User's Guide

CSC_quantification: A MATLAB-based tool for cervical spinal cord atrophy quantification using MRI images

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Brief Description of CSC_quantification

CSC_quantification is a software tool developed on MATLAB, specifically designed to help neurologists measuring Cervical Spinal Cord atrophy and tracking Multiple Sclerosis patients.

System Requirements

CSC_quantification is developed on MATLAB R2023b, thus its system requirements are identical to those of MATLAB. The following are the minimum system requirements for running CSC_quantification.

- *Operating Systems*

    - For Windows: Windows 11, Windows 10 (version 21H2 or higher), Windows Server 2019, Windows Server 2022.
    - For Linux Ubuntu 22.04 LTS, Ubuntu 20.04 LTS, Debian 11, Red Hat Enterprise Linux 9, Red Hat Enterprise Linux 8 (minimum 8.6), Red Hat Enterprise Linux 7 (minimum 7.9), SUSE Linux Enterprise Desktop 15, SUSE Linux Enterprise Server 12 (minimum SP2), SUSE Linux Enterprise Server 15.
    - For Mac macOS Sonoma (14), macOS Ventura (13), macOS Monterey (12.6),

- *Processor*

Minimum: Any Intel or AMD x86-64 processor with two or more cores Recommended: Any Intel or AMD x86-64 processor with four or more cores and AVX2 instruction set support.

- *RAM*

Minimum: 8 GB, Recommended: 16 GB

- *Storage*

3.8 GB for just MATLAB; 4-6 GB for a typical installation; 23 GB for an all products installation. An SSD is strongly recommended.

- *Graphics*

No specific graphics card is required, but a hardware accelerated graphics card supporting OpenGL 3.3 with 1GB GPU memory is recommended.

Installation

We propose two solutions to run the CSC_quantification software.

▪ **First solution: CSC_quantification_MATLAB_GUI**

The first solution is a CSC_quantification GUI and shared as repository (*CSC_quantification_MATLAB_GUI*) including all required matlab files (**.m* and **.fig*). Matlab software (version R2023b) should be installed with all required toolboxes on your computer. The *CSC_quantification GUI* does not need any installation. You have only to add the whole repository to your Matlab search path by Home -> Set Path -> Add Folder.

To read MRI image, SPM is needed. In fact, SPM is an academic software toolkit for the analysis of functional imaging data, for users familiar with the underlying statistical, mathematical and image processing concepts. It is made freely available to the imaging community, to promote collaboration and a common analysis scheme across laboratories. The software represents the implementation of the theoretical concepts of Statistical Parametric Mapping in a complete analysis package. The SPM software is a suite of (MATLAB) functions and subroutines with some externally compiled C routines. SPM was written to organise and interpret our functional neuroimaging data. More details about SPM and link to download the adequate version are available here. SPM folder should be added to your Matlab search path by Home -> Set Path -> Add Folder.

