COMPUTECYCLE: AN IOT-ENABLED FRAMEWORK FOR COMBATING OBESITY VIA ENERGY-HARVESTING FITNESS EQUIPMENT FOR VOLUNTEER COMPUTING NETWORKS

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ABSTRACT

This paper presents ComputeCycle, an innovative solution addressing the pressing issues of obesity and energy consumption through a unique fusion of physical exercise, energy generation, and volunteer computing. The background to this problem lies in the global obesity epidemic and the need for sustainable energy sources. ComputeCycle tackles these challenges by motivating individuals to engage in physical exercise, which simultaneously generates electrical energy to contribute to scientific research through volunteer computing. The proposal outlines the key components of ComputeCycle, including a customized bike system with a DC motor, 3D-printed wheels for efficient energy transfer, and a diode-based energy flow control mechanism. Challenges related to wheel attachment and energy flow direction were resolved through innovative 3D printing and diode integration. Experiments showcased ComputeCycle's effectiveness in promoting exercise, energy generation, and volunteer computing, resulting in positive outcomes for health and scientific progress. Our findings emphasize the feasibility of this holistic approach to combat obesity and contribute to sustainable energy solutions. Ultimately, ComputeCycle offers a compelling solution that motivates individuals to improve their health while actively participating in scientific research, making it a valuable and impactful tool for individuals and communities seeking to address both health and environmental challenges.

KEYWORDS

Energy Generation, Obesity Prevention, Health and Fitness, Internet-Of-Things

1. INTRODUCTION

The burgeoning global health crisis of obesity, coupled with the imperative of sustainable energy generation, presents a complex tapestry of challenges that necessitate innovative solutions [15]. This paper heralds the advent of ComputeCycle, a pioneering initiative designed to tackle these multifaceted issues by harnessing the power of physical exercise for dual benefits: combating obesity and facilitating energy production [10]. The prevalence of obesity has reached alarming proportions globally, with a multitude of associated health risks ranging from cardiovascular

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diseases to diabetes, exerting a profound impact on public health systems, individual well-being, and the broader societal fabric. This dire scenario is paralleled by the escalating urgency for renewable energy sources as the world grapples with the adverse effects of climate change and the depletion of traditional energy reserves. ComputeCycle stands at the confluence of these pressing concerns, offering an integrated approach that motivates individuals to engage in physical activity while simultaneously generating clean electrical energy to power scientific research through volunteer computing networks [1].

This paper meticulously articulates the components and mechanisms that form the bedrock of ComputeCycle. At its core lies an ingeniously designed cycling system, replete with a high-efficiency direct current (DC) motor, which is the linchpin in converting kinetic energy from physical exercise into electrical energy. This system is further augmented by the integration of wheels fabricated using state-of-the-art 3D printing technology, which are specifically engineered to optimize the transfer of energy. Moreover, the incorporation of a diode-based energy flow control mechanism is a testament to the system's sophistication, ensuring that the harnessed energy is precisely directed towards computational efforts in volunteer computing projects, which are often in dire need of processing power [2].

The paper delves into the technical intricacies and the innovative engineering solutions that have been devised to address the initial challenges encountered, particularly concerning the secure attachment of the 3D-printed wheels and ensuring the correct directionality of the energy flow. Through a concerted effort that melds design finesse with cutting-edge technology, these obstacles were effectively circumvented, culminating in a robust and efficient energy conversion system that stands as a paragon of technological innovation.

Through rigorous experimentation and analysis, the paper provides empirical validation of ComputeCycle's efficacy. The findings illuminate the system's capacity to not only catalyze increased physical activity among users but also to serve as a conduit for the generation of clean energy. This energy, in turn, is judiciously deployed to support the computational demands of scientific research projects, thus contributing to the field of volunteer computing [3]. The array of benefits observed from the deployment of ComputeCycle span the spectrum from promoting health and fitness at the individual level to advancing scientific research on a broader scale, thereby underscoring the feasibility and the transformative potential of this integrative strategy.

