Uncovering the Hidden Contributions of Women and Minorities  
in Real-Time Systems Scheduling Algorithms

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Computer science, like many scientific disciplines, has a diversity problem. A review of the literature shows a heavy predominance of white, male authors (Frachtenberg & Kaner, 2022). While there are signs that diversity is improving in the field, it still has a long way to go (Wang et al., 2021; Wu et al., 2014).

This lack of representation can have a chilling effect on inclusiveness as many people are made to feel like outsiders in the overwhelmingly white male dominated field. This effect was studied by researchers at Stanford University, who discovered obvious signs at recruitment events that women were not welcome which ranged from sexist jokes to a “chest-beating” competition to see which audience member could stump the presenter with the most technical question (Wynn & Correll, 2018). An article in Nature from 2022 reported that “Black and Hispanic people face huge hurdles at technology companies and in computer science education in the United States, with far-reaching consequences for science and all of society” (Galvan & Payne, 2024; Newsome, 2022). This includes signs of racism ranging from components with a “master/slave” relationship and a white hand used as a pointer icon (Daniels, 2015) to large language models that spew racist vitriol (Fuchs, 2018). It can even include life-threatening consequences, such as when an algorithmic tool used in criminal sentencing wrongly labels black defendants as future criminals at nearly twice the rate of white defendants (Chander, 2017).

What we have is a form of the classic chicken vs. egg problem. We need racist and sexist software and algorithms to be corrected, but that requires a level of diversity that seems difficult to obtain in a field riddled with microaggressions that augment the status quo of racist and sexist software and algorithms, leaving underrepresented portions of the population picking other careers or fighting the urge to quit (Newsome, 2022; Wynn & Correll, 2018).

This research paper is an effort to illuminate some of the key contributions to the field of real-time systems scheduling algorithms and related fields that were made by women and minorities.

# The origin of the field

Real-time scheduling systems are crucial in computer science, particularly for embedded systems where calculations must be completed within specific time constraints (Baumgartner & Wah, 1991). These systems are often used in environments where timing is critical, such as self-driving cars, avionics systems, and telecommunications. Loosely defined, a real-time scheduling system is a contract made up of several components – one or more processors, tasks, and jobs. Each task defines one or more periodic jobs that must be completed withing certain constraints and may use one or more processors to do so. Since a single processor (or core of a multi-core processor) can execute only one job at a time, this causes resource contention that is resolved with scheduling algorithms (Baumgartner & Wah, 1991).

The paper widely regarded as the seminal contribution to the field, “Scheduling Algorithms for Multiprogramming in a Hard-Real-Time Environment,” was co-authored by C. L. Liu, a Taiwanese mathematician who worked at MIT (Liu & Layland, 1973; Schmitt, 2020). In that paper, Liu and Layland defined and described several scheduling algorithms that have been cited in thousands of other papers since its publication in 1973.

A real-time scheduling algorithm is like a way of honoring the contract of a real-time system. It provides a way of guaranteeing the periodic and timely completion of calculations, so jobs are completed within the constraints they require. A task will have a period, which is the time between sequential releases of its jobs. Meanwhile, its jobs will have deadlines. If execution of a job is not complete by its deadline, it has failed and is discarded. If that job was required, the entire system collapses into undefined behavior due to a violation of the contract. This is what a good scheduling algorithm seeks to avoid.

Liu and Layland described several types of classical real-time scheduling algorithms:

1. Rate Monotonic Scheduling (RMS): This is a fixed priority scheduling algorithm where the jobs of a task with the shortest period are given the highest priority. It is very simple to implement in hardware and easy to understand (Liu & Layland, 1973).
2. Earliest Deadline First (EDF): This is a dynamic priority scheduling algorithm where the job with the earliest deadline of all the active jobs on the same processor is given the highest priority. Although more complex, it allows for tighter scheduling constraints without violating a contract because the job with the greatest risk of overflowing its deadline is always the one that can preempt other jobs (Kargahi & Movaghar, 2004; Liu & Layland, 1973).
3. Mixed scheduling algorithms: This is a class of scheduling algorithms that combine aspects of both RMS and EDF, which was born of an observation that hardware interrupts – event emitted hardware in response to external stimuli – are incompatible with the notion of dynamic priority scheduling (Liu & Layland, 1973).

These algorithms operate under certain assumptions, such as preemptive scheduling (meaning jobs can be interrupted), known runtimes (the processing time is constant for each job), and no task dependencies (jobs are not delayed based on the state of other tasks) (Liu & Layland, 1973).

From the sturdy footing of this research, scientists, engineers, and programmers have developed incredible technology and other contributions to the field.

# Evolution of Real-Time Systems Scheduling Algorithms

Beyond Liu and Layland paper, several key achievements in real-time systems can be identified. In 1979, meetings about real-time systems led to the formation of the IEEE Real-Time Systems Symposium. Soon after, Andre van Tilbord of the United States Office of Naval Research launched a Real Time Systems Initiative, which was fundamental in funding critical research in the field. This funding made real-time systems that depended on efficient scheduling algorithms possible, like the Global Positioning System (GPS).

When she began her career in 1956, Dr. Gladys B West was the second black woman hired at the naval base in Dahlgren, Virginia, which was known as the Naval Proving Ground at the time (Dyson, 2018). She was hired as a programmer taking part in a study related to the motion of Pluto relative to Neptune. By 1979, she had received a commendation from her department head and became project manager for an altimetry project. While on this project, she and her team led the groundwork for the algorithms and calculations that GPS satellites would use to determine their precise location (Mohdin, 2020; West, 1986).

By 1991, the U.S. Department of Defense (DoD) Software Technology Strategy report called the development of generalized Rate Monotonic Scheduling theory and related technologies a major payoff of DoD-sponsored research due to its ability to predict whether task deadlines will be met long before the costly implementation phase. During that same decade, the United States began launching parts of the International Space Station, which relied upon the real-time systems scheduling algorithms that made schedulability predictions possible (Doyle & Elzey, 1994; *International Space Station - NASA*, 2023).

Andrea J. Goldsmith, an IEEE fellow, co-authored a paper in 2006 that would become the second most cited publication in the field of scheduling algorithms (Omotehinwa, 2022). Her work was integral to the development of multiple-input/multiple-output algorithms that are used in modern WiFi devices and cellphones. This class of scheduling algorithm makes it possible to transmit data at faster speeds than a single transmitter can achieve with greater resiliency due to multiple paths the radio signals can travel (Gesbert et al., 2003).

In 2019, the Special Interest Group on Algorithms and Computation Theory (SIGACT) of the Association for Computing Machinery (ACM) awarded their Distinguished Service Award to Rebecca Wright for promoting diversity in computer science. Her research has widespread implications and she has authored or co-authored nearly a hundred articles. Her work includes research developing privacy-preserving distributed k-Clustering algorithms, which can be used for scheduling in environments where tasks themselves come from untrusted parties and may not be around long enough to see the result. This may sound like an unlikely scenario, but it’s exactly what is needed for self-driving vehicles to be able to coordinate travel time on public roads, among many other things.

# Conclusion

The achievements highlighted in this paper are just the tip of the iceburg. There are countless other contributions, both recognized and unrecognized, that remain to be celebrated. A significant effort must be undertaken to welcome diversity in computer science, which starts with the proactive efforts of people who are already in the field.

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