ULTRA-SR: Synthetic Data

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1 Introduction

The Ultrasound Localisation and TRacking Algorithms for Super Resolution (ULTRA-SR) Challenge was held at the 2022 Institute of Electrical and Electronics Engineers (IEEE) International Ultrasonics Symposium (IUS) in Venice, Italy. The aim of the ULTRA-SR challenge was to extensively evaluate the performance of localization and tracking algorithms for Ultrasound Localization Microscopy (ULM).

Two randomly generated networks of Microbubble (MB) seeded 3D vessel trees were simulated using BUbble Flow Field (BUFF)'s organic microvascular tree generator, Hagen–Poiseuille flow model, linear acoustic simulator with incorporated non-linear MB response. This simulated dataset with ground truth was used to evaluate the performance of the participant's localization and tracking algorithms.

The resulting frames are not only realistic, but also represent a challenging scenario for algorithms to perform due to its high MB and track concentration, relatively low framerate, varying signal to noise ratio, and the fact that the 3D simulation generates out-of-plane motion for some MB.

Two additional test datasets of lower density and number of frames were generated to allow participants to prepare for the challenge.

2 Test Datasets

Two test datasets of low vessel density were released to help participants prepare for the ULTRA-SR challenge at IUS 2022. This release allowed participants to:

- Have some idea of what the simulated data looks like

- Adapt their script's input for this data format

- Adjust their algorithms to reduce systematic errors

2.1   Simulation Parameters

Parameter	Description	Value
TxDucer	L11-4v Linear array	L11-4v
F0	Transmitteed Frequency	7.24 MHz
fs	Sampling Frequency	80.0 MHz
fr	Framerate	100 Hz
px_count	number of pixels	[512, 512]
nf	number of frames	20
X_range	range of X coordinates	[-7.5 mm, 7.5 mm]
Z_range	range of Z coordinates	[22.5 mm, 37.5 mm]

Table 1: Test Dataset: High Frequency Simulation Parameters

Parameter	Description	Value
TxDucer	GE M5Sc-D Phased array	GE M5Sc-D
F0	Transmitteed Frequency	2.841 MHz
fs	Sampling Frequency	80.0 MHz
fr	Framerate	100 Hz
px_count	number of pixels	[512, 512]
nf	number of frames	20
X_range	range of X coordinates	[-20 mm, 20 mm]
Z_range	range of Z coordinates	[62 mm, 92 mm]

Table 2: Test Dataset: Low Frequency Simulation Parameters

2.2   Data

For each of the networks, four files were provided: video, ground truth, metadata and example.

2.2.1   Video

The video file is in avi format, showing log compressed b-mode frames with a dynamic range of 40 dB. This serves as the input for the algorithms to perform the localization and tracking of the simulated MBs.

2.2.2   Ground Truth

The ground truth text file contains one row for each localization event. Each row has the format: $[frame\_number, bubble\_id, x, y, z]$. With all values in SI units. The $[x, y, z]$ position provides the localization ground truth, while the $bubble\_id$ across the frames provides the tracking ground truth.

2.2.3   Metadata

The metadata file contains three structures which provide information about the field of view and physical size of the image (PxSet), image settings (ImSet) and simulation settings (SimSet).

2.2.4   Example

An example image is provided for each set. Consisting in the plot of first frame of the video with the ground truth locations superimposed as blue markers.

2.2.5   Using the Data

An example Matlab code is provided. Executing this script will display the example images provided (Figure 1)

```matlab
% Initialize
close all
clearvars
clc

% Read video file
vid = VideoReader('net_001.avi');
video = read(vid);

% Select first frame
frame_01 = rgb2gray(video(:,:,:,1));

% Load metadata
load('metadata.mat');

% Display first frame
figure('Units', 'normalized', 'Position', [0.1 0.1 0.8 0.8]);
imagesc(PxSet.mapX*1e3, PxSet.mapZ*1e3, frame_01); ...
    colormap('gray'); axis image;
title(['Network 001 - Frame rate ', ...
    num2str(ImSet.frame_rate_Hz),'Hz']);
ylabel('Depth [mm]'); xlabel('Width [mm]');

% Load ground truth data
M = readmatrix('gt_scat_inside.txt');

% Select first frame
idx = M(:,1)==1;
M = M(idx,:);

% Overlay ground truth on video
hold on;
plot(M(:,3)*1e3,M(:,5)*1e3,'*')
```

