

IMPLEMENTATION OF A MATLAB WEB SERVER FOR INTERNET-BASED PROCESSING OF BIOMEDICAL IMAGES

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Abstract

The paper reviews the various methods implemented for the de-noising and visualization of biomedical images on the Web using the Matlab Web Server (MWS). MWS integrates the graphical and computational capabilities of MATLAB with a remote access through the Internet. MATLAB toolboxes provide a range of algorithms that enable image processing by different mathematical methods including the discrete wavelet transform. The paper presents basic methods for the de-noising and enhancement of biomedical images with suitable wavelet thresholding methods. The final part of the paper is devoted to the design of a graphical user's interface enabling the choice of input parameters and presentation of the results.

1 Introduction

A key application of modern educational technology is e-learning with a web-based approach using for example a MATLAB Web Server (MWS) application. MWS [2] allows clients (users) to run MATLAB applications remotely over the internet. Clients interact with MATLAB over a network with a TCP/IP protocol. This interaction takes place through HTML forms which serve as graphical interfaces for the application. This not only allows users to use MATLAB based tools without any prior MATLAB programming knowledge but it also prevents unauthorized user access to source code. Fig. 1 shows the interaction between clients and MWS.

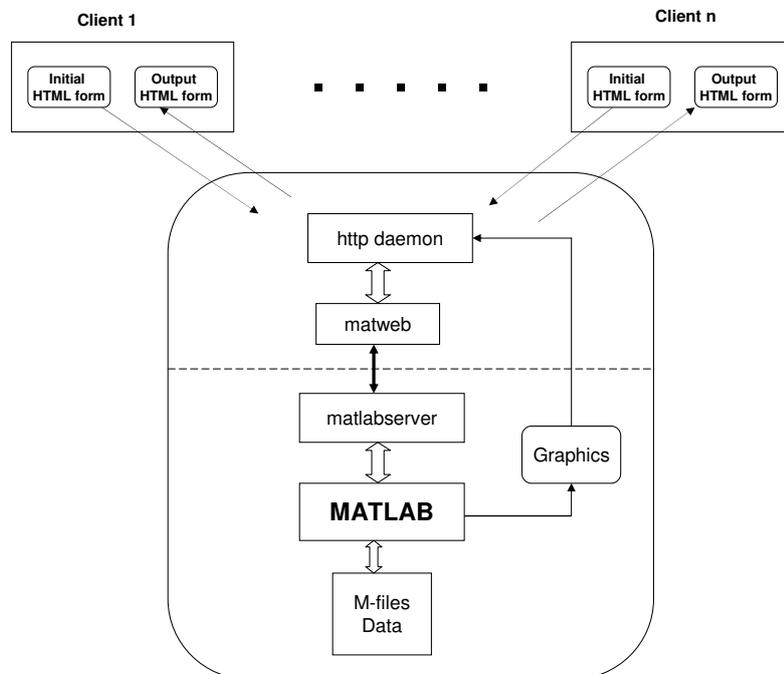


Figure 1: How MATLAB operates on the Web

In the paper the implementation of the MWS with the goal of its use for biomedical image processing - remote image processing is discussed. The mathematical tools to be used include discrete wavelet transform.

2 Principle of DWT

Discrete Wavelet transform (DWT) [4] decomposes a signal into a two-dimensional function of time and scale. Wavelet functions used for signal analysis are derived from the initial function forming basis for the set of basis functions. Two types of basis functions normally used are:

- Scaling function $\Phi_{mk}(t)$

$$\Phi_{m,k}(t) = 2^{-\frac{m}{2}} \Phi_0(2^{-m}t - k) \quad (1)$$

- Wavelet $\Psi_{mk}(t)$

$$\Psi_{m,k}(t) = 2^{-\frac{m}{2}} \Psi_0(2^{-m}t - k) \quad (2)$$

where m is the scaling index and k is the time translation. Every basis function Ψ is orthogonal to every basis function Φ .

The wavelet transform [3] is implemented using a pair of filters: a low-pass filter L and a high-pass filter H , which split a signal's bandwidth in two halves. The forward wavelet transform of a discrete-time signal $x(n)$ ($0 \leq n < N - 1$) is performed by convolving the signal with both a half-band low-pass filter L and high-pass filter H and down-sampling by a factor of two.