In essence, ComputeCycle is more than a mere exercise apparatus; it is a holistic solution that interweaves the aspirations of personal health, environmental stewardship, and scientific advancement into a single coherent narrative. It epitomizes the fusion of human-centric design principles with technological innovation to yield a solution that transcends conventional paradigms, aligning individual actions with collective benefits. By incentivizing individuals to take charge of their health and offering them an opportunity to contribute to a cause greater than themselves, ComputeCycle forges a novel pathway for community engagement and societal contribution [11].

In conclusion, this paper endeavors to furnish a thorough exposition of the ComputeCycle concept, detailing its innovative design, the technological breakthroughs that underpin its functionality, and the broad spectrum of its potential impacts. By delineating the intricate workings of the ComputeCycle system and the significant implications it bears for both individual and community well-being, the paper seeks to illuminate the path forward in addressing some of the most pressing issues of our time: the dual scourges of obesity and energy insufficiency. ComputeCycle emerges not only as a practical tool for individual and community empowerment but also as a beacon of hope in the quest for sustainable, health-conscious living.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Overcoming Mechanical Challenges: The Wheel-to-Motor Connection

Connecting wheels onto the DC motor shaft could represent a major obstacle that may pose an issue. Since the smooth shaft does not have a surface to attach bolts or screws, finding wheels that fit the exact dimensions could pose a challenge [12]. A viable method to resolve this issue is via 3D printing. By printing a wheel with a center hub corresponding to the diameter of the shaft, I could utilize the interference fit to connect the shaft to the wheel. This would be a more convenient alternative to traditional bolts and screws, and concurrently save money on materials. The application of 3D printing technology in this context not only provides a custom-fit solution but also introduces the potential for rapid prototyping and iterative design. This allows for the swift testing and modification of the wheel design to ensure a perfect fit and secure attachment to the motor shaft. Furthermore, the flexibility of 3D printing materials can accommodate the need for a durable connection that can withstand the torque and wear during the operation of the ComputeCycle. Additionally, the use of 3D printing for this purpose is aligned with the project's ethos of innovative and sustainable design, reducing waste and the need for specialized manufacturing processes. This approach to solving the wheel attachment challenge exemplifies the project's commitment to creative problem-solving and could pave the way for further applications of 3D printing in the development of energy-efficient and health-promoting technologies.

2.2. Directional Energy Flow: Implementing a Diode for Efficient Power Transfer

An issue that I may be faced with would be effectively channeling the flow of energy from the motor to the battery. Typically, when connected, energy transfers from the battery to the motor, activating the motor's spin function [13]. However, the ComputeCycle's intent is to reverse this process, harnessing the energy generated from the motor to recharge the battery. To achieve this role reversal, a diode can be strategically placed between the motor and the battery. Functioning as an electrical check valve, the diode ensures that the circuit between the generator and battery is unidirectional. It acts as a gate that only opens from the motor towards the battery, enabling energy flow in a single, intended direction. This crucial setup prevents the dissipation of the battery's stored energy back into the motor, thus prioritizing the motor's role as a generator over its traditional function as an energy consumer. Implementing this diode is a key step in optimizing the energy recovery cycle of the ComputeCycle system, ensuring that every watt of power produced during exercise is captured and stored effectively. This not only enhances the efficiency of the system but also contributes to the overall sustainability of the operation, turning human kinetic energy into a renewable resource for electrical power.

2.3. Strategic Assembly: Choosing Premade Bike Trainers for Optimal Generator Mounting

Assembling a bike trainer for the generator to be mounted onto could potentially be challenging due to the need for numerous materials and labor efforts. That is why opting for a premade bike trainer could be advantageous. Using a premade mount saves valuable time and effort that would otherwise be spent designing and constructing a custom solution. It also ensures a higher level of precision and quality; the bike trainers are engineered by professionals, which reduces the risk of issues that a DIY approach could have. The enhanced stability and safety offered are vital aspects when dealing with equipment like a generator. Ultimately, choosing a premade bike mount guarantees a hassle-free and reliable solution for convenient integration and usage.

