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RECORDING AND AUTOMATIC DETECTION OF AFRICAN ELEPHANT (*LOXODONTA AFRICANA*) INFRASONIC RUMBLES

by

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SUMMARY

Recording and automatic detection of African elephant (*Loxodonta africana*) infrasonic rumbles

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SUMMARY

The value of studying elephant vocalizations lies in the abundant information that can be retrieved from it. Recordings of elephant rumbles can be used by researchers to determine the size and composition of the herd, the sexual state, as well as the emotional condition of an elephant. It is a difficult task for researchers to obtain large volumes of continuous recordings of elephant vocalizations. Recordings are normally analysed manually to identify the location of rumbles via the tedious and time consuming methods of sped up listening and the visual evaluation of spectrograms. The application of speech processing on elephant vocalizations is a highly unexploited resource. The aim of this study was to contribute to the current body of knowledge and resources of elephant research by developing a tool for recording high volumes of continuous acoustic data in harsh natural conditions as well as examining the possibilities of applying human speech processing techniques to elephant rumbles to achieve automatic detection of these rumbles in recordings. The recording tool was designed and implemented as an elephant recording collar that has an onboard data storage capacity of 128 gigabytes, enough memory to record sound data continuously for a period of nine months. Data is stored in the wave file format and the device has the ability to navigate and control the FAT32 file system so that the files can be read and downloaded to a personal computer. The collar also has the ability to stamp sound files with the time and date, ambient temperature and GPS coordinates. Several different options for microphone placement and protection have been tested experimentally to find an

acceptable solution. A relevant voice activity detection algorithm was chosen as a base for the automatic detection of infrasonic elephant rumbles. The chosen algorithm is based on a robust pitch determination algorithm that has been experimentally verified to function correctly under a signal-to-noise ratio as low as -8 dB when more than four harmonic structures exist in a sound. The algorithm was modified to be used for elephant rumbles and was tested with previously recorded elephant vocalization data. The results obtained suggest that the algorithm can accurately detect elephant rumbles from recordings. The number of false alarms and undetected calls increase when recordings are contaminated with unwanted noise that contains harmonic structures or when the harmonic nature of a rumble is lost. Data obtained from the recording collar is less prone to being contaminated than far field recordings and the automatic detection algorithm should provide an accurate tool for detecting any rumbles that appear in the recordings.

KEY WORDS

elephant vocalizations, voice activity detection, infrasonic rumbles, bio acoustics, speech processing, pitch determination

OPSOMMING

Opname en outomatiese deteksie van Afrika Olifante (*Loxodonta Africana*) infrasoniese klanke

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OPSOMMING

Die waarde van die studie van olifantvokalisasies lê in die magdom inligting wat daaruit onttrek kan word. Opnames van infrasoniese olifantklanke kan deur navorsers gebruik word om die grootte en samestelling van 'n trop, die seksuele toestand van die olifant asook die emosionele staat van 'n olifant te bepaal. Dit is 'n moeilike taak vir navorsers om groot volumes aaneenlopende opnames van olifantvokalisasies te bekom. Die vokalisasies in opnames word normaalweg deur die vermoeiende en tydrowende metodes van versnelde luister en visuele evaluasie van spektrogramme geïdentifiseer. Die toepassing van spraakverwerkingstegnieke op olifantvokalisasies is 'n baie onderbenutte hulpbron. Die doel van hierdie studie was om by te dra tot die bestaande kennis en hulpbronne van olifantnavorsing deur 'n instrument daar te stel wat hoë volumes aaneenlopende akoestiese data in ongunstige omstandighede kan opneem asook om die moontlikheid te ondersoek om spraakverwerkingstegnieke aan te wend om outomatiese deteksie van olifantklanke in genoemde opnames te bewerkstellig. Die apparaat wat die opnames maak is ontwerp en geïmplementeer as 'n olifanthalsband met 128 gigagrepe geheue aanboord wat genoeg geheue is om nege maande se aaneenlopende opnames te stoor. Data word in die "wave"-formaat gestoor en die toestel het die vermoë om die FAT32 lêerstelsel te beheer en daardeur te navigeer sodat die klanklêers na 'n rekenaar toe afgelaai kan word. Die halsband kan ook die klanklêers merk met die datum en die tyd, die buitetemperatuur en "GPS"-koördinate. Verskeie opsies vir die plasing en beskerming van die mikrofoon is eksperimenteel getoets om sodoende 'n aanvaarbare

oplossing te kry. 'n Relevante stemaktiwiteitsdeteksie algoritme is gekies as 'n basis vir die ontwikkeling van 'n outomatiese olifantklank deteksie algoritme. Die gekose algoritme is gebasseer op 'n robuuste toonhoogtedeterminasie algoritme wat eksperimenteel geverifieer is om te werk teen 'n sein tot ruis verhouding van tot so laag as -8 dB mits 4 of meer harmonieke in klank teenwoordig is. Die algoritme is aangepas sodat dit vir olifantklanke gebruik kan word en is getoets met 'n stel vooraf opgeneemde olifantvokaliseringsdata. Volgens die resultate wat verkry is wil dit voorkom of die algoritme infrasoniese olifantklanke akkuraat kan opspoor. Die hoeveelheid vals alarms en onopgespoorde klanke neem toe as die opnames ongewensde geraas met harmonieke bevat en ook wanneer die botone van die klanke verlore raak in swak gehalte opnames. Data afkomstig van die olifanthalsband is minder vatbaar vir ongewensde geraas as vêrveld opnames en die outomatiese olifantklank deteksie algoritme behoort 'n akkurate stuk gereedskap te wees vir die opsporing van infrasoniese olifantklanke wat in opnames voorkom.

SLEUTELWOORDE

olifantklanke, stemaktiwiteitsdeteksie, infrasoniese klanke, bioakoestiek, spraakverwerking, toonhoogte bepaling

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List of abbreviations

ADC	:	Analogue to Digital Converter	(p. 26)
AGC	:	Automatic Gain Control	(p. 28)
CF	:	CompactFlash	(p. 22)
dB	:	Decibels	(p. 11)
ERB	:	Equivalent Rectangular Bandwidth	(p. 70)
FFT	:	Fast Fourier Transform	(p. 18)
GPS	:	Global Positioning System	(p. 3)
HMM	:	Hidden Markov Models	(p. 15)
PCBs	:	Printed Circuit Boards	(p. 40)
PSD	:	Power Spectral Density	(p. 108)
RAM	:	Random Access Memory	(p. 33)
RF	:	Radio Frequency	(p. 2)
SNR	:	Signal to Noise Ratio	(p. 31)
SPL	:	Sound Pressure Level	(p. 11)
VAD	:	Voice Activity Detection	(p. 4)
USART	:	Serial Asynchronous Receive Transmit	(p. 39)
USB	:	Universal Serial Bus	(p. 34)