Three dimensional wavelets can be derived from their one dimensional versions by their successive application in three spatial directions (x , y , and z). Fig. 2 shows a separable 3D decomposition of a volume. The volume $F(x, y, z)$ [3] is firstly filtered along the x dimension, resulting in a low-pass image $L(x, y, z)$ and a high-pass image $H(x, y, z)$. Both L and H are then filtered along the y dimension, resulting in four decomposed sub-volumes: LL , LH , HL and HH . Then each of these four sub-volumes are then filtered along the z dimension, resulting in eight sub-volumes: LLL , LLH , LHL , LHH , HLL , HLH , HHL and HHH (Fig 2).

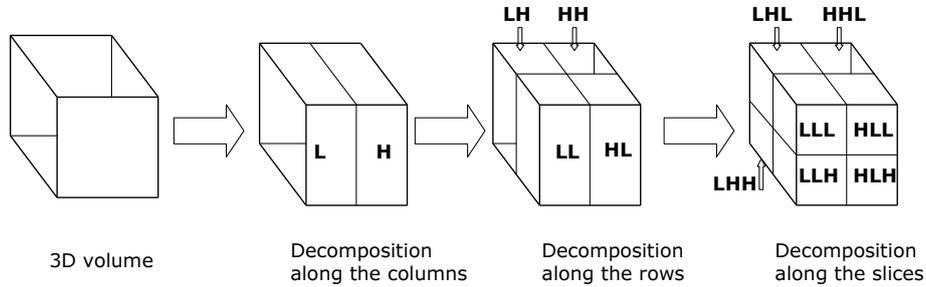


Figure 2: Three-dimensional WT decomposition

After decomposition it is possible to modify resulting coefficients before the reconstruction to eliminate undesirable signal components. To implement wavelet thresholding a wavelet shrinkage algorithm is applied which consists of the following steps:

- Application of the forward wavelet transform
- Estimation of a threshold
- Choice of shrinkage rule and application of the threshold according to the rule
- Evaluation of the inverse transform using the thresholded coefficients

3 Implementation of the Matlab Web Server

The MATLAB application resides on the server machine and the components of the MWS [2] include:

- `matlabserver` TCP/IP server running MATLAB continuously.
- `matweb.exe` common gateway interface (CGI) program that resides on the HTTP server and communicates with `matlabserver`. `matweb` requires information found in `matweb.conf` to locate `matlabserver`. An instance of `matweb.conf` looks like

```
[mri2D]
mlserver=atlas
mldir=H:/PHOBOS/MUSOKOV/m
```

where `mlserver` is the name of host running `matlabserver` and `mldir` is the working directory for reading m-files or save any generate any graphics writing files.
- Input HTML form data functions MATLAB utility functions that retrieve data from input HTML documents and then provide that data in a form convenient to MATLAB programmers.
- Output HTML document functions MATLAB functions for inserting MATLAB data into template HTML forms for return transmission to the end users Web browser.

There are three files associated with an `mri2D` function [1]:

- `mri2D_input.html`: the `mri2D` input document
- `mri2D_output.html`: the `mri2D` output document
- `mri2D.m`: the `mri2D` MATLAB m-file

Looking at the source from the `mri2D_plot.html` file there is a line

```
<input type="hidden" name="mlmfile" value="mri2D">
```

that sets the argument `mlmfile` to the value `mri2D`. The `mlmfile` argument contains the name of the MATLAB m-file to run. `matlabserver` uses the value of `mlmfile` obtained from the `matweb`, to run the MATLAB application. The `mri2D` takes the input data from `mri2D_input.html`, carries out the de-noising application and outputs the results using `mri2D_outpt.html` as a template.

