**MATITK: Matlab-ITK Interface for Medical Image Processing**

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**Introduction and Motivation**

- **MATLAB (MATrix LABoratory)**
  - environment developed by Mathworks
  - often used by engineers and researchers
  - facilitates matrix manipulations, numeric computations and graphics viewing.
  - provides a high-level programming language that alleviates the users from low-level details such as memory management.
  - available MATLAB toolboxes handle complicated peripheral tasks, such as GUI creation, graph plotting, statistical analysis, and 2D image acquisition.
  - many researchers and engineers are comfortable with the one dimensional biomedical signal processing capabilities of MATLAB.
  - as the dimensionality of the data increases (to two and three dimensional images) both the unavailability of advanced algorithms and slow processing speed quickly become a bottleneck.

- **ITK**
  - part of the Visible Human project
  - free open-source toolkit written and used in C++ environment.
  - contains various multidimensional filtering, segmentation and registration algorithms designed for medical image analysis.

- It is desirable to
  - use the state-of-the-art, compiled, fast, 3D (and higher) medical image processing capabilities of ITK; and
  - work in the fast-prototyping, high-level, environment of MATLAB that doesn’t require intimate knowledge of C++, generic programming, and other advanced ITK programming concepts.

- Notably, because medical image data volumes are often huge, it is impractical to
  - write the image volumes to disk in a suitable format; and read the volumes back with pre-compiled ITK algorithms.

- With the help of the wrapper that we introduce, biomedical computing researchers familiar with MATLAB can harness the power of ITK while
  - avoiding learning C++ and dealing with low-level programming issues.
  - avoiding manual marshalling (translation performed by the wrapper is done in memory, which is an order of magnitude faster).

- New additions to extend MATLAB medical image processing functionality can readily be used by the
  - Statistical Parametric Mapping (SPM), and
  - Extensible MATLAB Medical Analysis (EMMA) communities.

**Overview**

- MATLAB has the functionality to access dynamically linked library compiled in another language such as C and Fortran.
- Such dynamically linked library, also referred to as MEX file (for MATLAB EXecutables), can be run from the MATLAB environment like MATLAB M-functions or built-in functions.
- The work presented is a MEX that serves as a wrapper, or an interface between MATLAB computation environment and ITK, hereafter referred to as MATITK.
- Because image data is represented differently, the wrapper provides the necessary translations in an efficient manner.

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**Methods (Implementation of MATITK)**

- We used the following in our development environment:
  - MATLAB 7.0 on MS Windows
  - ITK toolkit v1.80
  - A MATLAB compatible compiler. MS Visual Studio 2003 C++ compiler was used.

- MATITK itself is written in C++.
- When MATITK command is issued in MATLAB the code compiled from matk.cpp is executed.

- matk.cpp is responsible for error handling and translation of image data passed from MATLAB into ITK-compatible format.
- This includes dealing with indexing differences between MATLAB and C++ arrays (ordering of dimensions and zeros vs. one-based array indexing).
- The image passed from MATLAB will be stored in an ITK Image container.

- itkcore.cpp calls the code in one of the three files, depending on whether the command invoked is a medical image filtering, segmentation, or registration command.

- Helper classes seedcontainer.cpp and parametercontainer.cpp contain the user-supplied seeds and parameters respectively.

- ITK methods can access the necessary seed points and parameters in the three ITK core files.

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**Results and Conclusions**

- The following ITK methods are currently supported:

- **MATITK commands can then be invoked in MATLAB environment by simply typing matk; which writes the following to MATLAB's window:**

`matitk(operationName,[parameters],[inputArray1],[inputArray2]);` (where operationName is the name of the itk method to be invoked.

- The second argument to matk, parameters, specifies the required parameters of the ITK method to be invoked (specified by operationName). The parameters that are required for a particular method can be found out by typing matk(operationName);

- For example to perform anisotropic diffusion filtering on a 3D image, the user types matk("FCA") and the following will be written to MATLAB's window that lists the required parameters:

```
FCA is being executed... You must supply parameters for this function in an array, with the elements in this order:
   numberofiterations, timeStep (which usually has value equal to 0.00625),
   conductance (which usually has value equal to 3.0)

3 parameters must be supplied. You supplied 0.
```

- The third and fourth arguments to matk, inputArray1 and inputArray2, specify the input image volumes. They must be three dimensional and contain double data type elements.

- To demonstrate the use of MATITK, the following commands are executed:

```
>> load mr1; D=rand(3);
>> matitk(’FCA’,[5 0.0625 3],double(D));
FCA is being executed... FCA has completed.
>> matitk(’SSC’,[1.4 10.255],double(b),[],[102 82 25]);
SSC is being executed... SSC has completed.
```

- The purpose here, of course, is not to optimally analyze medical images but rather to demonstrate the use of MATITK. Execution takes a few second on a 3GHz PC in both cases.

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* Figures 1 and 2: Architectural Design of MATITK Framework.

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* Figures 1 and 2: Example ITK results. Left to right, top row: Original 3D image, anisotropic smoothing, connected component segmentation.

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* We presented MATITK, an easy to install, use, and extend, MATLAB-ITK interface. MATITK enables researchers and scientists to easily and efficiently access advanced medical image processing and analysis methods of ITK from MATLAB.