Model for simulating scorpion substrate vibration and detection system

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[1]Model for simulating scorpion substrate vibration and detection system

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Abstract. Scorpion stings are vital health issues which requires prompt attention to minimize the pain inflicted on victims and avert death. A possible solution in averting the sting is the capability of detecting its presence earlier before it stings. Scorpion like other arthropods have a specific kind of movement pattern called substrate vibration, which generates a specific signal that is used in recognizing and locating mates and preys. This paper aims at developing an intelligent scorpion detection system using vibration frequency detection technique. A six step model for simulating scorpion substrate vibration and detection has been proposed. The surrounding vibrating signal is acquired and passed through a band pass filter. The resulting signal is model using autoregressive modeling technique.. Resulting co-efficients are further analyzed for activity detection. The frequency response of scorpion activities for mating behaviour was simulated, detected analysed using MATLAB environment. The resulting coefficients was also compared and analysed. Results obtained shows that the proposed technique is appropriate for model and simulating scorpion substrate vibration and detection system.

1. Introduction

Scorpions are ancient animals that have been in existence since 425 – 450 million years ago-according fossil records [1,2]. They evolved from an amphibious ancestor, and occur in many habitats ranging from deciduous forest, motane pine forests, intertidal zones, rain forest, caves, grasslands and savannahs [3,4]. Like the insects and spiders, scorpions belong to the phylum Arthropoda and like the spiders they belong to the Arachnida but belong to a different order, Scorpiones [2]

Scorpions are mostly nocturnal and hunt insects, spiders, centipedes and other arachnids including scorpions [3,4]. Figure 1a shows a Scorpion feeding on grasshopper. Bigger scorpions sometimes feed on vertebrate like small lizards, snakes and mice [4]. During the day they can be found under rocks, bark, cow-pats and rock crevices, often they are attracted to insect activity around lights. Many people leave lights on during the night and these attract insects that in turn attract scorpions [2].

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(a) (b)

Figure 1: (a) Scorpion feeding on a grasshopper. [5]
(b) Female scorpion with young on her back. [4]

In most species (not all) the male initiates the courting. The male grips the female pedipalps (chelae) and leads her in a mating dance that usually lasts about 30 to 60 minutes, but can vary from 5 minutes to 2 days and they can cover a distance of about 25 metres. Scorpions are viviparous (carry the eggs inside the reproductive tract and give birth to live young). After a 3 to 18 month gestation period, 1-105 live young are born, the average numbering approximately 26. The female, in most species, forms a basket with her first or first and second pairs of legs to catch the newborn at birth [2]. They then climb up her legs onto her back where they will moult for the first time as shown in figure 1b [4].

Envenomings by scorpion stings is an important but yet neglected health issue in many parts of the world, particularly in the extreme Northern and Southern parts of Africa; the Middle East; Southern states of USA; Mexico; some parts of South America, and the Indian sub-continent. Scorpion stings are very lethal in young children [6]. The venoms release autonomic nervous system mediators causing myocardial damage, cardiac arrhythmias, pulmonary oedema, shock, paralysis, muscle spasms and pancreatitis [6]. Despite the high rate of death associated with scorpion stings, little or no work has been reported which involve the use of intelligent approach in the detection of this arthropod's [7]. It is for this reason; this paper proposes an automatic and intelligent approach for the detection of scorpion.

The remaining part of this paper is organized as follows. Section II dwells on the review of various scorpion detection methods as well as the performance analysis of each of the methods. In section III, the scorpion substrate vibration was discussed and analysed. An overview of the development of the scorpion substrate vibration and detection modelling was presented in section IV. Section V present the result obtained. Section IV; and the discussion of the result. Section VI contains the conclusion of the paper.

2. Review of scorpion detection techniques

The earlier Scorpion detection methods involved locating areas suspected to be hiding places for scorpions and digging up such places in search of scorpions. This method is called the burrowing detection technique [8]. Another method is the rolling of rocks and checking for the presence of the scorpion [8]. Also detection can be done by peeling the tree-bark in search of the scorpion [8]. Furthermore scorpion can be detected using the pitfall traps method, in which hollow traps are set for scorpion to fall into and consequently captured [8]. All the aforementioned methods of detection, prove to be dangerous, time consuming, and also exposes the detector to the danger of being sting.