Step 1(a): Ensure that Matlab has been installed on your computer. Then, open Matlab and go to the directory where is contained the downloaded *CSC_quantification_MATLAB_GUI* folder. Therefore, open the main file of our software: *Patient_Information.m* file. Once you have located the file and opened it, select the "Run" button to execute it.
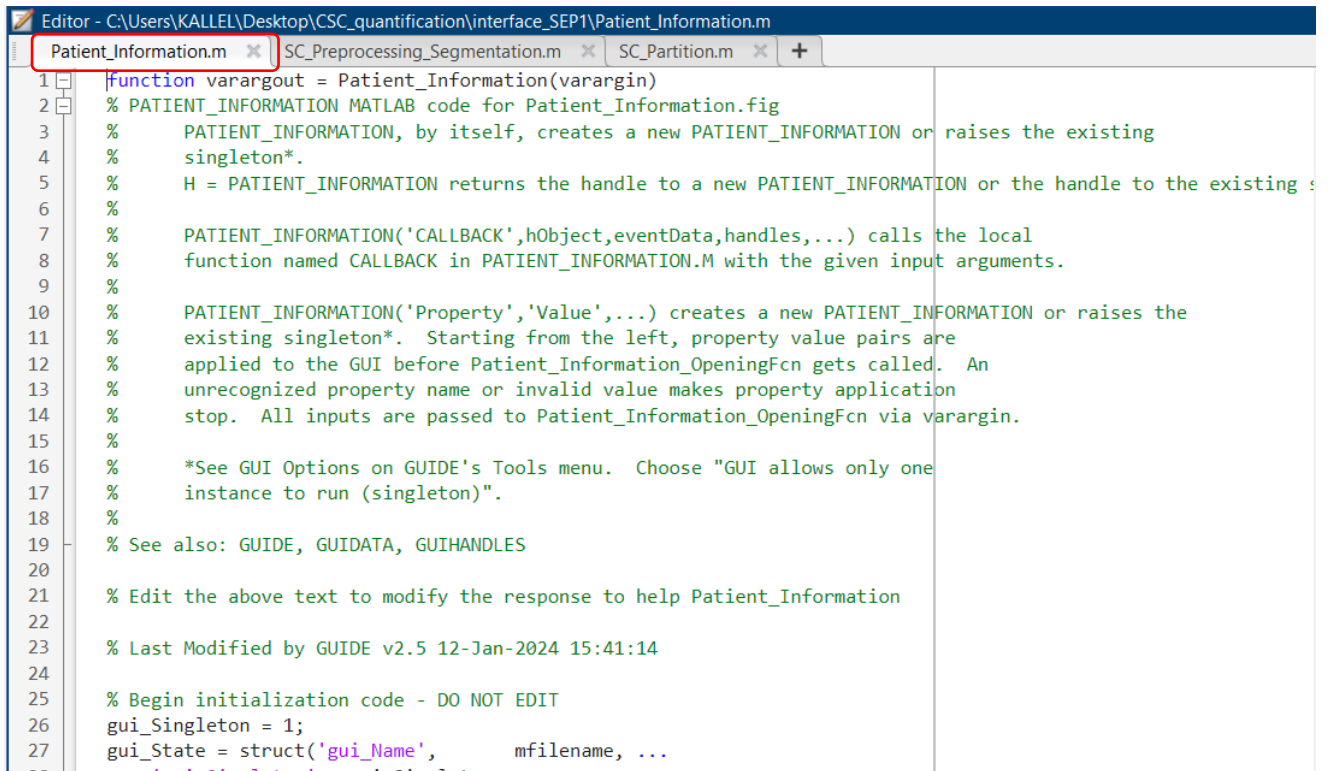

Figure 1. *The display of the Patient_Information.m file*

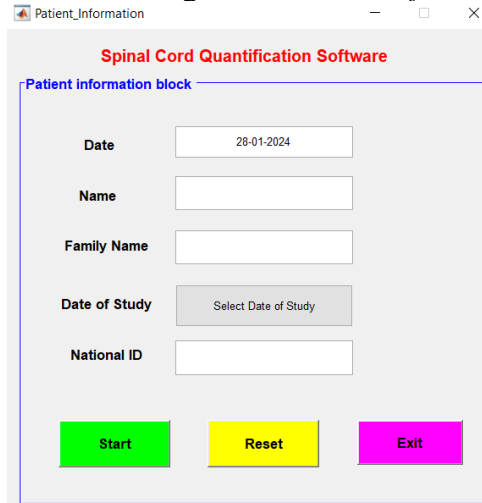Once "Run" button is pressed, the following main *Patient_Information* block is opened.

Figure 2. *The display of the Patient_Information block*

▪ **Second solution: CSC_quantification_Compiled_App**

The second solution is a compiled MATLAB application shared as a repository (*CSC_quantification_Compiled_App*) including an Executable file (CSC_quantification.exe). This solution gives users the ability to run our compiled MATLAB application without installing MATLAB software. However, MATLAB Runtime (R2023b) should be installed. It is possible to download and install the adequate version of the MATLAB Runtime for R2023b (available for Windows, Linux and Mac) from the following link.