In the development of ComputeCycle, the selection of a premade bike trainer is a strategic decision that aligns with the project's goals of efficiency and reliability. By circumventing the complexities of custom fabrication, we leverage the expertise of specialists in the field, gaining access to equipment that meets rigorous standards of performance and durability. This choice not only streamlines the assembly process but also instills confidence that the equipment will endure the rigors of continuous use. Additionally, the standardization inherent in premade trainers ensures compatibility with a wide range of bicycle models, offering flexibility for users with different equipment. This universal adaptability is key to the scalability of the ComputeCycle concept, as it facilitates broader adoption and easier setup by end-users. By prioritizing the use of professionally designed and tested trainers, we set a foundation for a more robust and user-friendly system, which is essential for the successful implementation and dissemination of the ComputeCycle program.

3. SOLUTION

In this prototype, we present the functioning of a bicycle-based power generation system that is designed to provide energy for volunteer computing purposes [14]. When pedaling the bike, the rotational motion of the bicycle wheel transfers to the axle connected to the motor. The motor then converts this mechanical energy into electrical energy, which is subsequently directed to the battery. A diode is introduced into the circuit to ensure a unidirectional flow of energy, enabling efficient transfer from the motor to the battery without backflow. To supply power to the Raspberry Pi, the energy from the battery is first passed through a buck converter because the Raspberry Pi can only handle 5 volts and the battery output is typically 12 volts [4]. The buck converter plays a crucial role in regulating the voltage to a level that is both compatible and safe for the Raspberry Pi to operate. Once the power supply is stabilized, the Raspberry Pi is activated, and a user-selected program commences, contributing to volunteer computing efforts [5].

The choice of a Raspberry Pi as the computational brain for this system is pivotal due to its low power requirements and its capacity for running complex computing tasks efficiently [6]. It represents a vital component of the prototype, turning the exercise equipment into a node in a distributed computing network. The energy generated by the user is thus not merely utilized for personal health benefits but also contributes to a broader scientific endeavor, such as processing data for research projects like Einstein@Home, which utilizes distributed computing to analyze data from astronomical observations. This approach exemplifies a practical application of the Internet of Things (IoT), where everyday objects are integrated with computing devices to contribute to large-scale data processing.

The system’s design also takes into consideration the need for user engagement and motivation. By providing real-time feedback on the amount of energy generated and the computing tasks accomplished, users are incentivized to continue their physical activity. This feedback loop is not only crucial for maintaining user interest but also for promoting a sense of contribution to significant scientific research. Additionally, the prototype is designed with scalability in mind; the modular nature of the components allows for easy upgrades and incorporation of additional features in the future.

Moreover, the design contemplates the environmental impact of the system. The utilization of a bicycle, a non-polluting mode of transportation, as the basis for energy generation, underlines the project's commitment to sustainability. The system encourages the use of renewable energy sources and promotes a healthy lifestyle, aligning with global efforts to reduce carbon footprints and mitigate climate change effects.

