape industry professionals" (NALP, n.d., p. 1), and claims that a ban on gasoline-powered leaf blowers would be "extremely harmful to the landscape industry" (NALP, n.d., p. 1), while also suggesting that electric leaf blowers may be hazardous to operators because of extension cords used near swimming pools (NALP, n.d.). However, some landscape company owners don't agree with the views of these professional associations, such as Steve Antos, owner of Setauket Landscape Design. In a letter discussing his concerns about gasoline-powered leaf blowers,

Antos states that, “gas leaf blowers are overused, misused, and are often unnecessary” (CALC, 2017, para. 1), and claims that reducing their use would, “provide a safer work environment,” and allow, “a more sustainable delivery of services” (CALC, 2017, para. 3).

Lawn equipment manufacturers and the trade associations that represent them protect their financial interests by political lobbying to protect gasoline-powered leaf blowers (Quiet Clean D.C., 2018). During his testimony during a public hearing for a bill intended to phase out two-stroke gasoline-powered leaf blowers in favor of battery-powered alternatives, Daniel Mustico, Vice President of Government & Market Affairs for the Outdoor Power Equipment Institute (OPEI), argued that we should, “recognize and rely on the continuous innovation” (Quiet Clean D.C, 2018, para. 239) of gasoline-powered leaf blowers. Mustico goes on to claim that innovations in gasoline-powered leaf blowers over the past 15 years have resulted in leaf blowers up to 75% quieter, with engine emissions reduced by 90% (Quiet Clean D.C, 2018). As an alternative to legislation restricting gasoline-powered leaf blowers, Mustico recommends “market-based solutions” (Quiet Clean D.C, 2018, para. 245), in which gasoline-powered leaf blowers continue to be used and sold under the assumption that technological advances will eventually make them more sustainable.

References

Bishop, S. (2022, Jan. 9). Landscapers challenge Westport's proposed leaf blower ordinance: 'It just doesn't make sense'. CT Insider. https://www.ctinsider.com/news/article/Landscapers-challenge-Westport-s-proposed-leaf-16759654.php

CALC (2017, Aug. 17). Clean Air Lawn Care. Leaf blowers: a landscaper's testimony. https://cleanairlawncare.com/leaf-blowers-a-landscapers-testimony/

EIA (2021). United States Energy Information Administration. What is the heat content of U.S. coal? https://www.eia.gov/tools/faqs/faq.php?id=72

EIA (2022). United States Energy Information Administration. U.S. energy facts explained. https://www.eia.gov/energyexplained/us-energy-facts/

Feiner, P. (2019, April). This is what many residents have said about leaf blower ban. Town of Greenburgh. http://www.greenburghgov.com/Cit-e-Access/news/index.cfm?mo=1&NID=48630&TID=10

Haj-Ali, A. (2021, Feb.). *Machine learning in compiler optimization*. [Doctoral dissertation, University of California, Berkeley]. http://www2.eecs.berkeley.edu/Pubs/TechRpts/2021/EECS-2021-2.html

Haron, Z., Darus, N., Han, L.M., Jahya, Z., Hamid, M.F., Yahya, K., Lee, Y.L., & Shek, P.N. (2015, Nov. 23). A preliminary study of occupational noise exposure among leaf blower and grass cutter workers in public university. *Journal of Engineering and Technological Sciences, 77(16),* 153-159. https://journals.utm.my/jurnalteknologi/article/view/6412/4224

Kisuki, T., Knijnenburg, P.M.W., O'Boyle, M.F.P., & Wijshoff, H.A.G., (2000). Iterative Compilation in Program Optimization. *Compilers for Parallel Computers*, 35-44. https://liacs.leidenuniv.nl/assets/PDF/TechRep/tr00-03.pdf

Kulkarni, P.A., Whalley, D.B., Tyson, G.S., & Davidson, J.W. (2006). Exhaustive optimization phase order space exploration. *International Symposium on Code Generation and Optimization (CGO'06),* 13-318. https://ieeexplore.ieee.org/document/1611550

Leather, H. & Cummins, C. (2020, Sep.). Machine learning in compilers: past, present and future. *2020 Forum for Specification and Design Languages (FDL),* 1-8. https://ieeexplore.ieee.org/document/9232934

MMR (2021). Maximize Market Research. Leaf blower market: global industry analysis and forecast (2021-2027) by product, fuel type, application, and region. https://www.maximizemarketresearch.com/market-report/global-leaf-blower-market/108959/

NALP (n.d.). National Association of Landscape Professionals. Leaf blowers. https://www.landscapeprofessionals.org/images/NALPFTP/NALP/advocacy/documents/leafblowers%20position%20paper.pdf

NASA (2022). National Aeronautics and Space Administration. The effects of climate change. https://climate.nasa.gov/effects/

Quiet Clean D.C. (2018, July 20). Full transcript of July 2, 2018 hearing, committee of the whole, on leaf blower legislation, Bill 22-234. https://www.quietcleandc.com/testimony/2018/7/19/full-transcript-july-2

Quiet Clean NOVA (2022). Why ban gas-powered leaf blowers? https://quietcleannova.wordpress.com/

Quiet Clean Seattle (2022). https://quietcleanseattle.org/

Quiet Clean Winchester (2022). https://www.quietcleanwinchester.org/

Sénécal, G. & Reyburn, S. (2006). The NIMBY Syndrome and the Health of Communities. *Canadian Journal of Urban Research, 15(2),* 244-263. JSTOR.

Stephenson, M.W., Amarasinghe, S.P., Martin, M., & O'Reilly, U. (2003, June). Meta optimization: improving compiler heuristics with machine learning. *SIGPLAN, 38(5),* 77–90. https://dl.acm.org/doi/10.1145/781131.781141

Thieme, J., Royne, M.B., Jha, S., Levy, M., & McEntee, W.B. (2015). Factors affecting the relationship between environmental concern and behaviors. *Marketing Intelligence & Planning, 33,* 675-690. Web of Science.

Volckens, J., Olson, D.A., & Hays, M.D. (2008, Feb.). Carbonaceous species emitted from handheld two-stroke engines. *Atmospheric Environment, 42,* 1239-1248. Web of Science.

Wang, Z. & O'Boyle, M.F. (2018, May). Machine learning in compiler optimization. *Proceedings of the IEEE, 106(11),* 1879-1901. https://arxiv.org/pdf/1805.03441.pdf

Wolske, K.S., Gillingham, K.T., & Schultz, P.W. (2020, Jan. 27). Peer influence on household energy behaviours. *Nature Energy, 5,* 202-212. Web of Science.