A more scientific method was proposed, based on the fact that scorpions fluorescence in the presence of ultraviolent (UV) light was proposed in [9]. The UV light is used by searcher usually at night for possible detection of scorpion. However, this method although more scientific, is only effective at night. Another scientific method was proposed by [7], which was based on image processing technique by using colour segmentation approach.

Table 1: Performance Evaluation of Scorpion Detection Methods

S/N	Detection Method	Advantages	Disadvantages
1	Burrowing Detection	It is cost effective, as the tool require are not expensive.	It is dangerous. It is tedious. It is time consuming. It is destructive as it involve digging the earth.
2	Rock Rolling	It is cost effective, as it requires simple or no tool at all.	It is dangerous. It is tedious. It is time consuming.
3	Bark Peeling	It is cost effective, as the tool require are not expensive.	It is dangerous. It is tedious. It is time consuming. It is destructive as it involved destruction of the tree.
4	Pitfall Trap	It is relatively less dangerous. It is also cost effective.	It relies on human intervention, as the detector has to manually set the trap and monitor it. It is also time consuming.
5	UV light Method	It is relatively less dangerous.	It relies on human intervention, as it is not intelligent enough to detect the scorpion automatically. It is more effective at night and not efficient during the day.
6	Image processing	There is absolute no chance of getting sting by the scorpion. It involved little or no human intervention.	It is more effective at night and not efficient during the day, as it also required the use of UV light. It is relatively expensive to deploy.

3. Scorpion substrate vibration

Insect of the order scorpiones (mantophasmatodia) to which scorpion belong to, are known to have a specific kind of movement pattern called substrate vibration [10]. Signal usually exhibited in recognition and locating their mates. This is achieved by making abdominal contact with the substrate in which signal are produced which generates compression and transverse waves, which propagate through the material. The signal propagation depends on the resonance properties as well as the characteristic of the substrate [10]. Sand scorpions receive two kinds of waves: longitudinal sound waves and surface waves also known as Rayleigh waves. It is believed that the mechanoreceptors respond to Rayleigh waves to detect the direction of a vibration source and longitudinal vibrations to estimate the distance [11].

Substrate vibration is detected by mechanoreceptors located in the scolopidia organ (i.e the legs) of the scorpion. Scorpion has five scolopidia organs in each leg of the male and female: femoral chordotonal organ subgenual organ, tibia distal organ, tibio-tarsal scolopidial organ and tarso-pretarsal scolopidial organ [10].These organs were found to be very sensitive vibration receptors (especially the femoral chordotonal and the subgenual organs) for certain range of frequency vibration [10].

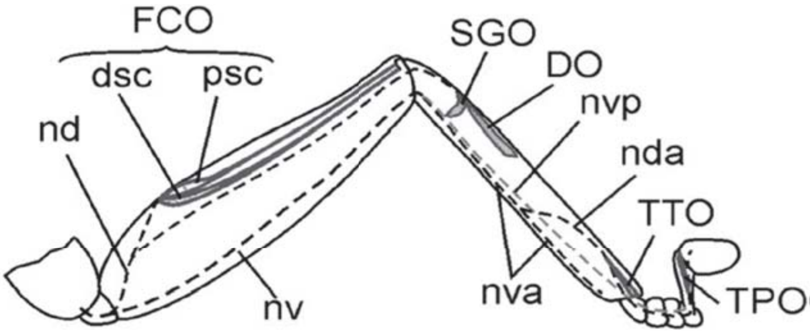
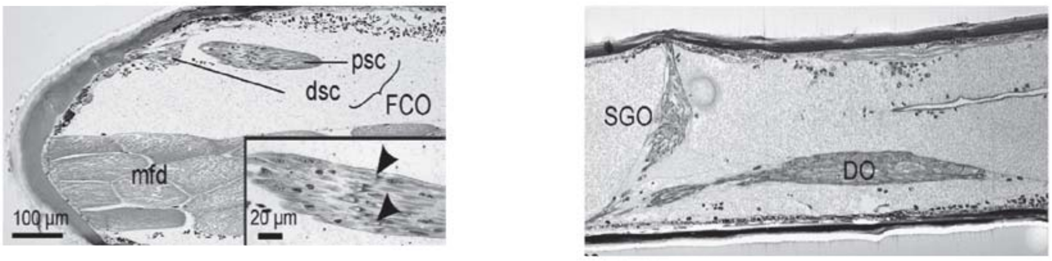