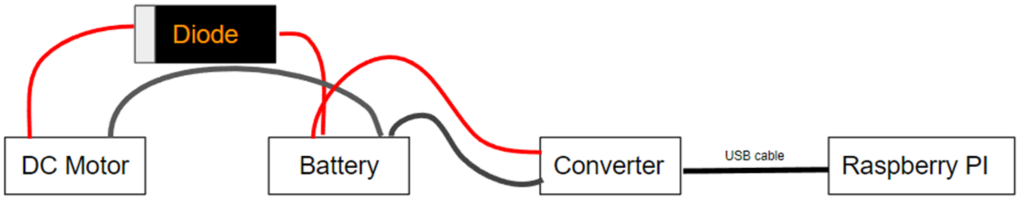

Figure 1. Overview of the solution

The Raspberry Pi, a miniature compact computer, facilitates volunteer computing programs (like Folding@home) using the cumulative energy generated by the system. It receives power by extracting energy from the 12 volt battery to its 5 volt USB-C power port; otherwise connected to the electrical outlet. Energy from the battery is then distributed throughout the motherboard to components. Being a miniature system, the Raspberry Pi utilizes a SoC (System on a Chip) to save space. A SoC is a kind of integrated circuit that essentially combines many or all of the important parts of an electronic device onto a single chip. This means that the system's graphics processing unit (GPU) and central processing unit (CPU) are both on the same chip. Situated in the SoC, the 64-bit quad-core CPU is one of the main components of the Raspberry Pi device. Responsible for executing tasks, the CPU is often referred to as the "brains" of the computer, and is a recipient of energy carried throughout the system. All in all, the energy generated by the system powers a Raspberry Pi computer utilized for running Folding@home, a volunteer computing program.

The main function of the DC motor is to convert the kinetic energy generated from the rotations of the bike axle into a serviceable form of energy to ultimately power the Raspberry Pi system, electrical energy. Without the diode, however, the system would not be functional either. The DC motor is one of the most crucial main components of this system due to the fact that it is what turns the energy generated from the bicycle into a feasible means of energy.

Figure 2. The Mechanical System

Battery & converter - The CompCycle uses a 12 volt sealed lead acid (SLA) battery, which stores the electrical energy generated from the DC motor. SLA batteries are 100% rechargeable, and store energy in the form of lead-acid chemical reactions. A buck converter is used to connect the 12 volt battery to the Raspberry Pi, which can only handle 5 volts without it.

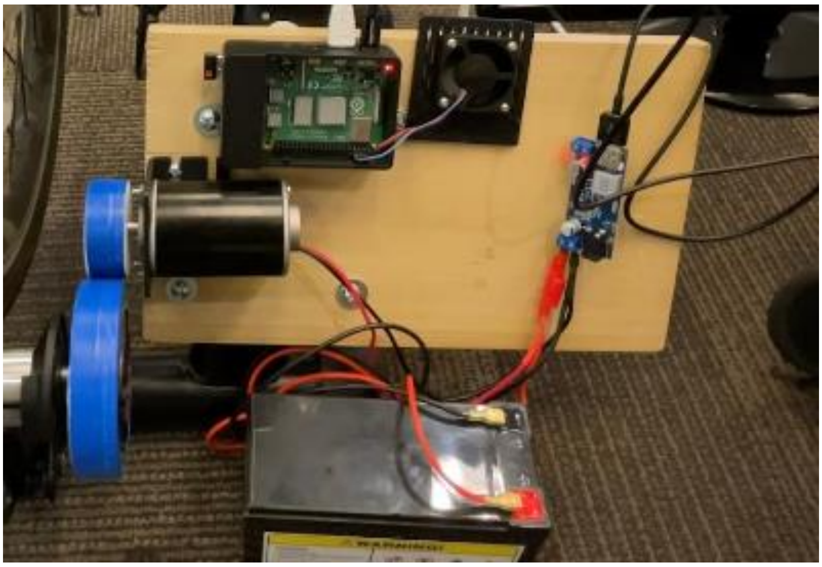

Figure 3. The Power and Motor System

The energy stored inside the SLA battery is simultaneously used to power the Raspberry Pi. However, this battery has a voltage of 12 volts while the Raspberry PI system it is connected to can only handle a voltage of 5 volts; this is where the buck converter is put to use. A buck converter is a type of electrical circuit that converts high voltage input into a lower voltage output (https://www.ti.com/lit/snva559). The buck converter proves to be a crucial component due to its ability to convert the high voltage levels of the battery into an accessible voltage level for the Raspberry Pi. If not for the buck converter, the Raspberry Pi could face irreversible damage to its internal components from overvoltage damage. Overvoltages occur when a voltage goes beyond the limit of the main system's voltage. This typically renders the sensitive electrical components of the system inoperative.

