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RESEARCH ARTICLE

Genetic Algorithms and Repurposed Electronics: Revolutionizing E-Waste Mitigation

Algoritmos genéticos y electrónica reutilizada: Revolucionando la mitigación de residuos electrónicos

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ABSTRACT

The fast pace of technological advancement and consumer demand contribute to an ever-growing accumulation of electronic waste. These devices' improper disposal and inadequate recycling have led to environmental degradation and potential health hazards due to hazardous substances. Moreover, this issue also adds to the depletion of valuable resources. To address the e-waste problem, innovative approaches are crucial. Many solutions attempt to exploit e-waste by having the obsolete devices perform work less substantially than initially designed. This study, in contrast, demonstrates that it is possible to repurpose e-waste electronics for sophisticated jobs. Specifically, the power of CPU boards from outdated tablets was harnessed to execute genetic algorithms. The successful results from the experiments in this study show that it is possible to use outdated devices to perform tasks such as fine-tuning antennas and attitude optimization of aerospace devices. By transforming discarded electronics into valuable resources for specific applications, we can help mitigate the environmental impact and contribute to a more responsible technological ecosystem.

KEYWORDS: genetic algorithm; e-waste; electronic waste; e-waste solution.

RESUMEN

El rápido ritmo de los avances tecnológicos y la demanda de los consumidores contribuyen a una acumulación cada vez mayor de residuos electrónicos. La eliminación incorrecta y el reciclaje inadecuado de estos aparatos han provocado la degradación del medio ambiente y riesgos potenciales para la salud debido a las sustancias peligrosas. Además, este problema contribuye al agotamiento de recursos valiosos. Para abordar el problema de los residuos electrónicos, es crucial adoptar enfoques innovadores. Muchas soluciones intentan explotar los residuos electrónicos haciendo que los dispositivos obsoletos realicen un trabajo menos sustancial que el diseñado inicialmente. Este estudio, por el contrario, demuestra que es posible reutilizar aparatos electrónicos de desecho para realizar trabajos sofisticados. En concreto, se aprovechó la potencia de las placas CPU de tabletas obsoletas para ejecutar algoritmos genéticos. Los resultados satisfactorios de los experimentos de este estudio demuestran que es posible reutilizar dispositivos obsoletos para realizar tareas como el ajuste fino de antenas y la optimización de la actitud de dispositivos aeroespaciales. Al transformar equipo electrónico desechado en recursos valiosos para aplicaciones específicas, podemos ayudar a mitigar el impacto ambiental y contribuir a un ecosistema tecnológico más responsable.

PALABRAS CLAVE: algoritmo genético; residuos electrónicos; residuos electrónicos; solución a los residuos electrónicos.

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I. INTRODUCTION

Electronic waste (e-waste) is a significant global problem due to the escalating volume of discarded electronic devices. In 2019, an estimated 53.6 million metric tons of e-waste was generated worldwide, which is expected to grow [1]. Many electronic devices are not appropriately recycled, so finding e-waste solutions is meaningful and necessary [2].

Traditionally, properly recycling e-waste goes through several steps. The electronic device is first dismantled, and its parts sorted. Hazardous materials, such as batteries, are removed, and the remaining e-waste is shredded. Metals and plastics from the shredded materials are separated for final recycling [3]. One way to improve proper e-waste disposal participation is through better recycling practices. Farjana *et al.* present an IoT and Cloud-based system for e-waste recycling management. They provide information on improving recycling practices using better surveillance of the problem [4].

Repurposing as a means of coping with e-waste is also noteworthy and has been explored in several papers. Kim and Paulos discuss challenges and practices of creative reuse, such as using discarded electronics for creative arts and crafts [5]. Coughlan *et al.* discuss repurposing computer components in various ways, such as creating new thin clients. They correctly point out that the manufacturing process of electronic components is significant and dictates the optimal use of such devices [6]. Repurposing has also been successfully used to provide affordable access to electronic devices, particularly in resource-constrained communities, facilitating digital inclusion to bridge the digital divide [7].

Although there are many creative approaches to achieving reuse, finding a new use for a device once it has reached obsolescence can be challenging. In many approaches, repurposed devices are put into service, performing tasks of more secondary importance than their original design. This paper instead explores using the discarded devices for greater purposes by creating a computational cluster from discarded mainboards. This cluster uses old CPU boards to execute genetic algorithms to solve optimization problems.

A genetic algorithm is an optimization technique inspired by the principles of natural selection. Genetic algorithms are often used to find very close, approximate solutions to complex optimization problems. They consist of components such as selection, crossover, and mutation. Selection favors solutions with the highest fitness [8]. In a genetic algorithm, population is a set with probable solutions that may solve the given problem. A chromosome is one of the possible solutions in the population. A gene is a part of a chromosome [9].

Two specific physics-related optimization challenges are examined for this investigation. The first experiment involves fine-tuning antennas when optimal physical space is unavailable for traditional installations. The second investigation discusses determining the optimal speeds of reaction wheels for maintaining the desired attitude of aerospace devices such as drones.

Successful results were achieved for both experiments. These outcomes offer valuable insights into the potential of repurposed electronics for applications that transcend the device's initial intended use. This work enhances sustainable waste management strategies by examining real-world examples and best practices in repurposing initiatives.