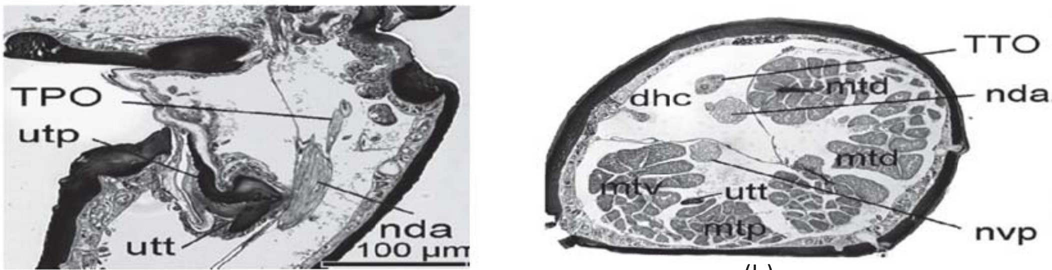
Figure 2: Schematic drawing of the leg scolopidial organs of Arthropods. [10]

The femoral chordotonal is responsible for detection of very low frequencies below 100Hz, while the subgenual organ is responsible for detection of frequencies between 100Hz-160Hz. It is therefore conclude that scorpions response best to frequencies below 120Hz [10].



(a) (b)

Figure 3: (a) Internal structure of femoral chordotonal organ (FCO) [10]
(b) Internal structure of subgenual organ (SGO) and distal organ. [10]



(a) (b)

Figure 4: (b) Internal structure of tarso-prestarsal organ (TPO) [10
(b) Internal sctructure of tibio-tarsal organ (TTO). [10]

The vibrating signal in female scorpion consist of individual pulses repeated at equal interval, while that of the male scorpion consist of repeated trains of pulses, the frequency distribution of the percussive call depends on the resonant properties of the material the scorpion is tapping on [12].Once a duet is established, the female becomes stationary and wait for the arrival of the male scorpion.

In scorpions a Duet is accomplished when a female within the range of communication respond to the male vibration signal using it own vibration signals and as a result become stationary [12]. When this is accomplished, the male began a localised search by orientation towards the stationary female until it locates it.

There are basically two types of Duet: 'two-way' duet and 'three-way' duet. In two-way the male call and then the female answer while in three-way duet the male call, female answer and then the male reply [12]

4. Model for scorpion substrate vibration and detection

The proposed model for simulating scorpion vibration technique is as shown in Figure 3.1. Detailed explanation of each unit is subsequently presented herewith.

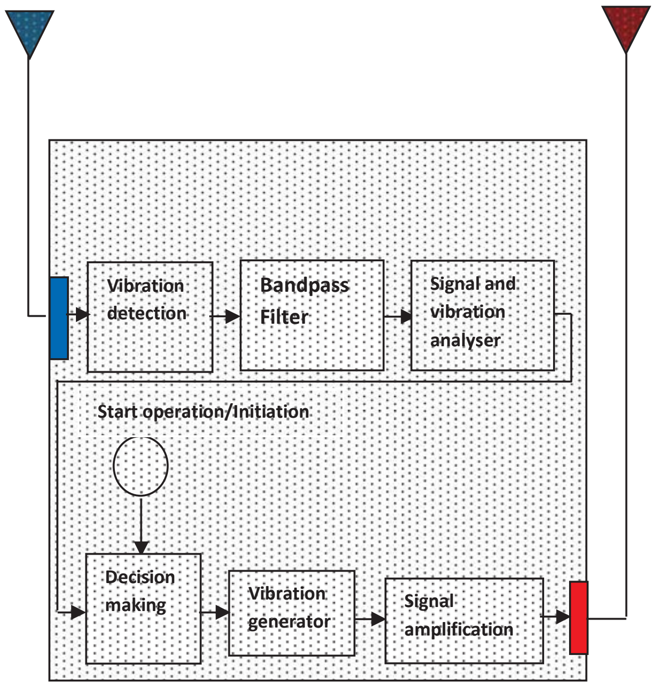


Figure 5: Block diagram of the proposed system.

4.1 Vibration detection module

The vibration signal propagated through the substrate is received via the receiving antenna; and passed unto the vibration detection module. Vibration sensors are used in this module. The receiving antenna is carefully selected as it has been observed that the choice of antenna improves system performance and at the same time reduce the cost.

4.2 Band pass Filter

A band-pass filter is a circuit that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range [14]. A simple cascade of a low pass filter in series with a high pass filter has been used in selecting appropriate frequencies in this work. Figure 3.2 shows the simple block diagram of the Bandpass filter used in this work.

