Dynamical analysis of ant colony's collective decision making to explore food from two different resources

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Abstract

A social insect-like Ant lives in a colony. Their collective behavior of food recruitment is a universal character. The mathematical model of the food recruitment of the ant colonies meets different challenges in resolving the nonlinearity due to choosing various food exploration contests between the ants and different environmental parameters. This study possesses several leading parameters to overcome the complexity of the model. Besides, the ants are exploring food sources in diverse trails with the intensity of a chemical substance of pheromone concentration also develops nonlinearity. For generality, this study evaluates two food sources of the ant colony's collective responses concerning environmental conditions without varying the ant's behaviors. The investigation of the ant's food quest in this work concentrates on the dynamical analysis of their food exploration from two different resources described by two ordinary nonlinear differentials equations (ODE). The mean-field model of ODE connected to their dynamical analysis demonstrates that food recruitment varies according to individual variability, supportive communication, and environmental restrictions establishing are connected to the stable or unstable system of the ODE.

Keywords Ant colony; Dynamical analysis; Equilibrium point; Jacobian matrix; Mean-field model.

Paper type Research paper

1. Introduction

Mathematical modeling is the widely used method for the analysis and future prediction of physical phenomena in science and engineering (Afshari & Hajimir, 2005; Hafez, Roy, Talukder, & Hossain Ali, 2016; Uddin, Hafez, & Iqbal, 2022; Iqbal, Hafez, & Abdul Karim, 2020). Moreover, modeling is a robust method in many other branches of real-world problems. The dynamical analysis (Iqbal, Hafez, Chu, & Park, 2022; Sheikht et al., 2020) initiates the physical model's investigation and forecasting to formulate the portrayed system's mathematical model. Subsequently, it is well defined that dynamical analysis is a mathematical procedure for predicting and
understanding the general physical phenomena (Iqbal, Hafez, & Uddin, 2022; Iqbal, 2021; Ali, Yilmazer, Yokus, & Bulut, 2020) concerning their previous state corresponded with the governing evaluation rules. Moreover, engineering, chemical, economic, biological, and even social problems can be predicted by understanding their stability and instability investigation by applying dynamical analysis (Marquié, Bilbault, & Remoissenet, 1995).

The dynamical model is classified into two types: a time-dependent system and the time-independent system. This study focuses on the time-independent(nonautonomous) dynamical analysis of the ant colony’s food exploration from the two food sources. This work accentuates how collective decision-making leading to two different resources of food exploration strategies may arise for the ant colony, especially Lasius niger (Black Garden ant) (Detrain & Prieur, 2014). Black garden Ant is found all over Europe, North America, and Asia. Without a brain, a genetically preprogrammed Ant colony employs complex, collective behavior to explore food by accessing minimal information (Pino et al., 1985; Dussutour & Nicolis, 2013). Ants communicate with each other using pheromones, sounds, and touch. The pheromone (secreted or excreted chemical factor that triggers a social response in members of the same species) approaches to exploring food. Most of the ants live on the ground. They use the soil surface and leave their pheromone trails which other ants follow. A forager ant quests for trails of food marks to explore food and leave its pheromone on trails on the way to head back with food to the colony; then, other ants reinforce the trail and head back with food to the colony. When the food source is exhausted, no new trails are marked by returning ants, and the scent slowly dissipates. This behavior helps ants deal with changes in their environment (Perna et al., 2012; Baird & Seeley, 1983; Dussutour, Beekman, Nicolis, & Meyer, 2009). For instance, when an obstacle blocks an established path to a food source, the foragers leave the path to explore new routes. If an ant is successful, it leaves a new trail marking the shortest route on its return. More ants follow successful trails, reinforcing better routes and gradually identifying the best path.

Previous work (Baird & Seeley, 1983; Nicolis & Deneubourg, 1999) was focused on amplifying the communications between essential places according to the diverse food sources in various animal societies. For instance, insects and bees are particular kinds of animal society that were studied in many more research works. One of the most rigorous investigations on the food requirements of ants and their process was carried out by Seeley, Camazine, & Sneyd (1991) and Wilson (1962). Their points of
view were largely experimental analyses. This work mainly focuses on the well-established mathematical model of ant colony's food explorations dynamical analysis.