II. METHODOLOGY

Creating the experiment involved several steps, including the construction of the physical system, software setup, and assembling the required data for the genetic algorithm.

A. HARDWARE CONSTRUCTION

The cluster was constructed entirely of repurposed materials and can be seen in Figure 1. The physical specifications of each device are shown in Table 1. For this project, no materials were purchased new. The monitor and keyboard were borrowed from other working systems. The Wi-Fi network hardware was acquired from a store selling used equipment. Even the wood used as the holding rack was left over from other projects.

B. SOFTWARE SETUP

Linux was installed on each device [10]. Once Linux was installed, the standard Python and Fortran programming languages were added. The specific software libraries required for each experiment were installed and modified as necessary. Pyeasyga [11], for the genetic algorithm, and Ray [12], which allows algorithms to be executed in multiple threads and on multiple hardware, were installed next. Pyeasyga was modified to use Ray. Other specific libraries and programs for each experiment were installed—PyBullet [13] and Basilisk [14] for the attitude experiment and the Antenna Scatterers Analysis Program (ASAP) for antennas [12].

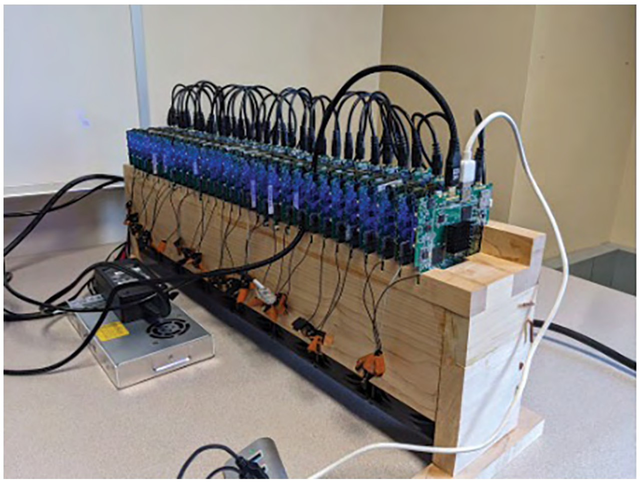

Figure 1. The E-Waste Cluster.

TABLE 1
Soil Classification

Component	Details
Processor Speed	1.4Ghz
Type	Quad-Core Intel Atom
Video	HDMI
Networking	Wi-Fi and Bluetooth
USB Ports	3
Operating System	Linux

C. ANTENNA EXPERIMENT

The goal of the antenna experiment was to achieve a standing wave ratio (SWR) of nearly one, for a random wire antenna [15]. The SWR is a measure of how efficiently radio-frequency power is transmitted [15]. A Python program was written to generate the x, y, and z Cartesian coordinates, which indicate the construction of the antenna in three dimensions. In order to generate the initial population, each x, y, and z value were randomly chosen based on a path. Basically, a first point was chosen, then going left or right and going up or down was randomly selected. The experiment was run at various antenna lengths at various frequencies.

D. ATTITUDE EXPERIMENT

Basilisk: In the first part of the attitude experiment, the Basilisk library was used. The goal of this testing was to minimize the amount of time required for a satellite to become stable. A reaction wheel is a flywheel used by spacecraft to control their attitude by varying the rotational speed [16]. The genes in this experiment were the rotational speeds of the satellite reaction wheels for the x, y, and z axes. For the fitness function, the scenarioAttitudeFeedbackRW.py program, included with Basilisk, returned the simulated time required in seconds for stabilization.

PyBullet: In the second experiment, PyBullet was used. First, a tumbling object was created. Within PyBullet, objects will encounter friction and eventually stop tumbling. This experiment requires the GA to determine the reaction wheel speeds necessary to maintain a desired attitudinal rotation. The reaction wheels are simulated using a simple Python function. The Euclidian distance [17] was used to compare against the desired attitudinal rotation.

III. RESULTS AND DISCUSSION

Since the goal of this paper was to demonstrate the feasibility of repurposed equipment and genetic algorithms, not solving long-standing problems, specific results will not be reported here. However, the genetic algorithm consistently selects antennas optimizing the standing wave ratio (SWR) to be less than 1.5. The genetic algorithm was able to efficiently recommend default reaction wheel speeds to Basilisk. The genetic algorithm was efficiently able to determine wheel speeds to maintain spacecraft attitudinal rotation. Per chromosome time to calculate for Basilisk was ten seconds. For PyBullet, it was two seconds. For ASAP, it was .21 seconds. Overall, the results from the experiments were successful.

IV. CONCLUSIONS

Since the goal of this paper was to demonstrate the feasibility of repurposed equipment and genetic algorithms, not solving long-standing problems, specific results will not be reported here. However, the genetic algorithm consistently selects antennas optimizing the standing wave ratio (SWR) to be less than 1.5. The genetic algorithm was able to efficiently recommend default reaction wheel speeds to Basilisk. The genetic algorithm was efficiently able to determine wheel speeds to maintain spacecraft attitudinal rotation. Per chromosome time to calculate for Basilisk was ten seconds. For PyBullet, it was two seconds. For ASAP, it was .21 seconds. Overall, the results from the experiments were successful.

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