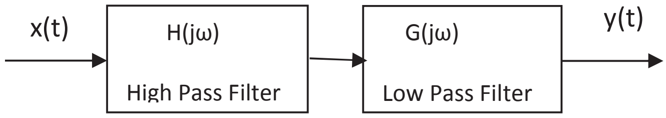


Figure 6: High and low pass filters combined to produce a band pass filter

4.3 Signal and vibration analysing module

In this stage, artificial neural network (ANN) based autoregressive (AR) modelling technique proposed in [15] is proposed for the analysis and detection of the frequency contained in the filtered signal. Detailed analysis of the technique is as contained in [15-17]. The filtered signals are windowed, and formatted for model coefficient determination using ANN based AR technique. A fixed model order of two have been proposed for this work. The received filtered signal is assumed to be an AR signal generated by the difference equation given as

$$y(n) = -a_1 y(n-1) - a_2 y(n-2) + w_n \qquad (1)$$

where the AR model coefficients are $a_1$and a_2, and w_n is a white Gaussian-distributed noise with zero mean and variance σ^2. As proposed in [15,18], the AR model coefficients are to be subjected to the following constraints.

$$-(1 + a_2) < a_1 < 0 \qquad (2)$$

$$| a_1(1 - a_2) | \leq | 4a_2 | \qquad (3)$$

$$a_1^2 - 4a_2 < 0 \qquad (4)$$

ANN based AR technique is applied in the determination of the coefficients and the computation of the signal frequency is computed using

$$\cos(2\pi f_0) = -\frac{a_1(1+a_2)}{4a_2} \qquad (5)$$

4.4 Decision making module

Here decision will be taking based on the on the previously analysed frequency (***f_o***), as to whether the frequency of the vibrating scorpion is for food or mating purposes for example.

TABLE 2: Likely Frequency and Activities of Scorpion.

S/N	**SORPION ACTIVITIES**	**FREQUENCE RANGE (f_O)**
1	Prey detection	4-17Hz
2	Mating Activity	40-80Hz

4.5 *Start operation/initiator*
This initiates the commencement of scorpion activities which are related to vibration movement of the Scorpion. These activities include prey detection and location of a partner for mating purpose.

4.6. Vibration generator Module
The vibration module generates the required vibration signal in accordance to intended activity.

4.7 Signal amplifier
The generated signal is amplified and conditioned by the signal amplifier before transmission.

5. Results and discussions

Typical result obtained using the proposed model will be reported in this section. A 60Hz signal for mating activity is sampled at the rate of 300Hz by the receiving scorpion module in a two way duet communication. The received was firstly filtered for noise and unwanted signal removal using a Bandpass filter. The resulting filtered signal was then analyzed using ANN based AR model technique. Comparison was done with the use of Yule Walker equation. Figure 7 shows the results obtained using both ANN based AR modeling technique and Yule Walker AR technique. Furthermore, Table 3 shows the results of the resulting coefficients for the two techniques.

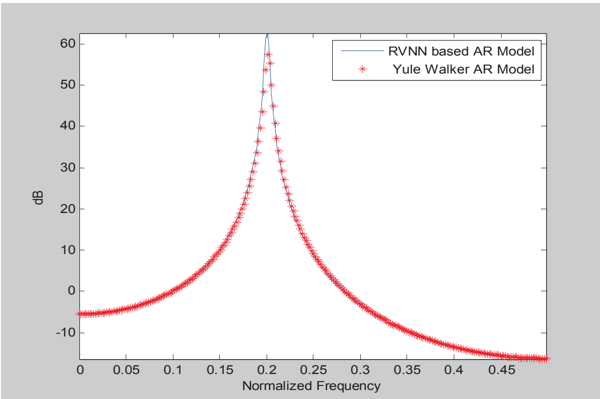


Figure 7: Spectral of the received signal

Table 3: Coefficients of the Received Scorpion Signal

AR Coefficients	Actual Values	ANN based AR technique	Yule Walker Method
a_0	1.0000	1.0000	1.0000
a_i	-0.6180	-0.5877	-0.5843
a_2	1.0000	0.9581	0.9537

6. Conclusions

The method of detecting scorpion using the vibrating pattern discussed in this paper, will definitely be a better method of detecting scorpion; since it can be used to effectively detect this dangerous animal before it could harm the victim.

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