The assembling of this study is organized after the introduction's outset; section 2 describes the mathematical model of the ant colony's food exploration connectively, section 3 illustrates the mathematical analysis, section 4 portrays the results and discussions, and lastly, the conclusion concludes this study.

2. Mathematical model
Figure 2 describes the communal choice of two food sources for the ants from the food source A and B. Generally, the ant colonies compete and confront each other to gather foods from diverse food sources.

![Figure 1](image1.png)

*Figure 1*  
*Lattius niger* (Black Garden ant) (*Ant species*, 2022)

![Figure 2](image2.png)

*Figure 2*  
*Schematic representation of ant's food choice*
In figure 2, $Q$ is the choice between two independent food sources ($A$ and $B$). There are various facts about the circumstances to confine their trails for the multiple food sources. This article highlights the nature of the traffic between the two trails directing to the two food sources and ignores individual and environmental variability. It is ignored direct contact between the individuals and considers individuals’ reactions to their pheromone concentration present in the given trail. The leading variables are pheromone concentrations $\chi_1$ and $\chi_2$ rather than the number of individuals present at a given time on the trails $T_1$ (Left side for food source $A$) and $T_2$ (Left side for food source $B$). The following model equations can capture the pheromone concentration $\chi_1$ and $\chi_2$ between two food sources.

\[
\frac{d\chi_1}{dt} = \Phi q_1 \frac{(k+\chi_1)^\gamma}{(k+\chi_1)^\gamma+(k+\chi_2)^\gamma} - \Gamma \chi_1 \quad (1)
\]

\[
\frac{d\chi_2}{dt} = \Phi q_2 \frac{(k+\chi_2)^\gamma}{(k+\chi_1)^\gamma+(k+\chi_2)^\gamma} - \Gamma \chi_2 \quad (2)
\]

In the equations Eq. (1) and Eq. (2), the first positive term represents the attractiveness of the trail $T_1$ or $T_2$ over the others, and the second negative term represents the disappearance of the pheromone on trial $T_1$ or $T_2$. Table I summarizes the description of the parameters, which are used in Eq. (1), Eq. (2), and the entire article.

**Table 1**

Description of the model parameters.

<table>
<thead>
<tr>
<th>Name of the Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi_1$</td>
<td>Pheromone concentration of in trail $T_1$</td>
</tr>
<tr>
<td>$\chi_2$</td>
<td>Pheromone concentration of in trail $T_2$</td>
</tr>
<tr>
<td>$t$</td>
<td>Time</td>
</tr>
<tr>
<td>$\Phi$</td>
<td>The flux of individuals leaving the nest</td>
</tr>
<tr>
<td>$q_1$</td>
<td>Quantity of the pheromone on the trail $T_1$</td>
</tr>
<tr>
<td>$q_2$</td>
<td>Quantity of the pheromone on the trail $T_2$</td>
</tr>
<tr>
<td>$k$</td>
<td>Concentration threshold</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>Evaporation rate of pheromone</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Measures the sensitivity of the food choice</td>
</tr>
</tbody>
</table>

3. Mathematical analysis

By Scaling the equations Eq. (1) and Eq. (2), one can do by letting $t = \frac{r}{\Gamma}, \chi_1 = \Xi_1 k, \chi_2 = \Xi_2 k$ and $\Phi = \phi k \Gamma$. Then $d\chi_1 = kd\Xi_1, \ dt = \frac{1}{\Gamma}dr$. 

\[
\text{Phase and Vector plot for the two food sources ant colony for the value of the parameters}
\]
By scaling the equations Eq. (1) and Eq. (2), one can do by letting 

\[ \Gamma k \frac{d\xi_1}{d\tau} = \phi k \Gamma q_1 \frac{(1+\xi_1)^\gamma k^\gamma}{((1+\xi_1)^\gamma + (1+\xi_2)^\gamma)k^\gamma} - \Gamma k \xi_1, \]

\[ \Gamma k \frac{d\xi_2}{d\tau} = \phi k \Gamma q_2 \frac{(1+\xi_2)^\gamma k^\gamma}{((1+\xi_1)^\gamma + (1+\xi_2)^\gamma)k^\gamma} - \Gamma k \xi_2, \]