Step 1(b): Ensure that MATLAB Runtime for R2023b has been installed on your computer. Then, open the directory where is contained the downloaded *CSC_quantification_Compiled_App* folder. Therefore, open the executable file of our software: *CSC_quantification.exe file. The Patient_Information block,* presented by Fig.3., and the same as presented by Fig.2., is displayed.
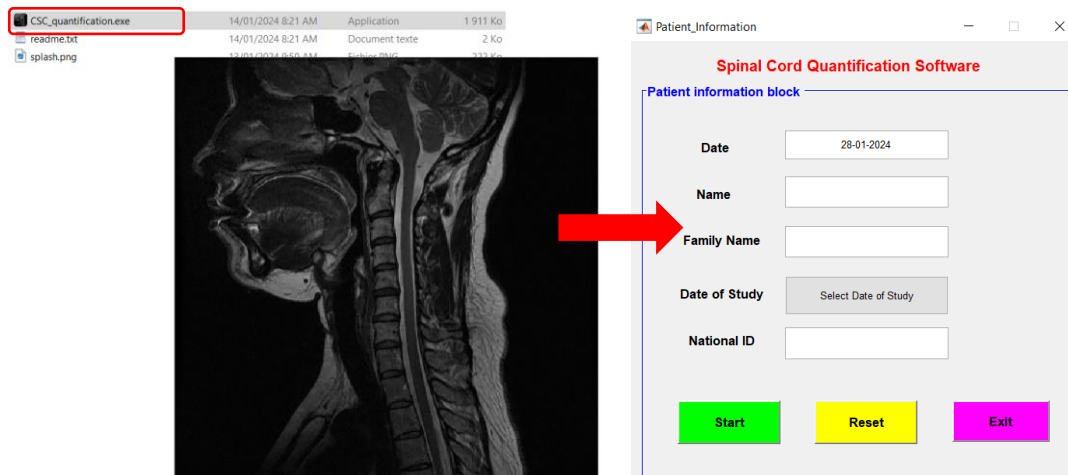

Figure 3. *The display of the Patient_Information block*

Patient_information block is used to collect and save basic information, especially Study date, Name, Family Name, and National ID, related to a particular patient. In addition, this block included three buttons labeled as Start, Reset and Exit useful to, respectively, open *SC_preprocessing_segmentation* block, reset all information of the considered patient and exit the block. An example of this block is presented in Fig.2.

All following blocks of the software and their corresponding description are identical for both presented solutions.

Step 2: *SC_Preprocessing_Segmentation* block include five blocks. The first is image and slice selection block used to load sagittal T2-w MRI and select and display the best slice.

The proposed software was configured by default to operate with *.nii* Sagittal T2-w MRI. However, additional image formats such as *.img* and *.*dcm* are also supported. As depicted in Figure 4, it could be selected at line 97 of the source code of the *SC_Preprocessing_Segmentation matlab* function (*SC_Preprocessing_Segmentation.m* file).

```
97     [NomFich,NomEmp] = uigetfile({'*.nii';'*.img';'*.dcm'},'File Selector');
98     if isequal(NomFich,0)
99         disp('Image not displayed') ;
100    else
101        disp(['Image displayed ', fullfile(NomEmp,NomFich)]);
102    end
```

Figure.4. *The display of the SC_Preprocessing_Segmentation.m file*

The image to be uploaded should be placed in the **main folder** of the proposed software (*CSC_quantification_MATLAB_GUI* folder for the first solution and CSC_quantification_Compiled_App folder for the second solution). An example of Sagittal T2-w MRI (T2_medull_sag_X055.nii) is included in both folders and could be considered to test our proposed software.

The user must select the T2-w MRI to be uploaded and the number of corresponding slices will be automatically calculated. The user must therefore select the and display the best slice.

