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Oil Spill Simulator Guide

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# Introduction

The Oil Spill Simulator application introduces a user interface which is created to sort all the algorithms and functions created for oil spill detection and oil thickness estimation into a structure, from which all the above can be called easily with carrying the inputs, without having to go back to each function individually and calling it through MATLAB. Moreover, the application contains a visualization of an oil spill which is randomly generated, and then can be analyzed according to the user’s inputs and preferences. This GUI is built using MATLAB app designer.

# Default Layout

Running the application, it will open with the default screen shown below.

Graphical user interface

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In this state, the properties are set by default as follows:

* Functionality: “Simulate Spillage.”
* Tmin=1mm.
* Tmax = 10mm.
* Thickness step = 1mm.
* Incident angle = 0 °.
* Number of observations M = 1.
* Surface roughness ks = 0.
* Oil dielectric constant = 3; (Ignoring the 0.01j imaginary part)
* Air dielectric constant = 1.
* Water salinity = 35 ppt.
* Water temperature = 20°C.
* Variance = 0.02.
* Noise samples = 1;
* This represents the number of samples used by the default detection algorithm to calculate the probability of oil detection.
* It is not used neither in the estimation algorithms nor in the joint pdf algorithm.
* The default algorithm used for detection algorithm is set to joint pdf algorithm.

# Functionalities

The application contains three functionalities:

* Simulate Spillage (default)
* Bayesian Statistics
* Constellations
* Experimental Results

## Simulate Spillage

This functionality is used for visualization purposes.



The spill button shown above is responsible for generating an oil spillage representation. Pressing this button will trigger the SpillButtonBushed callback function, which will generate the data needed in the figure using the function fractalsurface(app, app.n, app.H);

Where n determines the resolution which will be (2^n + 1) and is currently set to 8.

As for H, it is set to 0.7 and represents the hurst exponent.

This function outputs the surface matrix, which is a random matrix that is then normalized into the range [tmin tmax] according to the given inputs, and then drawn using the ‘Jet’ colormap, and with clims = [tmin tmax].

The data generated here is the thickness values that will be used to generate values of random reflectivity values representing the reflectivities collected back from a drone scan. This will be generated independent of the thickness step (resolution).

The output of the spill button will be as follows:

A picture containing graphical user interface

Description automatically generated

The calculate button can now be pushed so that reflectivity values can be calculated from the thicknesses shown in the figure above to represent the measured reflectivities which is then passed to the Detection and Estimation algorithms.

The default used Detection algorithm is set to Joint pdf and can be changed using the check box below the Detection figure.

Chart

Description automatically generated

When pressed, a wait bar will appear showing the current functionality and the progress.

For the detection figure, the Detect(app, measured\_reflectivity, frequency), which checks which check box is selected (Jointpdf or Default), and thus calls

app.Detect\_with\_joint\_pdf\_multiple\_points(measured\_reflectivity, frequency);

Or

app.Detect\_with\_default\_algorithm(measured\_reflectivity, frequency);

based on the checkbox values.

**Default Algorithm:** this algorithm use probability density functions to evaluate the probability of oil detection on one thickness only.

As for the estimation figure data, it is formed by calling

Estimate\_Thickness(app, measured\_reflectivity, frequency)

At the end of this process, the estimated thicknesses and the detection output will be shown as follows.

Graphical user interface, application

Description automatically generated

The detection plot uses gray scale, which is reversed, yielding the black spots to represent oil and the white spots to represent water. Also, clim is set to [0 1].

As for the estimation figure, the used colormap is Jet. Moreover, clim is set to [tmin tmax].

Moreover, using the “Show Histogram” button, the thickness present in the estimation will be shown in a histogram, thus the user can figure out a close distribution of the thicknesses present in the spill.

### Additional Plots

Graphical user interface, text, application, chat or text message

Description automatically generated

This section allows for choosing two options, one of which is the probability of detection, and the other is thickness estimation. Also, in this case, the user can choose which detection algorithm to use by checking either the “Default Detection,” or “Joint pdf detection” check box.

This section is responsible for generating all ten estimations or detections of the oil spill using the best frequency pairs of best frequency triads which are previously calculated.

This is done by selecting which plot option is needed, and then either the “Generate for all frequency triads” or “Generate for all frequency pairs” button is clicked.