Consequently, to calculate the equilibrium points (fixed points), one can obtain by letting the righthand side of Eq. (3) and Eq. (4) be equal to zero for the steady-state solutions:

\[ \frac{d\xi_1}{d\tau} = \phi q_1 \frac{(1+\xi_1)^\gamma}{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma} = 0, \]

\[ \frac{d\xi_2}{d\tau} = \phi q_2 \frac{(1+\xi_2)^\gamma}{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma} = 0. \]

After generalization the Eq. (5) and Eq. (6),

\[ \frac{(1+\xi_1)^\gamma}{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma} = \xi_1, \]

\[ \frac{(1+\xi_2)^\gamma}{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma} = \xi_2, \]

Consequently,

\[ \frac{q_1(1+\xi_1)^\gamma}{q_2(1+\xi_2)^\gamma} = \frac{\xi_1}{\xi_2}. \]

For instance, one can get from Eq. (7) for \( q_1 = q_2 \) applying the sensitivity condition, \( \gamma = 1 \) develop:

\[ \frac{(1+\xi_1)}{(1+\xi_2)} = \frac{\xi_1}{\xi_2}, \]

\[ \Rightarrow \xi_1 = \xi_2 \]

and \( \gamma = 2 \) create

\[ \frac{(1 + \xi_1)^2}{(1 + \xi_2)^2} = \frac{\xi_1}{\xi_2}, \]

\[ \Rightarrow (\xi_1 - \xi_2)(1 - \xi_1 \xi_2) = 0, \]

\[ \Rightarrow \xi_1 = \xi_2 \text{ or } \xi_1 = \frac{1}{\xi_2}. \]

Subsequently, by choosing the \( \gamma = 2, q_1 = q_2 = q \) then, from Eq. (5) and Eq. (6), one can obtain:

\[ \phi q \left\{ \frac{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma}{(1+\xi_1)^\gamma + (1+\xi_2)^\gamma} \right\} = \xi_1 + \xi_2, \]
Next, by using $E_1 = E_2$ in Eq. (9) develop:

$$E_2 = \frac{\phi q}{2},$$

(11)

$$\Rightarrow \phi q = E_2 + \frac{1}{E_2},$$

$$E_2^2 - \phi q E_2 + 1 = 0,$$

$$E_2 = \frac{\phi q \pm \sqrt{\phi^2 q^2 - 4}}{2}.$$  

(12)

Where $\phi q \leq -2$ and $\phi q \geq 2$.

As a result, the steady-state solutions for $\gamma = 2$, and $q_1 = q_2 = q$ are

$$(E_1, E_2) = \left(\frac{\phi q_1}{2}, \frac{\phi q_1}{2}\right), \text{ and } (E_1, E_2) = \left(\frac{\phi q \pm \sqrt{\phi^2 q^2 - 4}}{2}, \frac{\phi q \pm \sqrt{\phi^2 q^2 - 4}}{2}\right).$$

Figures 3 to Figure 6 illustrate the phase state profiles of Eq. (3) and Eq. (4) for the values $\phi(\tau) = 0.9, q_1 = 1, q_2 = 2$ and $\gamma = 1$. As a result, the fixed points $(E_1(\tau), E_2(\tau)) = (0.353, 1.093), (2.546, -3.293)$ and the Jacobin matrix $\Theta_1$ are calculated from the Eq.(3a) and Eq.(3b),

$$\Theta_1 = \begin{pmatrix}
\frac{0.9}{2 + E_1 + E_2} & \frac{0.9 + 0.9 E_1}{(2 + E_1 + E_2)^2} - 1 & \frac{0.9 + 0.9 E_1}{(2 + E_1 + E_2)^2} \\
\frac{1.8 + 1.8 E_2}{(2 + E_1 + E_2)^2} & \frac{1.8}{2 + E_1 + E_2} - 1 & \frac{1.8 + 1.8 E_2}{(2 + E_1 + E_2)^2} - 1
\end{pmatrix}.$$

