MATHEMATICAL MODELING OF A ROBOTIC BASED VACUUM CLEANING SYSTEM

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ABSTRACT

This research presents some exceedingly challenging problems in a Robot Vacuum Cleaner (RVC) such as the inefficiency of power or energy supply, which deals with the electrical circuit and the problem of it missing some paths or gap while cleaning the room, which is the kinematics of the RVC, they were mathematically modeled. The research work approaches each of the selected problems to be modeled mathematically by first formulating the problem as a mathematical expression in terms of variables, functions and equations. An ODE (Ordinary Differential Equation) was obtained for the electric circuit model and then simulated to obtain a sinusoidal result, while a matrix was acquired for the kinematics and a graph plotted to see its behavior at seventy-two different angles with intervals of 0:5:360 degrees. The system was simulated using MATLAB to study and understand the behavior of the RVC. At the end of the research firstly, it was concluded from the sinusoidal graph obtained for the model of the electrical circuit, that when the Ordinary Differential Equation (ODL) provided is been applied in test running any RVC electrical circuit, there would not be any problem of power failure or battery discharge. Secondly, it was concluded from observation that the graph gotten for the kinematics at the bases of every 5-point interval in 360 degrees beginning with 0, that when the matrix provided is applied in building a robot vacuum cleaner, there would be no missing of some part of the room while executing its duty of cleaning.

Keywords- Robots; RVC; Mathematical modeling; Kinematics; Electrical Circuit; ODE; Matrix

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1.0 INTRODUCTION

The world in which we are, is gradually been overcome by mechanisms with human-like abilities called robots, Bob (2011). To a scientist in robotics, robot is a completely different thing to what people think of when they hear the word. A robot is a special brew of motors, solenoids, wires and assorted electronic odds and ends, a marriage of mechanical and electronic gizmos, Okereke et al (2011). There are various categories and functions of robots in our modern day, which are used in the industries, homes, and schools, under water operations, hospitals, offices and virtually everywhere, Bob (2011). The paper focuses on the RVC (robot vacuum cleaner) categorized under the personal/domestic robot specifically for cleaning the floor.

The RVC is used to clean the floor automatically by the help of a program introduced into it. It is known that household cleaning is a series of repeated and tedious manual task, carried out by thousands of people every day. Hence, in the age of rapid development in science and technologies, how to apply these high-tech achievements to reduce the intensity of labour and improve quality of life is an important issue that should be solved by researchers, Xiao-bo et al (2011).

According to iRobot consumer's affair as at May 2016, several complaints were received by consumers of RVC. Specifically, the complaints pertained to poor navigation (kinematics) and poor power efficiency (electrical circuit) of the RVC. To completely clean a room it can miss cleaning some parts of the room, thereby leaving its users unsatisfied. Here are the two major complaints tendered by the consumer's:

- **Poorly built mapping technics (kinematics):** The autonomous RVC needs an effective cleaning path planning. A path planning can be broken down into two parts: cleaning path planning and return path planning. Effective and complete cleaning path planning has been one of the main investigations of manufacturers in recent years. A design, which is fully adapted to planning an effective mode for completing the cleaning task in an unknown environment, is very necessary. When this is affected, the RVC cannot navigate its way around a room.

- **Poor electric circuit modeling:** An electric circuit is the path provided for the flow of electric current. A poorly built electrical circuit can cause a bridge in the battery. Therefore, a poorly built electric circuit causes most weakness in battery.

The paper focuses its attention to the two specific problems, listed above. There would be no profit in the robot industries when their consumers begin to loss interest in the RVC because of the stated limitations. The implication of the two stated problems above to stakeholders is that, they would no longer want to risk their money for something that is not productive or have such limitations or does not yield profits.

In order to overcome these limitations, this paper suggests a mathematical modeling of the RVC. The method is based on providing an ODE (ordinary differential equation) for the electrical circuit and then a matrix for the kinematics. The research is focused on the fact that performing experiments to understand and solve real-life problem may be risky and expensive. Also, at times, it may not be feasible at all to perform experiments. Mathematical modeling is the only recourse in such situations. It is very inexpensive if we can represent a real problem in terms of appropriate equations and solve them.