* The frequency triads (GHz) used are:

[5 12 12]; [6 12 12]; [9 9 12]; [7 9 12]; [9 12 12]; [8 10 10]; [7 9 9]; [7 8 12]; [4 12 12]; [4 11 12]

* The frequency pairs (GHz) used are:

[6 12]; [6 12]; [4 12]; [10 11]; [9 9]; [8 12]; [7 10]; [6 8]; [4 8]; [4 12]

The figure below shows the detection over the best frequency triads using the joint pdf algorithm.

A picture containing application

Description automatically generated

The figure below shows the detection using the best frequency pairs using the default algorithm with number of samples = 1

A picture containing qr code

Description automatically generated

The two figures below show the estimation of an oil spill using the best frequency triads and pairs.

A picture containing text, screenshot

Description automatically generated

A picture containing application

Description automatically generated

The plotting of the previous graphs is done on another application called Plots. The information needed are calculated in the main application (Oil Spill Simulator) and is sent to the Plots application to be visualized.

## Bayesian Statistics

The default template for the Bayesian statistics page looks as follows:

Graphical user interface

Description automatically generated

In this functionality, “Reflectivity vs thickness” & “Probability of detection vs thickness” can be plotted. The plots are made on the UIAxes (first axes).

The inputs are almost common between the two plot options. What differs is that noise properties section is added whenever the “Probability of detection vs thickness” plot type is selected, rendering the template as follows.

Graphical user interface

Description automatically generated

Figures can be cleared, and extracted using the buttons above the plot, and grid lines could be turned on and off using the “Show Grid Lines” check box.

### Reflectivity vs. Thickness Plotting

In this case, when the “Plot” button is pressed, each frequency will be taken individually from the multiple frequencies entered, along with the surface roughness selected, and the reflectivity curves are plotted.

In case the user wants to add plots to the figure, they should just add the new inputs and press “Plot” again.

For example,

If the user wants to plot the reflectivity at 4 and 12 GHz at a ks = 0, they should enter the information as follows.

Chart

Description automatically generated

For example, if the user wants to add 2 other plots which are reflectivity at 4, 8, and 12 GHz with a surface roughness ks = 0.5, the new inputs should be entered as follows, and the “Plot” button shall be pressed again.

Graphical user interface, chart

Description automatically generated

As for the legends, every new legend added is being saved to a string array called “ReflectivityLegends” for all the legends to be plotted. This variable is cleared whenever the “Clear figure” button is pushed or when switching from one plot type to another to start adding new legends and plots.

In case the user intends to clear the figure and start adding new plots, the “Clear figure” button in the upper right corner can be used.

Also, the figure can be extracted using the “Extract Figure” Button to change options, check properties, print, …

### Probability of detection vs Thickness Plotting

In this case, whenever the “Plot” button is pressed, all the frequencies in the Frequency edit field are taken as one input (multiple frequencies), along with the other inputs and the probability is calculated accordingly.

This means that in this option, one curve can be plotted per button press.

For example, if the user wants to plot the probability of detection for 4,8,12 GHz with number of observations M = 1, and the other inputs are left as default, the following figure would be the result.

Chart, line chart

Description automatically generated

Now, if the user needs to add another plot of probability of detection at 4, 8 GHz at M = 5, they should change those inputs and press “Plot” again.

Chart, line chart

Description automatically generated

The user can also change all other inputs as oil dielectric constant, surface roughness, … and would get such outputs.

Chart

Description automatically generated

As for the legends, every new legend added is being saved to a string array called “ProbabilityLegends” for all the legends to be plotted. This variable is cleared whenever the “Clear figure” button is pushed or when switching from one plot type to another to start adding new legends and plots.

In case the user intends to clear the figure and start adding new plots, the “Clear figure” button in the upper right corner can be used.

Also, the figure can be extracted using the “Extract Figure” Button to change options, check properties, print, …

### Probability of detection using Joint pdf vs Thickness Plotting

In this case, whenever the “Plot” button is pressed, all the frequencies in the Frequency edit field are taken as one input (multiple frequencies), along with the other inputs and the probability is calculated accordingly.

This means that in this option, one curve can be plotted per button press.