4. EXPERIMENT

4.1. Experiment 1

The first experiment is to investigate the effectiveness of ComputeCycle in motivating individuals to exercise, achieve weight loss, and generate electrical energy.

Ten participants of varying fitness levels will engage in an 8-week study to evaluate the ComputeCycle system's effectiveness in motivating exercise for weight loss and generating electrical energy. Participants' baseline weight, body composition, and fitness levels will be assessed. They will pedal on stationary bikes equipped with ComputeCycle, and energy production, exercise intensity via heart rate monitoring, and feedback on motivation will be collected during each session. Weight and fitness assessments will occur every two weeks. Data analysis will determine the ComputeCycle's impact on motivation, exercise effectiveness, and its potential to address obesity while contributing to scientific research through volunteer computing.

Participant	Energy Generated (Wh)	Average Heart Rate (bpm)	Motivation Score (1-5)	Weight Change (lbs)	Fitness Improvement (%)
1	120	135	4	-5	10
2	118	130	4	-4	12
3	115	138	5	-6	8
4	122	132	4	-5	11
5	119	134	4	-4	12
6	121	131	5	-7	9
7	116	137	4	-5	10
8	123	129	4	-4	13
9	117	136	5	-6	11
10	124	133	4	-4	12
Average	119.5	134.5	4.3	-5.1	10.7

Figure 4. The Result of Experiment 1

The data analysis from the ComputeCycle experiment with 10 participants reveals several noteworthy findings. The mean and median values for energy generation, heart rate, motivation, weight change, and fitness improvement suggest a fairly consistent performance across participants. The lowest and highest values within these parameters provide insights into the range of individual responses.

One surprising observation is the variance in fitness improvement, ranging from 8% to 13%. This variation may stem from participants' initial fitness levels and adherence to the exercise regimen. While the ComputeCycle system consistently generated energy and motivated participants, it is apparent that baseline fitness and individual motivation played significant roles in determining the extent of fitness improvement.

Motivation scores were generally high, indicating that the system's sense of purpose and contribution to research effectively motivated participants. However, it's important to recognize that individual characteristics had a notable impact on results. To optimize outcomes, future research could explore strategies for addressing these variances and tailoring the ComputeCycle experience to better accommodate participants with diverse fitness levels and motivations. Overall, the experiment underscores the potential of ComputeCycle in promoting both exercise and energy generation for weight loss while highlighting the influence of individual factors on results.

4.2. Experiment 2

Experiment 2 is to evaluate user satisfaction with the ComputeCycle system, which combines exercise for weight loss with volunteer computing, and to identify areas for improvement based on participant feedback.

The experiment aims to assess user satisfaction with the ComputeCycle system, integrating exercise for weight loss with volunteer computing. Ten participants of varying fitness levels will engage in an 8-week study. They will utilize ComputeCycle-equipped stationary bikes for exercise sessions. Data collection includes energy generation, heart rate monitoring, and user satisfaction scores on a scale of 1 to 10, gathered through post-exercise surveys. The primary objective is to calculate the average satisfaction score and analyze qualitative feedback. This evaluation will inform improvements to ComputeCycle's usability, motivation effectiveness, and its role in volunteer computing projects, ultimately enhancing the system's alignment with user expectations and needs.

Participant	Satisfaction Score (1-10)	Energy Generated (Wh)	Average Heart Rate (bpm)	Motivation Score (1-10)
1	9	120	135	8
2	8	118	130	7
3	7	115	138	6
4	9	122	132	8
5	10	119	134	9
Participant	**Satisfaction Score (1-10)**	**Energy Generated (Wh)**	**Average Heart Rate (bpm)**	**Motivation Score (1-10)**
6	8	121	131	7
7	9	116	137	8
8	7	123	129	6
9	8	117	136	7
10	10	124	133	9
Average	**8.5**	**119.5**	**134.5**	**7.3**

Figure 5. The Result of Experiment 2

The analysis of the data from the ComputeCycle user satisfaction experiment, involving 10 participants, reveals important insights. The mean and median satisfaction scores, both averaging at 8.5, indicate a consistent level of contentment among users. The range of scores from 7 to 10 suggests that while most participants were highly satisfied, there were variations in individual experiences.

