Development of an Intelligent Scorpion Detection Technique Using Vibration Analysis

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***Abstract*—** A possible solution to address the problem of Scorpion stings is the capability of detecting its presence earlier before it stings. This paper presents efforts in Scorpion detection using substrate vibration modelling approach. An eight stage approach has been presented in this work. Using sinusoidal signal, signal representing Scorpion behaviour was firstly sampled and then amplified before transmitting to a nearby receiving module. The received signal undergoes filtering for noise removal before being modelled for coefficients determination. The computed coefficients were then clustered for analysis of behavioural determination. Results obtained in this work show that the proposed technique can be used for Scorpion detection.

Keywords— Detection, Frequency, Scorpion, Vibration Analysis.

I. Introduction

Scorpions are poisonous arthropods found in different habitats such as deciduous forest, motane pine forests, intertidal zones, rain forest, caves, grasslands and savannahs [1]. Mostly found at the bark of trees, burrows, beneath rocks etc. These arthropods are nocturnal, feed at night on a variety of insects and use their venom for defence and predation [1,2].

Recently, efforts are on-going in verifying the use of Scorpion venom in treating cancer and brain tumour [3]. Scorpions seek shelter during the day beneath rocks or logs, in piles of woods, cracks or burrows that they dig into the substrate, or beneath the loose outer layers of many plant shrubs and trees. Scorpions are ancient animals that have been in existence from about 425 – 450 million years ago [4,5].

In most species (not all) the male species initiates the courting process. 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 [5]. The young ones then climb up her legs onto her back where they will moult for the first time [6].

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 [7]. The venoms release autonomic nervous system mediators causing myocardial damage, cardiac arrhythmias, pulmonary oedema, shock, paralysis, muscle spasms and pancreatitis [7]. Despite high rate of death associated with scorpion stings, little or no work has been reported which involve the use of signal processing approach in the detection of this arthropod's [8]. Hence, this paper proposes a signal processing modelling approach for scorpion detection.

The remaining part of this paper is organized as follows. Section 2 dwells on the review of various scorpion detection methods as well as the performance analysis of each of the methods. In section 3, the methodology that was adopted in carrying out the research is discussed. The result and discussions is presented in section 4 and Section 5 presents the conclusion and recommendation.

II. Literature Review

Scorpion detection technique sometimes referred to as scorpion sampling technique [8, 9,10] can be categorised into two, namely the unaided detection method and the aided detection method. Techniques used for unaided approach include rock rolling detection technique [9], burrow detection technique [9,10], pitfall trap detection technique [9,10]. Similarly, the aided detection technique is subdivided into the use of ultraviolet (UV) flashlight and touch, and the use of pitfall traps [8, 10,11,13].

Rock rolling detection technique involves opening up rock and checking the presence of this arthropod's in there shelter under the rock [8,9]. The location of burrow detection method involves locating appropriate shelter under burrows and digging up the burrow for scorpion acquisition [10].The peeling loose back of tree detection method involves peeling back of trees in the day time to search for scorpions [12]. The pitfall detection technique involves setting pitfall traps for scorpion, by digging up ground surface for trap setting, covering and checking for possibility of catching scorpion; similarly this technique is not suitable for some environments and it is time consuming [9,10].

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The findings that scorpions florescence under ultraviolet wavelengths of black light has led to the use of ultraviolet light in the detection and study of scorpion [13]. 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 [6]. A digital processing approach for Scorpion detection was proposed in [8]. Digital camera was used to capture Scorpion images under UV light. Image segmentation approach was then applied to extract region of interest before further analysis. Performance analysis was also reported in the work however, this method although more scientific, is only effective at night [8].

Insect of the order scorpiones (Mantophasmatodia) to which scorpion belong to, are known to have a specific kind of movement pattern called substrate vibration [14]. These signals are usually exhibited in recognition and locating mates and preys [6,14]. 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 [14]. Sand scorpions receive two kinds of waves: longitudinal sound waves and surface waves also known as Rayleigh waves [14]. 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 [15].A concise detail of the various detection methods and their performance Evaluation is presented in Table 1.