The `mri2D` function uses the `htmlrep` command to place the computed graphics into the `mri2D_output.html` output template using the code

```
templatefile = which('mri2D_output.html');
rs = htmlrep(s, templatefile);
```

where `s` is a MATLAB structure containing the results of the `mri2D` computation. `htmlrep` extracts data from `s` and replaces variable fields in `mri2D_output.html` with the results of the MATLAB computation. The completed `mri2D_output.html` form is transmitted to the user's browser. In examining some parts of the `mri2D` and `mri3D` code, you will see how to include MATLAB graphics as part of a MATLAB Web Server application. The input document allows you to set the characteristics of the MRI plot you want to generate. The code in the source file

```
<form action="/cgibin/matweb.exe" method="POST"
target="outputwindow">
<input type="hidden" name="mlmfile" value="mri2D">
```

calls the `mri2D` function and targets the output to a frame on the lower portion of the input document itself. In `mri2D.m` the code

```
mlid = getfield(h,'mlid')
```

extracts `mliid` from the structure `h`. The `mliid` is a unique identifier that `matlabserver` provides. Using the value of `mliid` to construct filenames ensures that filenames are unique. The code

```
s.graf1 = sprintf('./icons/%smri2D.jpeg', mliid);
```

creates a name for a graphic (`jpeg`) file and save the files in the directory `/icons`.

The function `htmlrep` replaces MATLAB variable names that it finds in the HTML output template file `mri2D_output.html` with the values in the input structure `s` in our case `graph1`.

```
templatefile = which('mri2D_output.html');
rs = htmlrep(s, templatefile);
```

From the `mri2D_output.html`, `$graph1$`, the variable that represents the graphic output, is found in the line

```

```

An example of how of one level image processing of a noisy MR image slice is shown in Fig. 3 on an internet browser. In our demonstration the client has to select the type of data to be loaded, the number of levels and threshold value for de-noising of a noisy MRI slice.

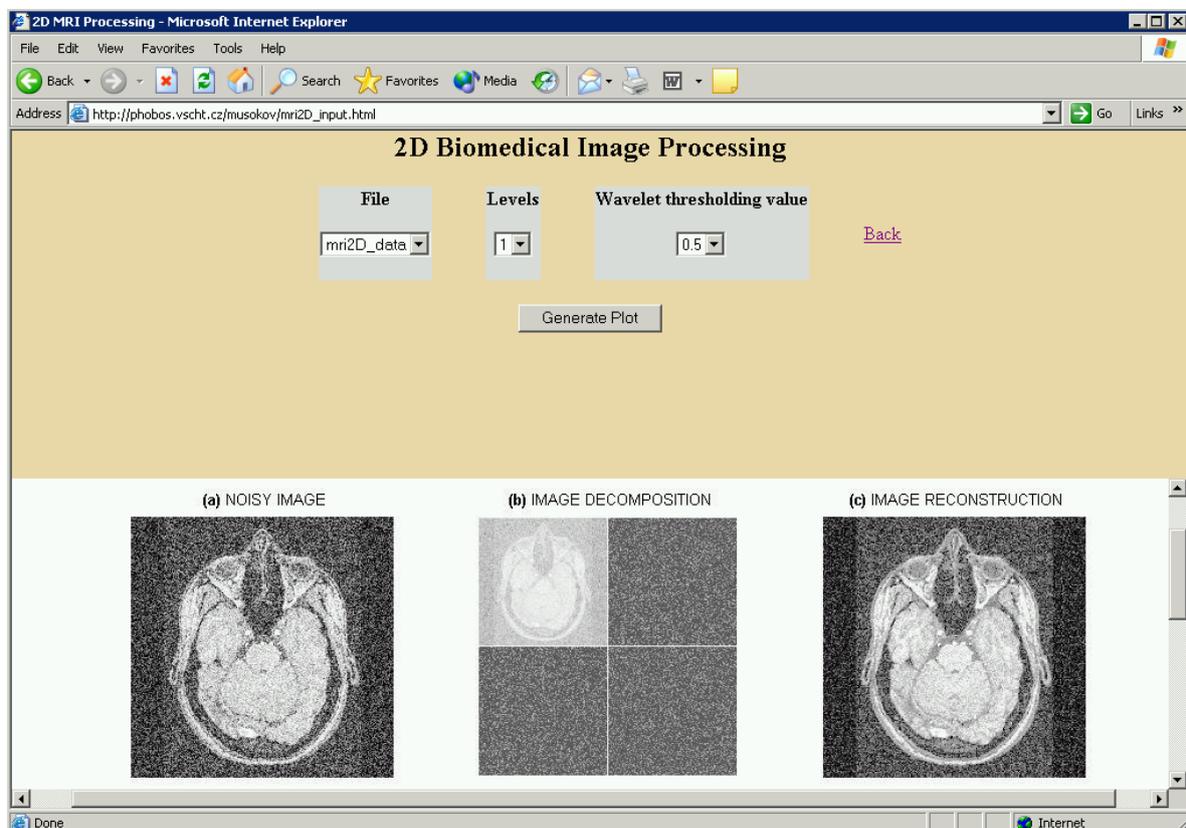


Figure 3: 2D biomedical image processing

The user's graphic interface for processing of 3D biomedical image is presented in Fig. 4, it is a template of an HTML form (the top frame). During the execution the user select the data file to be processed and choose the appropriate method of wavelet tresholding from the touch down button. After entering the suitable choice the user can press the **Generate plot** for the execution of the application.