At $E_1(\tau) = (0.353, 1.093), E_2(\tau) = (2.546, -3.293)$ the state classifications are in Table II.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase state classification for</strong> $\phi(\tau) = 0.9, q_1 = 1, q_2 = 2$ and $\gamma = 1$.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed points associated with Eigenvalues</th>
<th>Fixed points</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.353, 1.093)</td>
<td>(2.546, -3.293)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eigenvalues $(v_1, v_2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.00000000004361, -0.636283742956387</td>
</tr>
<tr>
<td>-0.636283742956387</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification</th>
<th>Stable</th>
<th>Unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( q_2 )</td>
<td>2</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3

Phase state profile for the two food sources ant colony for the value of the parameters \( \phi(\tau) = 0.9, q_1 = 1, q_2 = 2 \) and \( \gamma = 1 \).

Figure 4

Phase and Vector plot for the two food sources ant colony for the value of the parameters \( \phi(\tau) = 0.9, q_1 = 1, q_2 = 2 \) and \( \gamma = 1 \).

Figure 5

Time series for the two food sources ant colony for the value of the parameters \( \phi(\tau) = 0.9, q_1 = 1, q_2 = 2 \) and \( \gamma = 1 \).
Similarly, Figure 5 to Figure 9 illustrate the phase state profiles of Eq. (3) and Eq. (4) for the values $\phi(\tau) = 0.9, q_1 = 1, q_2 = 1$ and $\gamma = 1$, where the quantity of the pheromone is changed from $q_2 = 2$ to $q_2 = 1$. Consequently, the only fixed point $(\xi_1(\tau), \xi_2(\tau)) = (0.45, 0.45)$, corresponding Jacobian matrix $(\Theta_2)$ and eigenvalues (Table III) are calculated from the Eq.(3a) and Eq.(3b).

$$
\Theta_2 = \begin{pmatrix}
\frac{0.9}{2 + \xi_1 + \xi_2 - (2 + \xi_1 + \xi_2)^2} - 1 & -\frac{0.9 + 0.9\xi_1}{(2 + \xi_1 + \xi_2)^2} \\
\frac{0.9 + 0.9\xi_2}{(2 + \xi_1 + \xi_2)^2} & \frac{0.9}{2 + \xi_1 + \xi_2 - (2 + \xi_1 + \xi_2)^2} - 1
\end{pmatrix}
$$

**Table 3**

<table>
<thead>
<tr>
<th>Fixed points associated with Eigenvalues</th>
<th>Fixed points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues $(v_1, v_2)$</td>
<td>$(0.45, 0.45)$</td>
</tr>
<tr>
<td>Classification</td>
<td>$-0.6896551724, 1$</td>
</tr>
<tr>
<td></td>
<td>Stable</td>
</tr>
</tbody>
</table>
Figure 7
Phase state illustrations for the two food sources ant colony for the value of the parameters $\phi(\tau) = 0.9$, $q_1 = 1, q_2 = 2$ and $\gamma = 1$.

Figure 8
Phase and Vector plot for the two food sources ant colony for the value of the parameters $\phi(\tau) = 0.9$, $q_1 = 1, q_2 = 2$ and $\gamma = 1$.

Figure 9
Normalized vector for the two food sources ant colony for the value of the parameters $\phi(\tau) = 0.9$, $q_1 = 1, q_2 = 2$ and $\gamma = 1$. 
Likewise, Figure 10 to Figure 13 illustrate the phase state profiles of Eq. for the values $\phi(\tau) = 0.9, q_1 = 1, q_2 = 2$ and $\gamma = 1$. Where the quantity of the choice sensitivity is changed from $\gamma = 1$ to $\gamma = 2$. Consequently, the equilibrium points $(x_1(\tau), x_2(\tau)) = \{(0.450, 0.450), (0.450 \pm 0.8930285550i)\}$ Jacobian matrix $(\Theta_3)$ and corresponding eigenvalues (Table IV) are calculated from the Eq.(3a) and Eq.(3b).

$$
\Theta_3 = \begin{pmatrix}
\frac{1.8(1 + x_1)}{(1 + x_1)^2 + (1 + x_2)^2} & \frac{0.9(1 + x_2)(2 + 2x_1)}{((1 + x_2)^2 + (1 + x_2)^2)^2} & \frac{0.9(1 + x_1)^2(2 + 2x_2)}{((1 + x_1)^2 + (1 + x_1)^2)^2}
\end{pmatrix}
$$
Table 4
Phase state classification for $\phi(r) = 0.9, q_1 = 1, q_2 = 1$ and $\gamma = 2$.