Figure 1: Test Dataset Examples
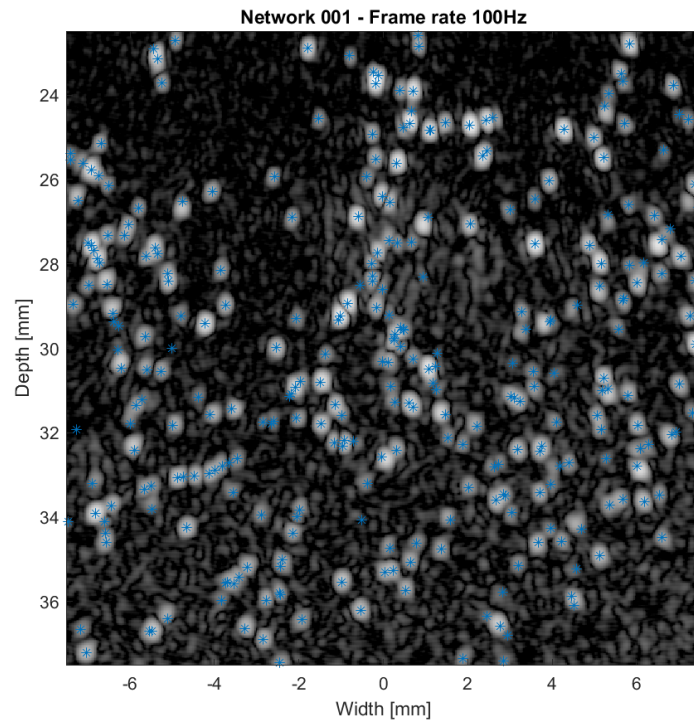
(a) First frame of the high frequency test data, with ground truth
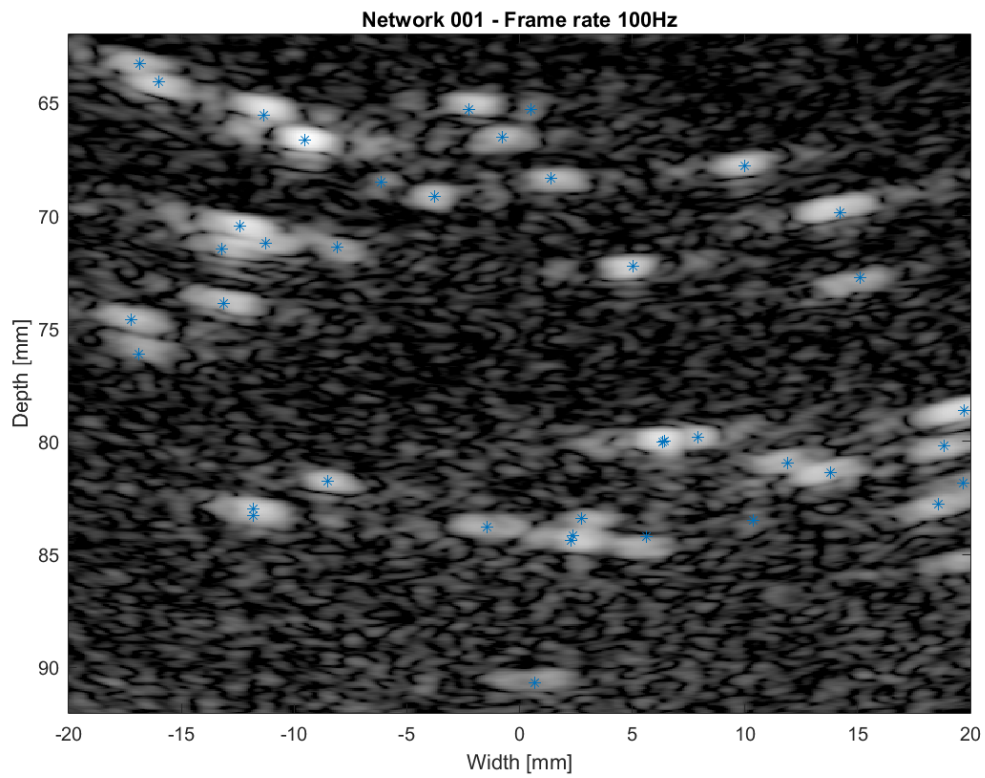
(b) First frame of the low frequency test data, with ground truth

3 Challenge Datasets

For the challenge data, two realistic simulated datasets of microvascular flow were generated and simulated. This synthetic data is far more complex than the test data. A varying network density was used on different spatial sections; all vessel tree generation parameters (bifurcation probability, angle between consecutive segments and MB seeding probability) were randomized; and multiple branching vessel trees were merged into a single network using a much higher MB concentration. Gaussian White Noise was band-pass filtered using the transducer's bandwidth. The resulting colored noise was added to the simulated RadioFrequency (RF) signals, and time gain compensation was applied before beamforming.