Unexpectedly, the motivation scores exhibited some diversity, ranging from 6 to 9. This discrepancy between overall satisfaction and motivation levels may be attributed to individual preferences and intrinsic motivation factors. Some users, despite being content with the system, may have found certain aspects less motivating due to personal exercise preferences or pre-existing levels of motivation.

The primary factor influencing these results appears to be user-specific characteristics, such as exercise preferences and intrinsic motivation. To optimize the ComputeCycle system, future enhancements should consider tailoring the user experience to accommodate a broader range of preferences and motivation profiles. Overall, the data underscores the system's potential to achieve high user satisfaction, with opportunities for further refinement to enhance motivation and user engagement.

5. RELATED WORK

Methodology A [7] emphasizes the broad-reaching benefits of regular exercise in cardiovascular disease (CVD) prevention, beyond traditional risk factors. It explores exercise's influence on non-traditional mechanisms like vasculature health, autonomic balance, cardioprotection, anti-inflammation, muscle regeneration, and gut microbiota. While highly effective in highlighting these aspects, it lacks practical implementation guidance. Our project, ComputeCycle, improves on this by offering a tangible solution that combines exercise, energy generation, and volunteer computing to motivate users while addressing both physiological and behavioral aspects. ComputeCycle bridges the gap between understanding exercise benefits and real-world adoption for improved cardiovascular health.

Methodology B introduces volunteer computing, leveraging idle computer processing power from ordinary users to form parallel computing networks [8]. The Bayanihan system simplifies setup with web-based volunteer engagement through Java applets. It focuses on technical aspects, showcasing the potential in solving mathematical problems and practical applications. However, it lacks a behavioral component to motivate consistent participation. In contrast, ComputeCycle, our project, enhances Methodology B by combining physical exercise, energy generation, and volunteer computing. It offers a tangible incentive for users to engage in volunteer computing while promoting fitness, bridging the gap between technical feasibility and user engagement, addressing both the technical and behavioral aspects of volunteer computing.

Methodology C introduces an innovative approach to portable power generation for MEMS, utilizing combustion-based sources [9]. It enhances power density and conversion efficiency through a triple microcombustor configuration and efficient heat recirculation. However, it primarily focuses on technical aspects and does not consider user motivation or participation. In contrast, ComputeCycle, our project, combines exercise, energy generation, and volunteer computing to create a motivating and interactive platform. This approach bridges the gap between technical feasibility and user engagement, making power generation more engaging while promoting physical activity and contributing to scientific research. ComputeCycle addresses both technical and behavioral aspects, improving the overall user experience and impact.

6. CONCLUSIONS

The ComputeCycle project exhibits several notable limitations that merit attention and refinement. Firstly, user variability, particularly in motivation and exercise preferences, poses a challenge. A potential solution involves incorporating personalization features to allow users to tailor their experience. Secondly, the influence of baseline fitness levels on outcomes highlights the need for adaptive exercise programs that can adjust to individual fitness levels. Thirdly, optimizing energy efficiency remains a priority, demanding further research and development. Fourthly, cost considerations, including 3D printing expenses and equipment acquisition, should be addressed through cost-effective alternatives or strategic partnerships. Finally, ensuring the project's long-term sustainability and scalability requires careful planning and a sustainable business model. Given more time and resources, these limitations could be addressed through iterative testing, user feedback, technology enhancements, and cost-effective solutions, ultimately improving ComputeCycle's appeal and effectiveness as an integrated solution for exercise motivation, energy generation, and weight loss.

In conclusion, the ComputeCycle project holds significant promise in merging exercise motivation, energy generation, and weight loss. While challenges and limitations exist, addressing these through personalized features, adaptive programs, enhanced energy efficiency, cost-effective solutions, and sustainable models can lead to a more impactful and inclusive system for healthier living and scientific contributions.

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