<table>
<thead>
<tr>
<th>Fixed points associated with Eigenvalues</th>
<th>Fixed points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues $(v_1, v_2)$</td>
<td>$(0.450, 0.450)$</td>
</tr>
<tr>
<td>Classification</td>
<td>Stable</td>
</tr>
</tbody>
</table>

Figure 12
Phase plot for the two food sources ant colony for the value of the parameters $\phi(r) = 0.9, q_1 = 1, q_2 = 1$ and $\gamma = 2$.

Figure 13
Phase and Vector plot for the two food sources ant colony for the value of the parameters $\phi(r) = 0.9, q_1 = 1, q_2 = 1$ and $\gamma = 2$. 
4. Results and discussions

The objective of this study is to analyze the phase-portrait (Iqbal, 2021) compared to the stability and instability of the model equations: Eq. (1) and Eq. (2) of the ant's food exploration from the two different Source-A and Source-B. As a result, the equations: Eq. (3) and Eq. (4) are reduced by applying dimensionless parameters from Eq. (1) and Eq. (2). The following cases investigate the model equations Eq. (3) and Eq. (4).
Case-1:
Applying the arbitrary value of the parameters $\phi(\tau) = 0.9$, $q_1 = 1$, $q_2 = 2$, and $\gamma = 1$ in Eq. (3) and Eq. (4). Consequently, the two fixed points $(\xi_1, \xi_2) = \{(0.353, 1.093), (2.546, -3.293)\}$ associate with the Jacobian matrix $\Theta_1$ and their corresponding eigenvalues (Iqbal, Hafez, & Uddin, 2022) classify the phase state of the model Eq. (3), Eq. (4). The state classification is illustrated in Table II accompanied by Figure 3 to Figure 6. It is observed that, at point $(\xi_1, \xi_2) = (0.353, 1.093)$, the eigenvalue $(\nu_1, \nu_2) = (-1.00000004361, -0.636283742956387)$ represent both the $\nu_1$ and $\nu_2$ are real and negative-signed, developing a stable node at the point $(0.353, 1.093)$. In contrast, compared with another fixed point $(2.546, -3.293)$ has, the eigenvalues $\nu_1 = -1.0000000073890$, and $\nu_2 = 1.7510033873890$ real but opposite in sign, which confirms that the Eq. (3) and Eq. (4) are developing an unstable saddle node. Figure 3 and Figure 4 display the phase portrait and the vector plot of food exploration ants from the two diverse sources (A and B). Connectively, Figures 5 and 6 illustrate their corresponding time series of the food explorations.

Case-2:
Likewise, by choosing only the equal concentration of pheromone $q_1 = q_2 = 1$, compared to Case-1. The only equilibrium point is derived from the Eq. (8), which is $(\xi_1, \xi_2) = (0.45, 0.45)$ associated with the Jacobian matrix $\Theta_2$ and their resultant eigenvalues classify the phase state of the model Eq. (3), Eq. (4). Table III depicts the phase state stability at the point $(\xi_1, \xi_2) = (0.45, 0.45)$. At $(0.45, 0.45)$ both the eigenvalues $\nu_1 = -0.6896551724$, and $\nu_2 = -1$ are real and negative-signed, which is developing a stable node at the point $(\xi_1, \xi_2) = (0.45, 0.45)$ which is clear from Figure 7. The corresponding vector plot in Figure 8 and Figure 9 illustrates the flow of the discovery from the various food sources (A and B). Figure 10 and Figure 11 demonstrate their subsequent time series of the food explorations.