Those to benefit from this research are the industrialist in the robotic field and the users. The industrialist would benefit because when the solution provided by this project work is harnessed and implemented it will cause the society to invest their time and money into it. The slope of demand would be on the increase from what we have now to a greater dependability. The users would also benefit in having a more interactive RVC that carry out the cleaning job more accurately in the home. This paper provides a solution to the inefficiency of energy or power supply by controlling the rate of energy or power discharge through the modeling of the electric circuit and its path planning or navigation around the room by modeling its kinematics. In other for our robotic industries to benefit from this research, the solutions provided by this project work are meant for implementation.

2.0 REVIEW OF RELATED LITERATURE

Several researchers had come up with various ways of tackling the limitations of the RVC. This paper reviewed three related paper work, one of the paper work handled the issue of the power efficiency while the two other looks at the navigation planning.

Ying-wen et al (2012) presented an algorithm they seek to improve the kinematics of RVC. According to their study, the system architecture of their design algorithm can be divided into three parts: (1) marking the location of the origin of the coordinates, (2) executing the cleaning task and (3) executing the return charge task. They include in their work that the autonomous RVC has a sensing device to obtain the real-time location of information, calibrate the deviation derivative in the process of its movement and simultaneously mark the obstacle position. Their design especially, uses an adaptive iterative learning algorithm to provide dynamic return path planning to find the best path for the distance between the cleaner current location and origin and for by passing unexpected obstacles immediately. When the return path function is activated, the cleaner records the location and at this time converts the vector coordinates to the grid coordinates. The grid coordinates plan a dynamic return path to the origin from the current location of the cleaner. The distance between two grid points is the radius of the eight directions within the summation of both numerical computation and comparison, which are required to obtain the minimum value and to find the shortest path, as shown in their equation below:

$$Sd = (Xd, Yd)$$

$$Xd = \min(\sum (Xi' + Xi) ; i = 1 - 8)$$

$$Yd = \min(\sum (Yi' + Yi) ; i = 1 - 8)$$

The algorithm computes $\boldsymbol{Sd}$ values and chooses the minimum value, and then as a result the autonomous RVC follows the direction.

Vaussard et al. (2014) conducted research on energy consumption in RVC. According to the researchers, the question of energy efficiency for these kinds of appliances was only considered recently, and only to point out the lack of regulations and standards compared to other home appliances. Therefore, their study proposes to fill in the current gap in the state of the art by studying a sample of the latest domestic robots, with a special focus on the energy efficiency of the overall system. First, they formulate a supporting equation to help in their reasoning around the energetic agent. Their equation was

$$Etotal\overrightarrow{(a)} = \frac{1}{\bar{\cap}\ \text{charger}} \int_0^{Ttask(\overrightarrow{\alpha})} Probot(t, \overrightarrow{\alpha}) d$$

Their methodology was based on some number of assumptions. Not being able to achieve a complete autonomous RVC as they intended, they imply the necessity of embedding some kind of energy harvesting into the mobile robot and/or on a charging station, providing it with energy extracted directly from the surrounding environment. In other words, light, heat, or mechanical work produced by human could act as the primary source of energy. Thus, Vaussard et al. (2012) did not provide a reliable solution, but worked its way through with a number of assumptions.

Again, Hyunsoo and Amarnath (2015) desired to improve the kinematics of a RVC by suggesting a new and effective simulation based optimization (SO) framework for generating an overall schedule and an effective path for each cycle. In the simulation stage, a dust prediction model is generated using absorbed dust data and floor information. This process uses a multi-modal Gaussian mixture model as a basic model. The generated prediction model provides the needed constraints for different mathematical programming models in the optimization stage. They argued that their proposed framework is considered as an efficient scheduling method in terms of minimizing redundant paths while maintaining tolerable dust levels during multi cleaning cycles. Their paper reviews that this process is only possible through the use of home ecosystem. The role of the ecosystem is to let the robot have sufficient information (e.g. size of space and location of walls/obstacles) about the environment. The installed cameras on the walls of the rooms capture the shapes of floor, wall and obstacles, and transmit the information to the main controller. The main controller assimilates the information and transmits it to the RVC wherever it is. Then, the RVC decomposes the target space into several cells and sets up an overall cleaning schedule and the related cycle path for each cell. The formulae for the generated dust probability $G_x(i, j)$ to be transmitted from the main controller to the cleaning robot for generating overall schedule and cleaning path for each cycle is:

$$f_x(i,j) = \frac{1}{2\pi\sigma_i\sigma_j\sqrt{1-\rho^2}} e^{-\frac{1}{2(1-\rho^2)}\left[\frac{(i-\mu_i)}{\sigma_i^2}+\frac{(j-\mu_j)}{\sigma_j^2}-2\rho\frac{(i-\mu_i)(j-\mu_j)}{\sigma_i\sigma_j}\right]}$$

Hyunsoo and Amarnath (2015) provided a solution that would be very tedious and expensive for consumers, because every consumer would have to install cameras on every room the RVC is expected to clean.