Table 3 and Table 4 contain the simulation parameters. The parameters of this dataset are broadly similar to the test dataset, with the exception of the framerate, the number of frames and the field of view.

Parameter	Description	Value
TxDucer	GE M5Sc-D Phased array	GE M5Sc-D
F0	Transmitteed Frequency	2.841 MHz
fs	Sampling Frequency	80.0 MHz
fr	Framerate	50 Hz
px_count	number of pixels	[512, 512]
nf	number of frames	500
X_range	range of X coordinates	[-15 mm, 15 mm]
Z_range	range of Z coordinates	[47 mm, 107 mm]

Table 3: Challenge Dataset Simulation 1: Low Frequency Simulation Parameters

Parameter	Description	Value
TxDucer	L11-4v Linear array	L11-4v
F0	Transmitteed Frequency	7.24 MHz
fs	Sampling Frequency	80.0 MHz
fr	Framerate	50 Hz
px_count	number of pixels	[512, 512]
nf	number of frames	500
X_range	range of X coordinates	[-10 mm, 10 mm]
Z_range	range of Z coordinates	[10 mm, 30 mm]

Table 4: Challenge Dataset Simulation 2: High Frequency Simulation Parameters

Figure 2: Challenge Dataset Examples
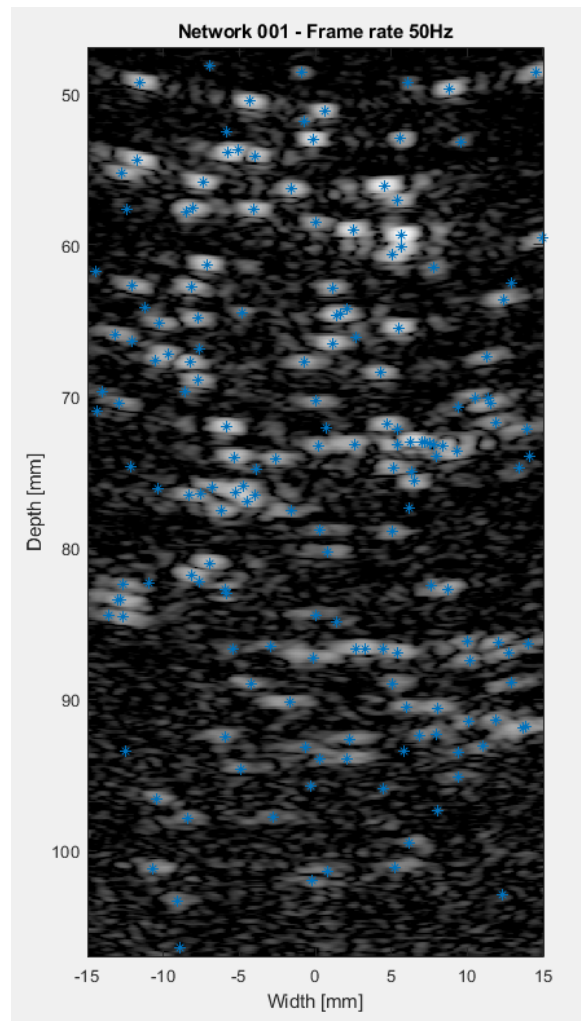
(a) Challenge Dataset Simulation 1: first frame with ground truth
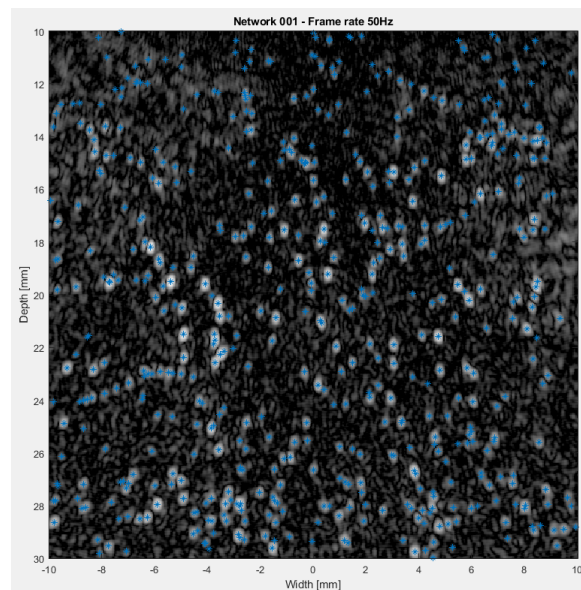
(b) Challenge Dataset Simulation 2: first frame with ground truth

4   Contact

For any further questions, contact us at: `info@ultra-sr.com` or `mengxing.tang@imperial.ac.uk`