Case-3:
Finally, remaining the arbitrary parameter value $\phi(\tau) = 0.9$, $q_1 = q_2 = 1$ unchanged compared to Case-2. Only the sensitivity measure of the food choice parameter ($\gamma$) is changed from $\gamma = 1$ to $\gamma = 2$. The nonlinearity is observed in Eq. (3) and Eq. (4). Consequently, the equilibrium points are calculated using Eq. (9) to Eq. (12). It is observed that one root is $(\xi_1, \xi_2) = \left(\frac{\phi q_1}{2},\frac{\phi q_2}{2}\right) = (0.45, 0.45)$, which is the only real root for the
values of $\phi(\tau) = 0.9$, $q_1 = q_2 = 1$. It is analogous that other roots are obtained from the Eq. (12), where the condition for real roots must satisfy the $\phi q \leq -2$ and $\phi q \geq 2$. However, the arbitrary choosing value $\phi(\tau) = 0.9$, $q_1 = q_2 = 1$ does not meet the condition $\phi q \geq 2$ hence the complex roots $(0.450 \pm 0.8930285550i)$ are obtained. Consequently, the phase plot, along with the connected vector plot, are displayed in Figure 12 and Figure 13 for the real equilibrium point $(\Xi_1, \Xi_2) = (0.45, 0.45)$. The state point $(0.45, 0.45)$ is a stable node, since its eigenvalues (Table-IV) $(\nu_1, \nu_2) = (-0.3793103448, -1)$ are in the same negative-signed. The related time series of Figure 14 and Figure 15 also illustrate the stability of the fixed point $(0.45, 0.45)$.

5. Conclusion
This study works on the food recruitment (Dussutour, Beekman, Nicolis, & Meyer, 2009) of ant colonies for the two trials, $T_1$, and $T_2$. Where the arbitrary number of parameter values are considered to analyze the model equations Eq.(1) and Eq.(2), the analysis is based on both sources ($A$ and $B$). The food sources are identical by assessing the rate of concentration ($q_1$ and $q_2$) of each trail's phenomenon and the sensibility ($\gamma$) of choosing the trails. It is noted that, at the equilibrium points $(\Xi_1, \Xi_2)$. Coordinate in negative-signed indicates the pheromone concentration is decreasing rapidly. Table II demonstrates that one pair of real-equilibrium points, where the point $(\Xi_1, \Xi_2) = (2.546, -3.293)$ has negative-signed and point $(\Xi_1, \Xi_2) = (0.353, 1.093)$ is positive-signed, define ants exploring foods from the trails going $(2.546, -3.293)$ point to a stable point $(0.353, 1.093)$. The flow is illustrated in Figure 3 and Figure 4. As a result, point $(0.353, 1.093)$ is saddle-node unstable, and point $(2.546, -3.293)$ is a stable node. In comparison, when the coordinates of the equilibrium points $(\Xi_1 = \Xi_2 = 0.45)$ (coordinates) are equal. It demonstrates the pheromone concentration of both trails $T_1$, and $T_2$ is identical; consequently, ants choose two foods trails equally to form one equilibrium point. It is portrayed in Figure 7, Figure 8, Figure 9, Figure 12 and Figure 13. Two food sources $(A$ and $B)$ have identical or dissimilar qualities. In the case of equal sources, it is observed that there is equivalent exploitation for the small amount of pheromone deposition (Nicolis & Deneubourg, 1999) on the trail of the two food sources. The system switches to a chosen advantage of one or another food source if a small amount changes the threshold (for instance, $\phi, \gamma$) (Nicolis & Deneubourg, 1999) value for the species Lasius niger. In the same tone, using a state diagram, we can represent other techniques for food.
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recruitment from more than two food sources. This research can be beneficial for biological developments or artificial systems and control the conduct of the population in the agriculture field.