3.0 METHODOLOGY

The method used in achieving the desired solutions:

- **System Analysis and Design**

The RVC will have to be operating in a wide variety of environments either conserved or exposed. In order for it to be able to fulfill its objectives of cleaning, interacting with its users and maneuvering in such environments the following criteria are listed after considering vast environments where unmanned ground robots operate.

1. The robot must have good enough stamina to overcome rough terrains and high torque motors to drive it through such areas.
2. The components to use for construction must be reliable, available and reasonably low in price so as to avoid large expenses during and after construction.
3. It must be able to have good power sufficiency either from the battery or circuit construction or design.
4. The robot must be controlled by brain source otherwise known as the microcontroller.
5. It must be able to navigate its way around any given environment.

- **Analysis of the Existing System**

According to Diego (2006), the first Roomba was thirteen inches in diameter and four inches high roughly. The newer generations Roomba's are virtually completely automated. The user only has to place the Roomba on the floor and choose either clean, spot, or max. Based on the information gathered, the analyses of what makes up the present RVC can be divided into five Sections: Shape, Sensors, Batteries, Suction, and Motors.

1. **Shape:** The typical shape of a robotic vacuum cleaner is a disk. The reasons they are disk-shaped is because of mobility. They can maneuver through tight spaces and still clean effectively. When they bump into a wall or piece of furniture, since it is a circle, it can easily turn around and adjust its position and continue cleaning. The major problem with the vacuum being a circle is that it cannot clean the corners of rooms very well.
2. **Sensors:** There are two types of sensors in the RVC;
    - **Dirt sensors:** There are two potential ideas on how the RVC detect the amount of dirt entering the suction. First one is the use of an ultrasonic sensor. Basically there are two sensors mounted on the opposite sides at the dirt entrance and monitor the amount of dirt using a voltmeter circuit.
    - **Obstacle sensors:** The present RVC detect obstacles through a microscopic bumper which can be small and, in any shape, wanted.
3. **Batteries:** The main focus of the battery part of the RVC is to provide enough power to all the components of the robot while lasting long enough to clean an average room without having to recharge.
4. **Suctions:** This is the cleaning system of the vacuum which consists of the brushes in action and the blower power. These components determine how well the dirt is collected.
5. **Motors:** The system needs motors to power the rollers for cleaning and the wheels for motion. In the design, one motor is used to rotate the wheel base and one motor is used to rotate the wheels. The third motor is used to delivery power to the four brushes throughout the system.

- **Problems inherent in the Existing System**

Unfortunately, in a practical setting these RVC underperform. According to Pushkin et al (2005), These RVCs are truly not intelligent devices and can make a lot of assumptions in order to simplify the world around them. For instance, the RVC navigate through their environment in a random fashion. They move forward until they encounter a wall or obstacle, then they make a turn randomly and begin moving forward again until another wall or obstacle is hit. In a simple environment, such as a rectangular room, with very few obstacles this method may be acceptable. However, in the complex environment of the real world, this method proves to be inefficient and ineffective. According to Pushkin et al (2005), reviews of these RVC claim that when these products were used in a real world setting they ended up not vacuuming the whole room.

Obviously, a better system of navigation must be devised for these systems. With all the technology available today, there must be a better, more efficient way to autonomously navigate through a house.

- **Analysis of the Proposed System**

This paper work proposes to:

1. Mathematically model and develop RVC with energy efficiency.
2. To improve the kinematics of a RVC mathematically.

- **Research Design**

According to Ajibola (2009), the modeling process is divided into three; formulation, finding solution and evaluation.