For example, if the user wants to plot the probability of detection for 4,8,12 GHz with number of observations M = 1, and the other inputs are left as default, the following figure would be the result.

Chart, line chart

Description automatically generated

Now, if the user needs to add another plot of probability of detection at 4, 8 GHz at M = 5, they should change those inputs and press “Plot” again.

Chart, line chart

Description automatically generated

The user can also change all other inputs as oil dielectric constant, surface roughness, … and would get such outputs.

Chart

Description automatically generated

As for the legends, every new legend added is being saved to a string array called “Jointpdflegends” for all the legends to be plotted. This variable is cleared whenever the “Clear figure” button is pushed or when switching from one plot type to another to start adding new legends and plots.

In case the user intends to clear the figure and start adding new plots, the “Clear figure” button in the upper right corner can be used.

Also, the figure can be extracted using the “Extract Figure” Button to change options, check properties, print, …

## Constellations

In this option, MATLAB will generate noisy reflectivity values with a mean being the reflectivity value at a thickness given by the user as “Desired Thickness.” The noise will have a variance and a quantity given also by the user though the variance edit field and the samples slider.

The template of this page will be update in three cases. If the user enters two frequencies, the page will contain a 2D scatter plot on UIAxes (first axes), a histogram on UIAxes2 (2nd Axes), and a couple of other fields showing some numerical info as the Thickness Estimated, Probability of error, and the maximum error.

In case of three frequencies given, the page will contain a 3D scatter plot on UIAxes (1st Axes), a histogram on UIAxes2 (2nd Axes), and the rest of the information.

In case of 1 frequency, or more than 3 frequencies, only a histogram will be shown on UIAxes2 (2nd Axes), in addition to the numerical information, since the 1D and 4D+ cannot be visualized in scatterplots.

The page automatically updates its outputs after any change the user enters using the following function:

UpdateConstellationsPage()

This function checks the number of frequencies given as input and updates the page front-end accordingly.

Points are scattered on the main axes using:

scatter\_points()

The histogram and all the numeric information are calculated using:

analyze\_constellation\_results()

When the points are first scattered on the UIAxes, along with the noise, the theoretical reflectivity values are plotted which allows the user to visually compare the closest thickness values to the generated noise. In the two frequency cases, the thickness regions are shown as in the figure below:

Chart

Description automatically generated

Those regions are restricted for thickness steps greater than 0.5mm since adding regions for steps less than that would make the figure a mess. This can be changed from the following function:

scatter\_points()

The histogram is built by using:

minimum\_euclidean\_distance(app, measured\_reflectivity, frequency)

which using a loop, measures to which thickness is the measured noise closest, and thus showing how many points are being estimated as each respective thickness.

The thickness estimated will be the thickness which has the highest estimations in the histogram.

The probability of error shows how many estimations were done wrong, with an error range that can be modified by the user. (The error range default value is 0).

The maximum error is the furthest value estimated as compared to the actual thickness.

In case of three frequencies, the output will be shown as follows:

Chart

Description automatically generated

In cases of one frequency and more than three frequencies, the output will be shown as follows:

Chart, histogram

Description automatically generated

The +/- spinner, increases and decreases with increments of thickness\_step, and as a result the probability of error will change since the error range will change.

Also, the figure can be extracted using the “Extract Figure” Button to change options, check properties, print, …

## Experimental Data

When the functionality drop-down is changed to this option, The user will se the following page with the “Calculate” button locked:

Graphical user interface, chart, box and whisker chart

Description automatically generated

The “Calculate” button will unlock whenever the user selects the folder that should contain the experimental results.

The format of the included files should be of the following format:

“ReflectivitiesX.mat” where X is the oil thickness at which the experimental data are measured. The file should look as following:

Table

Description automatically generated

Note that the Thickness edit field is limited currently to 3->9 values since this is the available data now. So if the range of thicknesses increased, the limits of the edit field shall be changed.

The user shall now choose the directory which contains the data. If the user closes the browser, an error message will appear and the browser will re-open till the user chooses a folder.

The user can then select the thickness they are willing to test on, and calculate the outputs accordingly.

Graphical user interface, chart

Description automatically generated

Data is picked randomly from the files according to the given frequencies and thickness, and the number of selected data is selected according to the value of M. However, the data selected are only the positive ones.