TABLE I. SCORPION DETECTION APPROACHES

S/N	Detection Method	Merits	Demerits
1	Burrowing Detection	It is cheap and easy to set up.	It is tedious and time consuming.
2	Rock Rolling	It is very cheap as little or no tools are needed in this technique.	It is time consuming, dangerous and tedious
3	Bark Peeling	The tools needed in this method are inexpensive thus it is cheap to set up.	It is dangerous, tedious, time consuming and also destructive as it involved destruction of the tree.
4	Pitfall Trap	It is relatively less dangerous and less expensive.	This detection approach relies heavily on human intervention because the detector has to manually set up the trap and monitor it and also time consuming.
5	UV light Method	It is relatively less dangerous.	It relies on human intervention, as it is not intelligent enough to autonomously detect the scorpion. Also it is not effective during the day.
6	Image processing	It is safe and requires little or no human intervention.	It is expensive to set up and used this method in detecting the arthropods

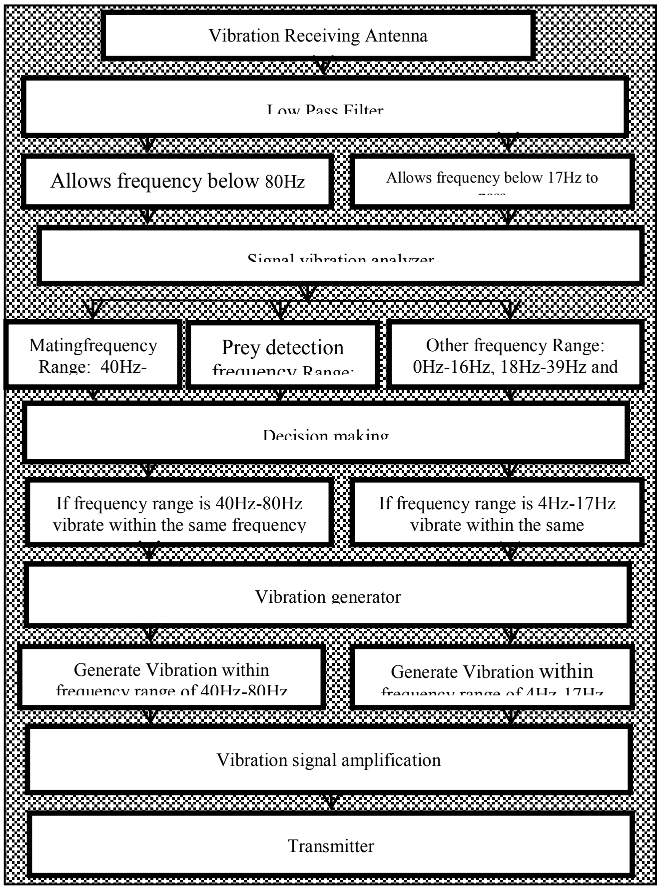

Fig. 1. Block Diagram of the proposed scorpion detection model

III. METHODOLOGY

The model for the implementation of the system is as depicted in the block diagram shown in Figure 1. It comprises of; a signal receiving module; Vibration detection module; Low pass Filter module; Signal vibration analyser module; decision making module; Vibration generator Module; Signal Amplification module and finally the transmission antenna. Detail discussion of each module is subsequently presented herewith.

A. Vibration Receiving Module

The vibration signal generated by neighbouring scorpion, passes through the substrate to receiving module. The receiving antenna receives the vibration signal in form of electromagnetic waveform and changes the radiating energy received into voltage between the terminals of the antenna. The module is mounted so that it is vertically oriented with respect to the floor; so as to ensure maximum amount of energy to radiate out into the intended coverage area.

B. Vibration Detection Module

The received signal in terms of voltage from the receiving antenna is passed unto this module, which consists of a piezoelectric transducer element. When the vibration signal strikes the transducer element, tiny electrical pulses are generated within the transducer; in other words the vibration signal is converted into electric pulse with amplitude corresponding to the intensity of the vibration. The pulse is then amplified, processed and the passed on to the filter.

C. Low Pass Filter Module

The following conditions were taking into consideration in the design of low pass filter to be used in implementing the proposed system:

- That for the mating activity, the system is assumed to give -3dB cut-off of 75Hz and an attenuation of 50dB at 100Hz; while for prey detection activity, the system is assumed to give -3dB cut-off of 16Hz and an attenuation of 50dB at 20Hz.
- That the filter is to give a linear phase with sampling frequency (FS) of 400Hz.