Formulation

The research work will take three steps:

i. **Stating the Question:** an accurate description answers such questions as: how long? Why this? What it means and what it doesn't mean. The questions are not to be vague or complicated. The problem of the RVC drawn from the real life would be done by describing the context of the problem and then stating the problem within the context.

ii. **Identifying Relevant Factors:** Decisions on which quantities and relationship that are important or unimportant for the research question would be made. The unimportant quantities are those that have very little or no effect on the process.

iii. **Mathematical Description:** each important quantity would be represented by suitable mathematical entity e.g. a variable, a function, a geometric figure etc. each relationship would be represented by an equation inequality, or other suitable mathematical assumption.

Finding the Solution

The mathematical formulation would not just give answer directly. An operation has to be carried out, which often involves some calculation, solving an equation, proving a theorem, doing some simulation etc.

Evaluation

The most important question is to decide whether the model is a good one or not i.e. when the obtained results are interpreted physically whether or not the model gives reasonable answers. If a model is not accurate enough, then the source of the shortcomings must be identified. It may happen that there is a need for a new formulation, new mathematical manipulation and hence a new evaluation. Therefore the mathematical modeling can be a cycle of the three modeling. At the end of each formulation in this paper work, evaluations were carried out using MATLAB to check how accurate and reliable the equations are. In modeling the energy efficiency the equations obtained were evaluated using the Simulink in MATLAB to see its behavior. In the process of evaluation a sinusoidal wave was obtained to show the free flow of energy. After modeling the kinematics of the RVC the equation was evaluated through MATLAB to show the pattern of its movement round the room.

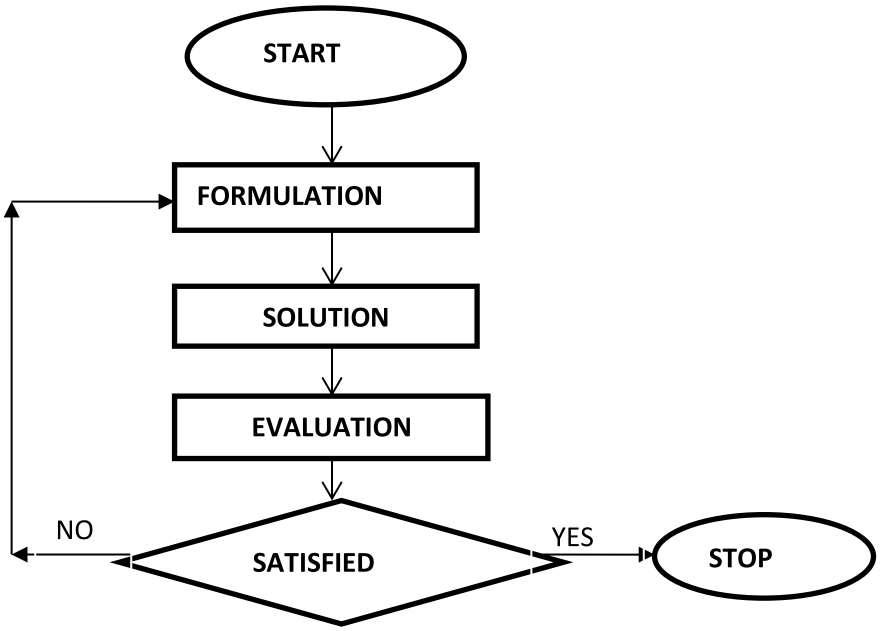

Figure 1: A flow chart for steps to mathematical modeling. Source: ***Ajibola, S. (2009).***

4.0 IMPLEMENTATION, EVALUATION, RESULT AND DISCUSSION

This section deals with the implementation and evaluation of the methodology stated above, to produce the desired result as the solution to the stated problems of the RVC. This section will extend the frontiers of knowledge in the field of robotics through Mathematical modeling. Finally, this section will be wrapped up with the discussion of the results.

Modeling the Electrical Circuit

The potential difference between any two points in an electric field is defined as the work done in moving a positive charge of one coulomb from one point in the field to another. Potential difference is an essential condition for the flow of current in an electric circuit.

$\boldsymbol{V} = \boldsymbol{iR}$ holds between the potential difference across the resistor and current flowing in a pure resistor.

