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FIELD: A Program for Simulating Ultrasound Systems

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FIELD: A Program for Simulating Ultrasound Systems

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Abstract: A program for the simulation of ultrasound systems is presented. It is based on the Tupholme-Stepanishen method, and is fast because of the use of a far-field approximation. Any kind of transducer geometry and excitation can be simulated, and both pulse-echo and continuous wave fields can be calculated for both transmit and pulse-echo. Dynamic apodization and focusing are handled through time lines, and different focusing schemes can be simulated. The versatility of the program is ensured by interfacing it to Matlab. All routines are called directly from Matlab, and all Matlab features can be used. This makes it possible to simulate all types of ultrasound imaging systems.

INTRODUCTION

Modern ultrasound scanners use a number of schemes for attaining high resolution and high contrast images. Multi-element transducers are used to steer the ultrasound beam and to use multiple foci zones. Apodization is used for reducing side-lobe levels and thereby increase the dynamic range of the image. Both focusing and apodization are dynamic and change as a function of depth in tissue or corresponding time. Also many array transducer geometries exist from small phased array probes for use in cardiac imaging to convex linear arrays suitable for the abdomen.

The optimization of these transducers and their use is eased by employing software scanning. Here the transducer, phantom, and image processing are simulated by a computer and the different choices can easily be studied. The problems are the many types of arrays and the dynamic nature of the image formation.

We have previously made a general simulation program for all types of ultrasound transducers [1]. This program has been used successfully at a number of universities and has yielded accurate results, when compared to measurements [2]. It uses the Tupholme-Stepanishen approach [3], [4] of spatial impulse responses, that assumes linear propagation. It can handle any type of transducer geometry and excitation and all ultrasound fields can be calculated by this method. In our program the transducer surface was split into rectangles and a far-field approximation used for making the calculation fast. This has made it possible to simulate

images from computer phantoms in about 24 hours. The program is based on a menu interface that makes it flexible to use at the price of less flexibility.

A new version of the FIELD program has been developed that is more flexible. It is based on the Matlab programming system, which has been extended by a number of commands for transducer simulation. These commands are used for defining transducers, setting their properties and calculating fields for these transducers. All the commands are written in C for fast execution.

THE FIELD PROGRAM

The prime application of the FIELD program is to simulate the image of an ultrasound scanner. This necessitates that multiple foci zones can be taken into account and that dynamic apodization can be used. The two concepts are introduced through time lines. The focus time line holds information about the dynamic behavior of the focusing. Each focal zone is characterized by a time point and a delay value for each transducer element. The time point indicates the time after pulse emission when these delay values are used. The same approach is used for the apodization time line, which assigns an apodization value for each transducer element.

Multiple transducers can be handled by the program. Commands for defining linear, phased, and 2D matrix arrays are given. The commands return an identifier for the array, which can be passed to the routines for field calculation. Thereby different transducers can be used on the same scatterers and the effect of different choices can readily be evaluated. Commands are also found for setting the excitation waveform of the transducer and the electro-mechanical impulse response.

Commands for calculating the emitted, the pulse-echo, and the scattered fields are given. Thereby the transducers can be evaluated and images for computer phantoms can be found. A simple cyst phantom with point scatterers has been defined, and can be used in imaging. A simple example of linear array imaging is shown in the next section. Other configurations can easily be defined and it is also possible to simulate flow imaging by using Matlab's flexible commands for loops.

AN EXAMPLE

This example shows the main commands using for

simulating a linear array image.

```

% Generate aperture for emission and set impulse response
emit_aperture = xdc_linear_array (N_elements, width,
    element_height, kerf, 1, 1, focus);
xdc_impulse (emit_aperture, impulse_response);
xdc_excitation (emit_aperture, excitation);

% Generate aperture for reception
receive_aperture = xdc_linear_array (N_elements, width,
    element_height, kerf, 1, 1, focus);
xdc_impulse (receive_aperture, impulse_response);

% Load the computer phantom
[phantom_positions, phantom_amplitudes] =
    cyst_phantom(50000);

% Do the imaging
x = -image_width/2;
for i=1:no_lines
    % Set the focus and apodization for this direction
    xdc_focus (emit_aperture, t0, [x 0 z_focus]);
    xdc_focus (receive_aperture, focus_times,
        [x*ones(Nf,1), zeros(Nf,1), focal_zones]);
    xdc_apodization (emit_aperture, t0, apo_vector);
    xdc_apodization (receive_aperture, t0, apo_vector);

    % Calculate the received response
    [v, t1] = calc_scatter(emit_aperture, receive_aperture,
        phantom_positions, phantom_amplitudes);

    % Store the result
    image_data(1:max(size(v)), i) = v;
    times(i) = t1;

    % Move the beam
    x = x + d_x;
end

% Make the image
make_image

```

First the receive and transmit apertures are defined and the excitation and impulse responses are set. Then the computer phantom is generated and a loop is performed for doing the imaging. In this the focus points are set and the apodization is set to use only the elements above the focal point. A linear scan is done by moving the focal point laterally. Then the scattered signal is calculated and stored. Finally the resulting image is made.

The routine has been run on an HP9000 Model 819/K200 with 50,000 scatterers in the cyst phantom. This took 11 hours to run with a 128 elements linear array transducer. The result of the processing is shown in Fig. 1. The circles indicates the position of the cyst, and the strong point scatterers are indicated by \otimes .

CONCLUSION

A fast program for the simulation of ultrasound imaging has been made. It can realistically simulate all kinds of ultrasound systems including color flow mapping [5]. A full simulation can be performed in 11 hours on a state-of-the-art workstation, and fast prototyping is, thus, possible in software.

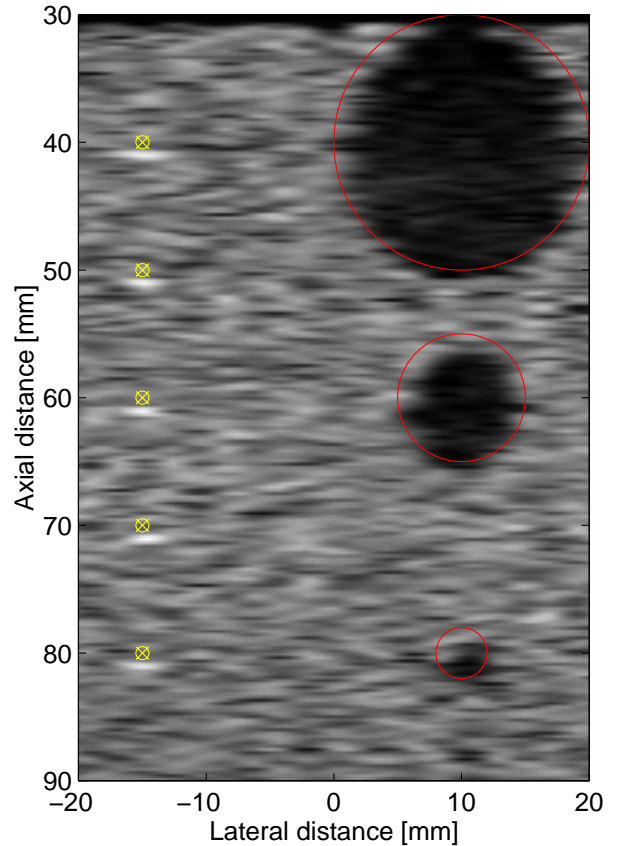


Figure 1: Simulation of cyst phantom with the program.

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