D. Signal and vibration analysing module

In the analysis and detection of the frequency contained in the filtered signal, an artificial neural network (ANN) based autoregressive (AR) modelling technique proposed in [16] was adopted. The filtered signals are windowed, and formatted for model coefficient determination using ANN based AR technique [17-19].A fixed model order of two has been proposed for this work and the model difference equation is expressed as

$$y(n) = -a_1 y(n-1) - a_2 y(n-2) + w_n \text{ ....(1)}$$

Where a_1 and a_2 are the **autoregressive** model coefficients and w_n represents the white Gaussian-distributed noise with zero mean and variance σ^2. In [16-19], it was shown that the AR model coefficients are to be subjected to constraints in (2) - (4).

$$-(1+b_2) < b_1 < 0 \quad \text{.....................(2)}$$

$$|b_1(1-b_2)| \leq |\, 4b_2 \,| \quad \text{.....................(3)}$$

$$b_1^2 - 4b_2 < 0 \quad \text{.....................(4)}$$

Then, an ANN based AR technique can be used in determining the coefficients of the model. Furthermore, it was also shown that (5) can be used for the determination of signal frequency.

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

E. Decision making module

In this module, decision will be taking based on the previously analysed frequency ranges for scorpion activities, in order to ascertain whetherthe frequency range is between 40Hz to 80Hz for mating activity or between 4Hz to 17Hz for prey detection.

F. Start operation/Initiator

This triggers 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.

G. Vibration generator Module

In this stage, vibration signal is generated in accordance with the received frequency to which scorpion can respond. This can be model using

$$x(t) = A \sin 2\pi f t \text{ .... (6)}$$

Where $A, t \text{ and } f$ are the Amplitude, time and frequency of the signal respectively.

H. Signal Amplifier

The signal coming from the vibration generation module is then amplified to certain level and conditioned by the signal amplifier, so as to be strong enough for the other scorpion to recognise, after receiving it from the transmitting antenna. The amplification is linear in order to prevent distortion in the generated signal; hence an operational amplifier is employed to boast up the amplitude of the generated signal.

IV. RESULTS AND DISCUSSIONS

In evaluating the proposed model for Scorpion mating process, a 60Hz sinusoidal signal was generated, and then sampled at the rate of 300Hz in a two way duet communication system. The received signal was firstly filtered for noise and unwanted signal removal using the Low-pass filter described in section 3. The resulting filtered signal was then model for coefficient determination using ANN based AR model technique. The computed coefficients were then analyzed for decision making. The decision module clustered the model coefficients using appropriate technique so as to determine what the coefficients are meant for. In this paper, the model coefficients are compared with the expected coefficients. Furthermore, comparison was done with the use of Yule Walker equation while evaluating the proposed technique. Figure 2 shows the results obtained using both ANN based AR modeling technique and Yule Walker AR technique. Furthermore, Table 2 shows a typical result of the resulting coefficients for the two techniques. The two approaches evaluated in this work were able to accurately compute the coefficients and clustered it as a mating process and not as prey detection.

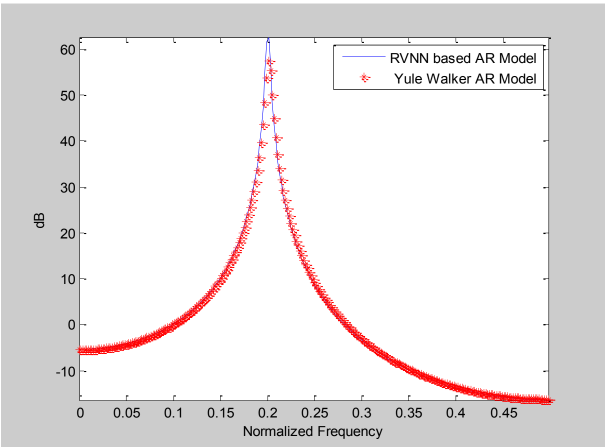

Fig. 2. Power Spectral Density of the received signal

TABLE II. 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

V. CONCLUSIONS AND RECOMMENDATION

In this paper, Scorpion detection technique using substrate vibration approach has been presented. Mating process using the proposed model has also been evaluated and results obtained were later benchmarked against the expected results and results obtained using Yule Walker approach. Preliminary results obtained in this work have shown the applicability of this system in accurately modelling the Scorpion substrate vibration for eventual Scorpion detection. Though emphasis has been placed on modelling of the received signal in this paper, future work will involve communicating with Scorpion using this approach.