The components for an electric circuit are resistor, inductor and capacitor respectively.

$$Inductor\ of\ inductance = \boldsymbol{L\frac{di}{dt}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn1}$$

$$Potential\ difference\ \boldsymbol{V} = \boldsymbol{iR} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn2}$$

$$Capacitor\ of\ capacitance\ \boldsymbol{V} = \boldsymbol{\frac{q}{c}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn3}$$

Summing up equation 1, 2, 3 and equating it to zero because the switch and wire joining the components have negligible resistance, capacitance and inductance, which makes the total potential difference around the circuit to be zero. We have

$$\boldsymbol{L\frac{di}{dt} + Ri + \frac{q}{c} = 0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn4}$$

For the final differential equation where the dependent variables are $\boldsymbol{i}$ and $\boldsymbol{q}$, there are two possible ways

a) Eliminate $\boldsymbol{q}$ since $\boldsymbol{q = it}$

$$\boldsymbol{L\frac{di}{dt} + Ri + \frac{1}{c}\int i\ dt = 0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn5}$$

b) Eliminate $\boldsymbol{i}$ since $\boldsymbol{i = \frac{dq}{dt}}$ (the principle of conservation of charge)

$$\boldsymbol{L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{c}q = 0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn6}$$

Otherwise, the equation can be differentiated w.r.t.t

$$\boldsymbol{L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{c}i = 0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eqn7}$$

Evaluation

Let an RLC-circuit with 5Ω (ohms resistor), $3.5H$ (inductor), $3F$ (capacitor) and $50Hz$ be introduced into the RVC then a simple model was created using simulink MATLAB.

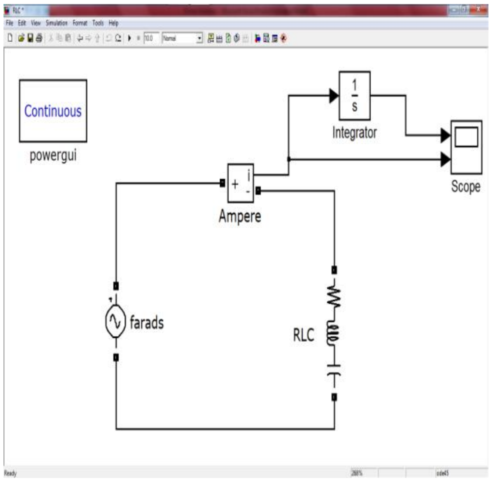

Figure 2. A simple model of RLC. *Author.*

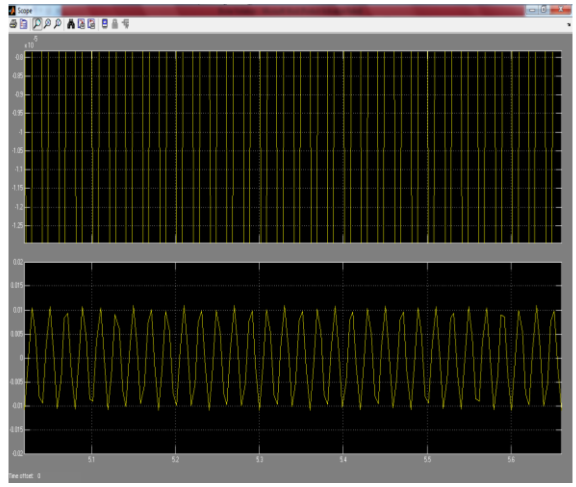

Figure 3. The behavior of the system after simulation.

Modeling the Kinematics

Kinematics deals with the geometric relationship that governs the RVC, which is the relationship between the RVC and the room. In order to locate the position of the RVC in a plane, it is customary to draw two lines intersecting at an origin O and perpendicular to each other.

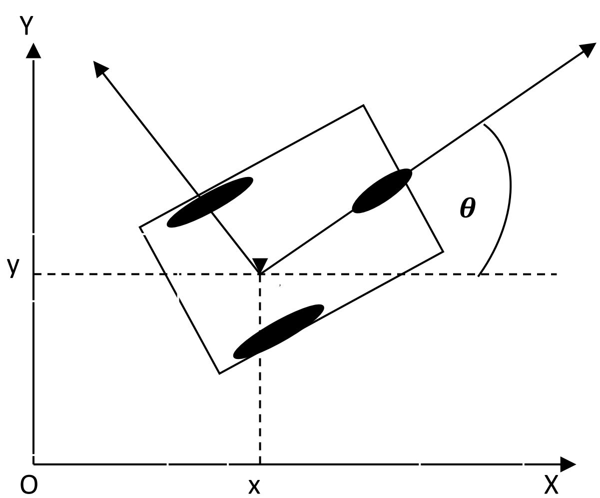

Figure 3: Position of the RVC

The relationship between the co-ordinates of RVC in the Oxy room and $Ox'y'$ room; it gives the trigonometry

