

## Appendix S1: High-level code for the extraction of echolocation calls from background noise and measurement of call parameters

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DEFINE SoundFile //Wave file
DEFINE SoundFileDirectory
DEFINE PowerSpectrumSignal //Will hold Signal post power spectrum processing
DEFINE BandPassFilter //Internal MATLAB function
DEFINE SpectralMeanSubtraction //External Plug-in MATLAB function found in
VoiceBox Toolbox
DEFINE ZeroPadding //Internal MATLAB function
DEFINE AverageAmplitudes AS 2D ARRAY
DEFINE AveragePower AS 2D ARRAY
DEFINE Positions AS 2D ARRAY
DEFINE CorrespondingFrequency AS ARRAY
DEFINE HighestAmplitude
DEFINE Threshold
DEFINE IsForward AS BOOLEAN
DEFINE NumberOfSamplesInCall AS DATAPOINTS
DEFINE SampleFrequency AS KHz/s
DEFINE DurationOfCall AS TIME
DEFINE StartFrequency AS KHz
DEFINE CentreFrequency AS KHz
DEFINE EndFrequency AS KHz
DEFINE PeakFrequency AS KHz
DEFINE MovingAverageValue

// ----- PRE-PROCESSING
IMPORT SoundFile FROM SoundFileDirectory
SET BandPassFilter CuttOffFrequency = BETWEEN 10 KHz TO 120 KHz
APPLY BandPassFilter ON SoundFile
APPLY SpectralMeanSubtraction ON SoundFile

// ----- CALL DETECTION ALGORITHM
FOR EACH DATAPOINT IN SoundFile
    READ this DATAPOINT + upcoming 99 DATAPOINTS

    CALCULATE average amplitude
    SAVE average amplitude in AverageAmplitudes
    SAVE this DATAPOINT

END FOR

FOR EACH DATAPOINT IN AverageAmplitudes
    READ average amplitude

    IF average amplitude = highest
        GET DATAPOINT
        SAVE DATAPOINT in HighestAmplitude
    ELSE
        Do nothing
    END IF

END FOR

SET ZeroPadding Points = 1024
SET SampleFrequency = 256 KHz
SET IsForward = TRUE

READ SoundFile
GOTO HighestAmplitude DATAPOINT
```

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REPEAT

    READ this DATAPOINT + upcoming 255 DATAPOINTS
    CALCULATE power spectrum on selected DATAPOINTS
    APPLY ZeroPadding on power spectrum output
    CALCULATE power spectrum again after ZeroPadding
    SAVE output IN PowerSpectrumSignal

    // Signal Smoothing
    FOR EACH DATAPOINT IN PowerSpectrumSignal
        READ this DATAPOINT + upcoming 19 DATAPOINTS

        CALCULATE average power
        SAVE average power in AveragePower

    END FOR

    ITERATE THROUGH AveragePower
        CALCULATE Maximum average power
        CALCULATE Minimum average power
        GET corresponding frequency for the maximum power obtained FROM
PowerSpectrumSignal
        SAVE corresponding frequency for the maximum power obtained IN
CorrespondingFrequency
    END ITERATION

    ITERATE THROUGH AveragePower
        NORMALISE average power using MAX/MIN power between 0&1
        SAVE normalised value in AveragePower
    END ITERATION

    FOR EACH element IN AveragePower
        GET current normalised value
        GET next normalised value
        Threshold = (current normalised value - next normalised value) /
Length of elements in AveragePower

        IF Threshold > 0.01
            IF IsForward = TRUE
                SET IsForward = FALSE
                SAVE end position IN Positions
            ELSE
                SAVE start position IN Positions
                SET NumberOfSamplesInCall = End Position - Start
Position
                SET DurationOfCall = NumberOfSamplesInCall /
SampleFrequency
                IF DurationOfCall < 1 MILLISECOND
                    SOFT DELETE sample FROM SoundFile
                    RESTART REPEAT LOOP
                END IF
            END IF
        END IF

    END FOR

    IF (current corresponding frequency - previous corresponding frequency)
> 8
        IF IsForward = TRUE
            SET IsForward = FALSE

```

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        SAVE end position IN Positions
    ELSE
        SAVE start position IN Positions
        SET NumberOfSamplesInCall = End Position - Start Position
        SET      DurationOfCall      =      NumberOfSamplesInCall      /
SampleFrequency
        IF DurationOfCall < 1 MILLISECOND
            SOFT DELETE sample FROM SoundFile
            RESTART REPEAT LOOP
        END IF
    END IF
END IF

IF IsForward = TRUE
    MOVE DATAPOINT + 6
ELSE
    MOVE DATAPOINT - 6
END IF

UNTIL END OF FILE

// ----- GET START FREQUENCY

READ SoundFile
GOTO Start Position DATAPOINT
READ FROM current position DATAPOINT TO upcoming CONVERT ( 256 MICROSECONDS
TO DATAPOINTS )
APPLY ZeroPadding
CALCULATE power spectrum on selected DATAPOINTS
GET corresponding frequency for the maximum power obtained FROM Power Spectrum
Signal Output
SET StartFrequency = corresponding frequency for the maximum power obtained
FROM Power Spectrum Signal Output

// ----- GET CENTRE FREQUENCY

READ SoundFile
CALCULATE Position by (Start Position + ((End Position - Start Position) / 2
)) - CONVERT ( 128 MICROSECONDS TO DATAPOINTS )
GOTO Position DATAPOINT
READ FROM current position DATAPOINT TO upcoming CONVERT ( 256 MICROSECONDS
TO DATAPOINTS )
APPLY ZeroPadding
CALCULATE power spectrum on selected DATAPOINTS
GET corresponding frequency for the maximum power obtained FROM Power Spectrum
Signal Output
SET CentreFrequency = corresponding frequency for the maximum power obtained
FROM Power Spectrum Signal Output

// ----- GET END FREQUENCY

READ SoundFile
CALCULATE Position by End Position - CONVERT ( 256 MICROSECONDS TO DATAPOINTS
)
GOTO Position DATAPOINT
READ FROM current position DATAPOINT TO upcoming CONVERT ( 256 MICROSECONDS
TO DATAPOINTS )
APPLY ZeroPadding
CALCULATE power spectrum on selected DATAPOINTS
GET corresponding frequency for the maximum power obtained FROM Power Spectrum
Signal Output

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SET EndFrequency = corresponding frequency for the maximum power obtained FROM  
Power Spectrum Signal Output

// ----- GET PEAK FREQUENCY

READ SoundFile

GOTO Start Position DATAPOINT

READ Current Position TO End Position

APPLY ZeroPadding

CALCULATE power spectrum on selected DATAPOINTS

SET MovingAverageValue = Length of DATAPOINTS in Power spectrum / 1024

REPEAT

    CALCULATE Maximum power while dispose other power values

    MOVE DATAPOINT = MovingAverageValue

UNTIL END OF SAMPLES

GET corresponding frequency for the maximum power obtained

SET PeakFrequency = corresponding frequency for the maximum power obtained

// ----- OUTPUT

OUTPUT DurationOfCall

OUTPUT StartFrequency

OUTPUT CentreFrequency

OUTPUT EndFrequency

OUTPUT PeakFrequency