REFERENCES

[1] Chowel G., Hyman J. M., Diaz-Duenas P., & Hengartner N. W. (2005). Predicting Scorpion sting incidence in an endemic region using climatological variables. International Journal of Environmental Health Research, 425-435.

[2] Dawn H.G. and Carl O. (2001).scorpions Arizona Poison Control and Drug Information Center -1 (800) 222-1222)

[3] Rudovsky J. F. (April 8, 2013). Miami Newtimes News. In Blue Scorpion Venom: Cuba's Miracle Drug. Retrieved June 5, 2013, from http://www.miaminewtimes.com/2013-04-18/news/blue-scorpion-escozul-cancer-treatment-cuba/

[4] Bradley, R. A., & Brody, A. J. (1984). Relative abundance of three vaejovid scorpion across a habitat gradient. J. Arachnol, 11, 437-440

[5] Eastwood, E. B. 1977. Notes on the scorpion fauna of the Cape. Part 2. The Parabuthus capensis (Ehrenberg) species -group; remarks on taxonomy and bionomics (Arachnida, Scorpionida, Buthidae). Annals of the South African Museum 73: 199-214

[6] Sadiq B.A., Aibinu A. M., Joseph E., Salau H.B. and Salami M.J.E. (2013). "Model for Simulating Scorpion Substrate Vibration and detection". In the proceeding of the 5th International conference on mechatronic (ICOM'13), Kualar Lumpur Malaysia.

[7] Warrell D., Gutierrez J-M, and Padilla A., (2007). Rabies and envonomings: a neglected public health issue: Report of consultative world health organization, Geneva. Pp 12

[8] Joseph E., Sadiq B.A., Aibinu. A. M. and Salami M. J. E. (2013). Scorpion Image Segmentation system. In the proceeding of the 5th International conference on mechatronic (ICOM'13), Kualar Lumpur Malaysia.

[9] Shehab, A. H., Amr, S. Z., & Lindsell, A. J. (2011). Ecology and biology of scorpions in Palmyra, Syria. Turk J Zool, 35(3), 333-341

[10] Williams, S. C. (1968). Method of Sampling Scorpion Population. Proceeding of the California Academy of Science, (pp. 221-230). California

[11] Raz, S., Sion, R., Tomas, P., Adam , H., Hagay , K., Dan , Z., et al. (2009). Scorpion Biodiversity and Interslope Divergence at "Evolution Canyon", Lower Nahal Oren Microsite, Mt. Carmel, Israel. Peer-Reviewed open access Journal, e5214

[12] Druce, D., Hamer, M., & Slotow, R. (2004). Sampling strategies for millipedes (Diplopoda) centipedes (Chilopoda) and scorpions (Scorpionida) in savanna habitats. Africa Zoology, 39(2), 293-304

[13] Lourenco, W. R. (2012). Fluorescence in scorpions under UV light; can chaerilids be a possible exception? Comptes Rendus Biologies, 335, 731-734

[14] Eberhard M. J., Lang D., Metscher B., Pass G., Picker M. D. and Wolf H. (2010). Structure and sensory physiology of the leg Scolopidial organ in mentatophasmotodea and their role in vibration communication. Journal of arthropod structure and development. Vol. 39; Pg 230-241

[15] DaeEun K. (2006). Neural Network Mechanism for the Orientation Behavior of Sand Scorpions Towards Prey: IEEE transactions on neural networks, Vol. 17, N0. 4. Pg 1070-1076

[16] Aibinu A.M., Salami M.J.E. and Shafie A. A. (2012). "Artificial neural network based autoregressive modeling technique with application in voice activity detection", Engineering Applications of Artificial Intelligence 25 (2012) 1265–1276

[17] Aibinu A. M., Shafie A. A. and Salami M. J. E. (2012). Performance Analysis of ANN based YCbCr Skin Detection Algorithm, International Symposium on Robotics and Intelligent Sensors 2012, Procedia Engineering, Vol. 41, August 2012.

[18] Aibinu A. M., Salami M.J.E. and Shafie A. A. (2011). "A novel signal diagnosis technique using pseudo complex-valued autoregressive technique. Expert Systems with Application", 38 (8). pp. 9063-9069, 2011

[1] S. Haykin,and S. Kesler (1979). "Prediction error filtering and maximum entropy spectral estimation", In: Non-Linear Methods of Spectral Analysis, Springer-Verlag, New York, pp. 16–32 (Chapter 2), 1979.