To improve the illumination information of the selected slice and display the generated enhanced image, a contrast enhancement block is considered. Since the principal task of this research work is the quantification of the CSC, ROI selection block is integrated to define the desired region of the SC. Furthermore, a SC segmentation block is considered to extract the CSC using the localized active contour method. We note here that user needs to point the cursor inside the SC to initialize the segmentation process. When the desired segmentation result of SC is achieved, the stop segmentation button is pressed as well as the display button to get extracted SC. Finally, the Start SC partition button opens the SC Partition block. Reset button could be used to restart all the already described steps.
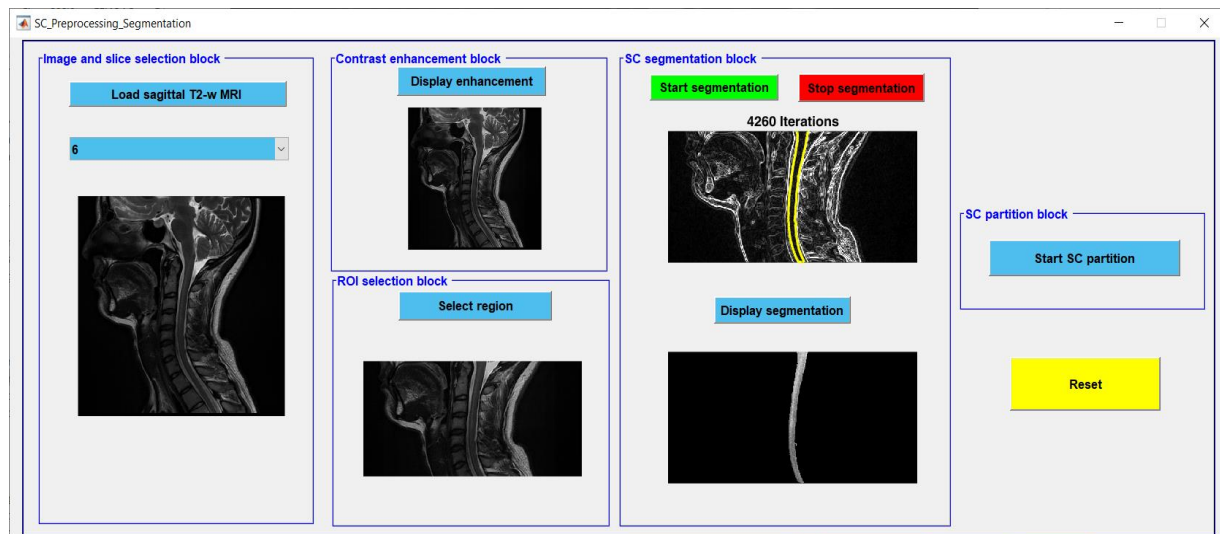

Figure.5. *SC_Preprocessing_Segmentation block in CSC quantification software*

Step 3: *SC_partition* block contains three blocks. The first SC partition block is used to shift the squelotonized SC shown in red colour towards vertebrae by changing shifting value. Once red line has been well positioned, the second SC display block is used to display fragmented and labeled SC for all vertebral levels. In fact, a specific color and number is attributed to each SC fragment. The indicated number corresponds to patient vertebrae level. Finally, the SC measures block opens the SC quantification block. While, reset button could be used to restart all the already described steps.
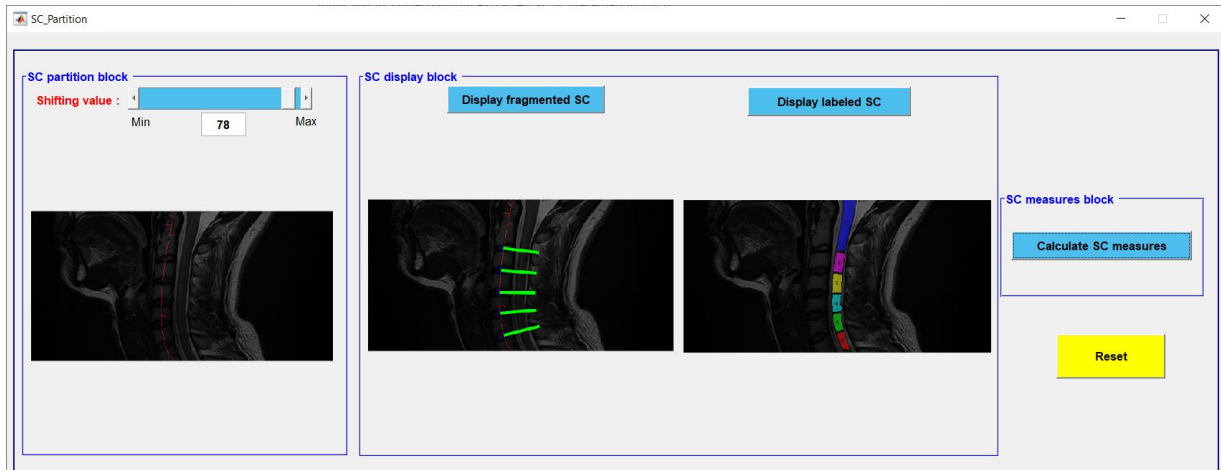