$X = r\cos\alpha,$

$Y = r\sin\alpha$ (Where $\boldsymbol{\alpha}$ the angle of the initial position of the RVC and $\boldsymbol{\theta}$ is the angle of the final position). And

$X' = r\cos(\alpha - \theta), \quad Y' = r\sin(\alpha - \theta),$

Expanding the expression gives us

$X' = r\cos\alpha\cos\theta + r\sin\alpha\sin\theta = x\cos\theta + y\sin\theta$

$Y' = r\sin\alpha\cos\theta - r\cos\alpha\sin\theta = y\cos\theta - x\sin\theta$

Putting X' and Y' equations in a matrix

$A = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}; \quad X = \begin{bmatrix} x \\ y \end{bmatrix}; \quad X' = \begin{bmatrix} x' \\ y' \end{bmatrix}$

The matrix becomes

$X' = Ax$

Therefore, we have; $\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$

Evaluation

With interval 0:5:360 degrees, a square robot with corners $\begin{bmatrix} 1 \\ 1 \end{bmatrix}, \begin{bmatrix} 1 \\ 2 \end{bmatrix}, \begin{bmatrix} 2 \\ 2 \end{bmatrix}, and \begin{bmatrix} 2 \\ 1 \end{bmatrix}$ is mapped onto a room to see if it could successfully clean a room without missing a part of the room.

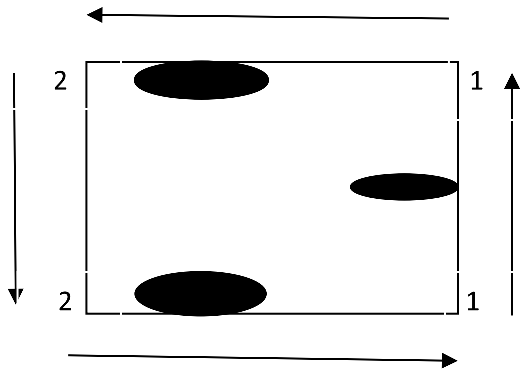

Figure 5: A square RVC

Computing the values with the formula $X' = Ax$ in MATLAB. The result is shown below

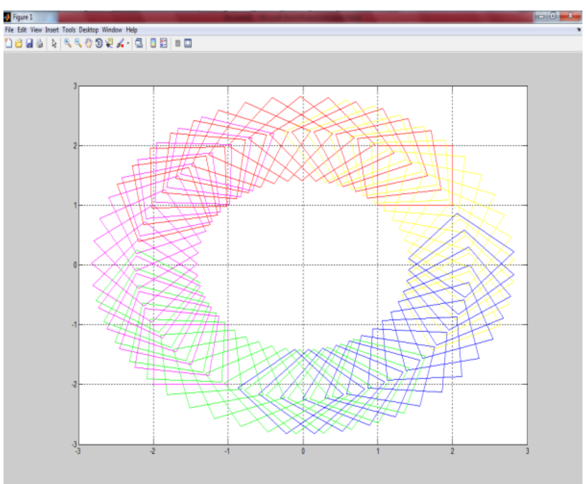

Figure 6: the graph shows the position of the RVC.

Result

An ODE (ordinary differential equation) was derived for the electric circuit model and then simulated to obtain a sinusoidal result, while a matrix was obtained for the kinematics and a graph plotted to see its behavior at seventy two different angles with intervals of 0:5:360 degrees.

Therefore the **ODE** result obtained for the model of the electrical circuit of the RVC is as follows:

- $L\frac{di}{dt} + Ri + \frac{1}{C}\int i\ dt = 0$
- $L\ \frac{d^2i}{dt^2} + R\ \frac{di}{dt} + \frac{1}{C}i = 0$
- $L\ \frac{d^2q}{dt^2} + R\ \frac{dq}{dt} + \frac{1}{c}q = 0$

The **Matrix** result obtained for the model of the kinematics of the RVC is

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

The result has its matrix format as $X' = Ax$

Therefore, the results obtained do not show any relationship with any author.