References


Many systems have been proposed for patients with paraplegia caused by neurodegenerative disease. The prototype includes a communication interface tailored to the individual's remaining motor skills. Patients can think but can't complete their thoughts. However, some people encounter obstacles because they are unable to move their heads. Previously, head movement techniques were used to control wheelchairs. The research article aims to develop a device that can help paraplegic patients who can only move their heads. The device is controlled by the spontaneous modulation of the subject's sensorimotor cortex. The message generated by the brain was captured by the implanted electrodes and was translated into machine-understandable activity. The message is then transmitted to the microcontroller via the Bluetooth module. The converted signal passes through a dot-matrix display to image the patient's needs. A buzzer sounds when the user wants to alert the caretaker. The device has a push button that allows the user to deactivate the system. The system is advantageous, as it eliminates the constant need for caregivers to be physically present beside paralyzed patients. The primary objective revolves around improving the quality of life of patients and providing an advantage to caregivers. The device is simple and easy to use, and the necessity for both healthcare providers and caregivers to share information and regulate medical equipment is increased. Our primary objective revolves around improving the quality of life of patients and providing an advantage to caregivers. The device is simple and easy to use, and the necessity for both healthcare providers and caregivers to share information and regulate medical equipment is increased.

In the 21st century, paralysis is attacking many people's lives. Paralysis is a lack of muscle characteristics in some parts of the body, and the mind guides the body at every moment. However, some people encounter obstacles because they are unable to move their heads. Among them, some papers are presented in this section.

2. Literature review

2.1. Electroencephalography (EEG)

Many papers have been published on making home appliances, such as lights and fans, work by eye movements. Udayashankar, Kowshik, Chandramouli, and Prashanth (2012) have developed a system to move two DC motors to control the wheelchair based on eye directions. The GeoEye-1 satellite image is used to identify the object's position, and the subject wears an eye-gaze system to make the wheelchair. The object's position is determined from the eye-gaze system, and the wheelchair travels toward the object. If the movements of both eyes are within the threshold, a buzzer sounds, and the wheelchair stops. If the movements of both eyes are out of the threshold, the wheelchair travels in the opposite direction. The system is simple and easy to use, and the need for caregivers is reduced.

2.2. Head movement

Many systems have been proposed for patients with quadriplegia. Goyal and Saini (2013) used a 3-axis accelerometer to detect head movements. The complete system is divided into two blocks as shown in figure 1: transmitter circuits and receiver circuits. The transmitter circuit comprises an electronic device that detects head movements and sends it to a microcontroller. The microcontroller converts the signal into an LED light. The microcontroller also sends it via a Bluetooth module. The microcontroller sends it to a microcontroller in the receiver circuit. The received circuit is shown in figure 1. The microcontroller sends the signal to the dot-matrix display to indicate pre-stored images with dot-matrix display, through a predefined set of head gestures. The central focus of our work is the inspiration that patients can easily communicate with others. If the patient selects a Pitch command, the buzzer turns it into a tone. This device has a push button that allows the user to deactivate the system. With a predefined number of head movements, the buzzer is activated.

2.3. Other devices

Mathew, Sreeshma, Jaison, Pradeep, and Jabarani (2019) proposed a method that could help paralyzed patients control home appliances with a predefined number of blinks. Sourab, Chakravarthy, and D’Souza (2014) proposed a project consisting of a head movement detection system prototype as part of a refurbishment of a quadriplegic, 3-axis accelerometer, Bluetooth module. Their system detects head movements with a Bluetooth module and sends it to a microcontroller. The converted signal passes through a dot-matrix display to image the patient's needs. After this was shown, the buzzer turned it into a tone. This device has a push button that allows the user to deactivate the system. With a predefined number of head movements, the buzzer is activated.

2.4. Conclusion

In this section, the authors have provided an overview of the system's block diagram. The complete system is divided into two blocks as shown in figure 1. The blocks are named transmitter circuits and receiver circuits. The transmitter circuit comprises prior research that is connected or relevant to our current work. Table 1 shows the summary of the paper. It is the director of the body, and the mind guides the body at every moment. However, some people encounter obstacles because they are unable to move their heads. Among them, some papers are presented in this section.