Figure.6. *SC_partition block in CSC quantification software*

Step 4: *SC_quantification* block included several buttons used to display considered measurements related to lower-diameter, upper-diameter, length and volume for all segments with numbers indicated in the first column. Also, total CSC length and total CSC volume could be computed and displayed using adequate buttons. A saving button is designed to export SC measurements in Excel file with a name generated as: *Name_FamilyName_NationalID* specified in the first block of the software.

For a particular patient, imaged several times and so having multiple MRIs, SC measurements of the different follow-up images could be saved in different sheets of the same Excel file. The date of MRI acquisition, specified as the date of study in the *Patient_information* block, is used to rename a particular sheet. This file serves as a reliable source of information. It assists neurologist in making their reports and facilitate their results analysis.

Figure.7. *SC_quantification block in CSC quantification software*

The following figure illustrates an example of a particular patient imaged 3 times and so having 3-follow-up MRIs. We note here that three different sheets are generated, each one with the date of each Study date.
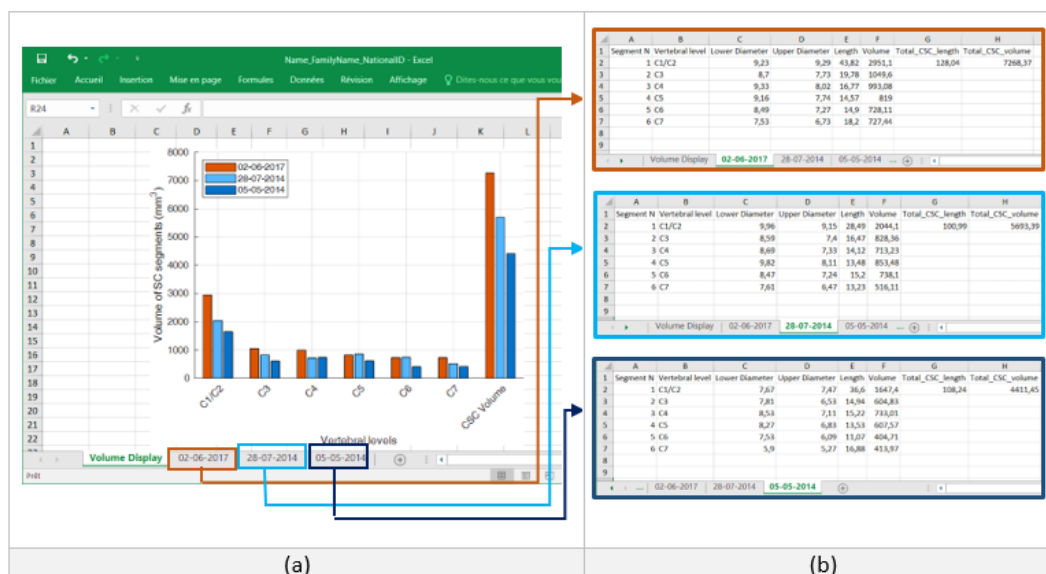

Figure.8. Generated Excel file for 3 follow-up MRIs of RRMS patient; (a) Volume display of SC segments and total CSC volume per vertebral levels, (b) 3 follow-up MRIs measures of a given RRMS patient