The visualization and the graphical results are returned to the browser as an image in `jpeg` format as shown in Fig. 4. The demonstration of a 3D image processing was done using off-line results since computation of such large volumetric image data in real time takes is very long.

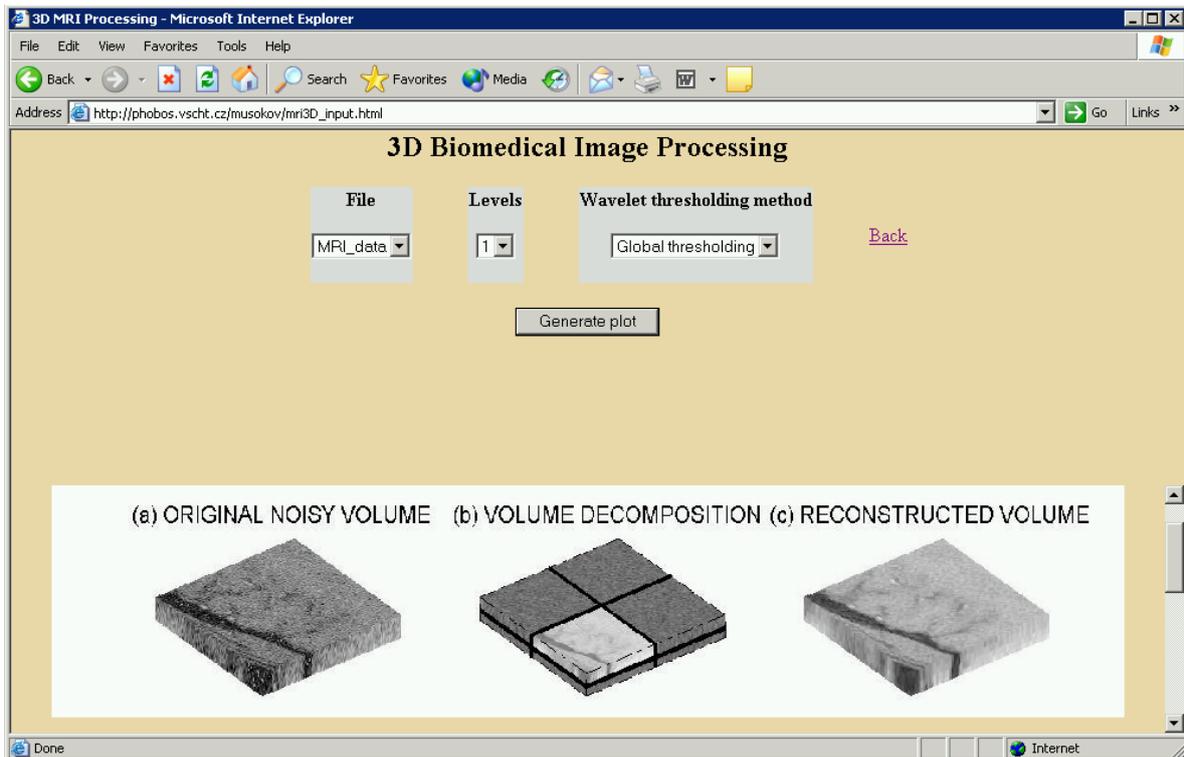


Figure 4: 3D biomedical image processing

4 Conclusion

With a large demand for a powerful graphical user interface (GUI) tools and a possibility of e-learning there is a need to improve the GUI and MWS as new educational tools. An increase in MWS graphical user interface capabilities can enhance a powerful tool for distance e-learning. Using e-learning material is interactive and the great advantage is that it allows clients to access MATLAB independent from place and time.

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References

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