2.4.1. Summary

This research article aims to develop a device that can help paraplegic patients who can only move their heads. The device is controlled by the spontaneous modulation of the subject's sensorimotor cortex. The message generated by the brain was captured by the implanted electrodes and was translated into machine-understandable activity. The message is then transmitted to the microcontroller via the Bluetooth module. The converted signal passes through a dot-matrix display to image the patient's needs. A buzzer sounds when the user wants to alert the caretaker. The device has a push button that allows the user to deactivate the system. The system is advantageous, as it eliminates the constant need for caregivers to be physically present beside paralyzed patients. The primary objective revolves around improving the quality of life of patients and providing an advantage to caregivers. The device is simple and easy to use, and the necessity for both healthcare providers and caregivers to share information and regulate medical equipment is increased.

3. Methodology

3.1. Block diagram of the system

3.2. Components

Components include a 3-axis accelerometer sensor, Bluetooth module, microcontroller, and dot-matrix display.

4. Conclusion

This research article aims to develop a device that can help paraplegic patients who can only move their heads. The device is controlled by the spontaneous modulation of the subject's sensorimotor cortex. The message generated by the brain was captured by the implanted electrodes and was translated into machine-understandable activity. The message is then transmitted to the microcontroller via the Bluetooth module. The converted signal passes through a dot-matrix display to image the patient's needs. A buzzer sounds when the user wants to alert the caretaker. The device has a push button that allows the user to deactivate the system. The system is advantageous, as it eliminates the constant need for caregivers to be physically present beside paralyzed patients. The primary objective revolves around improving the quality of life of patients and providing an advantage to caregivers. The device is simple and easy to use, and the necessity for both healthcare providers and caregivers to share information and regulate medical equipment is increased.

5. References


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3.2. Methodology

Block diagram of the system.

Nonetheless, there is currently no mechanism in place for detecting head movements, which could enable quadriplegic individuals to express their needs with others. Therefore, patients and caregivers can easily interact. In testing, the system shows superior accuracy when controlling appliances compared to LCD microcontroller. The microcontroller converts this signal and sends this to the second accelerometer detects the movement of the paralyzed patient’s head and sends it to a detector. These messages are split into data packets, and these packet data are sent to the transmission channel. The HADO measurement section can detect messages from the patient, even when they are alone in the room. The display of the message is shown on the computer screen.

The complete system is divided into two blocks as shown in figure 1. The blocks are named transmitter circuits and receiver circuits. The transmitter circuit is shown in figure 1(a). The purpose of the transmitter circuit is to read EEG rhythms on the scalp. This skill was acquired despite the subject's long time of paralysis. Cincotti et al., (2008) implemented a system that gives the user a novel idea by controlling the mouse cursor of a computer with the movement of the eyes, it controls home appliances for the disabled who can move their heads. Therefore, the purpose of this project is to develop devices that inform and regulate medical equipment, as it offers simplicity and convenience.

Consequently, the first target of this project is to ready a helping machine that can assist the paralyzed patient. 24 hours assistance is needed in situations where the patient is alone in the room, you can use this device by moving your head and asking for help. The recent task is only for the impaired person will surely help and the patient can ask for help. In situations where the patient is alone in the room, you can use this device by moving your head and asking for help. The alerting system will send the message to the transmission channel. The microcontroller converts this signal and sends this to the second detector. These messages are split into data packets, and these packet data are sent to the transmission channel. The HADO measurement section can detect messages from the patient, even when they are alone in the room. The display of the message is shown on the computer screen.

3.1. Block diagram of the system

First, the camera uses the Viola Jones algorithm to detect faces and try to adjust to face the patient, the patient is connected to the system. The camera for this purpose, we use an IR camera to record video in the dark. Adjusted to face the patient, the patient is connected to the system. Depending on the patient's position, whether sitting or sleeping, the camera of the device is ready to connect with the mind. In general, the mind and body is ready to connect with the mind. In other words, the brain is running but the body is paralyzed. When the spinal cord is damaged, a person is affected with complete paralysis of both limbs. This type of patient cannot move their body totally and is paralyzed. In the 21st century, paralysis is attacking many people's life. When the body is ready to connect with the brain, it controls home appliances for the disabled who can move their heads. Therefore, the purpose of this project is to develop devices that help patients use appliances such as lights and fans or ask for help by number of head motions.