The outputs of the result for the electrical circuit are as follows:

i. The RVC has free flow of current
ii. The issue of overheating is corrected
iii. The issue of battery drainage is corrected
iv. The formula can detect any electrical fault or wrong connection.

The outputs of the results for the kinematics are as follows:

i. The RVC no longer misses any part of the room while executing its duty
ii. The RVC has a proper path plan, since the solution was based on coordinates
iii. The RVC can navigate to any degree
iv. The RVC can operate in both a simple and a complex room setting.

Discussion

This section focuses on the discussion in comparison to the reviewed works.

1. **Modeling the electrical circuit:** This was a different approach from that of Vaussard et al (2012) on the lessons learned from the RVC entering in the home ecosystem. Different approach in the sense that they tackled the issue of energy or power deficiency which also causes the RVC to miss some parts while cleaning the room through the battery, while this paper work tackled it from the electrical circuit. Solving the problem from the electrical circuit is more reliable than from the battery because, if it is resolved only from the battery

and the electrical circuit is wrong, it would lead to overheating, frequently discharge of energy and eventually damage the battery. On the other hand, if it is tackled from the electrical circuit, a battery which is faulty would be spotted. Thus, this paper work provides a more suitable approach to energy efficiency so that there would be enough and constant energy flow for the RVC in performing its task without stopping until it's done cleaning.

In modeling the electrical circuit, an ODE (ordinary differential equation) was gotten and simulated to provide a sinusoidal result that shows a continual flow of current. The sine wave or sinusoidal describes a smooth repetitive oscillation of current flow. This is a simple way of describing the solution to poor power efficiency in an electronic like the RVC. Sine wave is important to an electronic scientist because of its purity; it alternates regularly above and below its mid value at a constant rate. Complex periodic waves that are made of series of pure sine waves are not the best, because of its complication. It is much easier to use single sine waves, because the result obtained are the major source of information in understanding the operation of the RVC. Moreover, this paper work had produced a solution.

2. **Modeling the kinematics:** Interestingly, this study agrees with Ying-wen et al (2012) on the fact that improper navigation technique is also a cause of the RVC missing some part while cleaning. They approached the problem by using an adaptive iterative learning algorithm while this paper work approached the problem by using a simple matrix. Also, this study does not totally agree with Hyunsoo and Amarnath (2015), because the solution they produced using home ecosystem is too complicated and expensive. So many things might go wrong with their theory for instance, if one of the cameras is bad or the home ecosystem base is faulty, then troubleshooting will be complicated and there will be no cleaning for that day. With the different approach there seems to be some sorts of results. The use of matrix solution would be more appreciated because it is unambiguous, and can be applied in both a simple and complex room setting. Ying-wen et al (2012) team only narrated how the RVC could navigate from the starting point (charging base) to the finishing point and then back to its starting point (charging base) using algorithm without the angles, because some room setting are very complex with various angles. That means, even if it could navigate through the room there are areas it cannot touch and there are

some significant probability that it can still miss some path. This paper work provides a matrix solution that when applied has the ability to take any degree.

In modeling the kinematics of the RVC, an equation in the form of $X' = Ax$ was obtained. After some computations, using an analysis of a square RVC in a space (this space acts as a room, whether complex or simple room) using MATLAB and a graph was plotted representing the operation. This graph shows the RVC plotted on 72 different angles (0:5:360). It was observed that the RVC could navigate its way around the room on any angle of degree it takes. The graphs above show the geometrical positions of the RVC at any given angle to perform its duty in cleaning the room. A careful observation of the graph above shows that there was no space left between each angle. Which means that, if this simple equation in a matrix form is applied in the industrial world of RVC, the issues of misalignment, missing some part as it does its work and its inability to find its path to the charging base would be solved.

5.0 CONCLUSION

This research work presented a mathematical modeling of a robotic based system for cleaning a room. Specifically, it narrowed down to Robot Vacuum Cleaner (RVC), a class of personal/domestic robot used for cleaning the floor of a room. Precisely, two of the problems bothering on electricity consumption and kinematic of effective cleaning were addressed in this study through mathematical model. Subsequently, the results obtained for the tricycle like RVC could be used in an effective cleaning of both simple and complex room settings and environment. Thus, the study showed improvement over existing system with potential to reduce the complaint of users and increasing its value demand in the market.

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