Cardiovascular and Pulmonary Model Format (CPM) Version 2.0

(Version 2013.07.12.1)

Executive Summary

This document serves as a reference for the Cardiovascular and Pulmonary Model (CPM) file format. After a brief introduction, the file format and standard conventions are detailed in the sections that follow.

Introduction

A file format for cardiovascular and pulmonary models (CPMs) has been developed. While several existing file formats were considered for the Cardiovascular and Pulmonary Model Repository, the format specified herein has been developed to enable the representation of anatomy and physiology necessary for cardiovascular and pulmonary simulation (see Figure 1). The driving principles behind the design of the format are simplicity and functionality. That is, an attempt has been made to avoid a common pitfall of many proposed "standards" that they are so complex and comprehensive that no full implementation ever exists (or takes years to develop). The latest version of this document can always be found on the model repository website (i.e. http://www.vascularmodel.com).

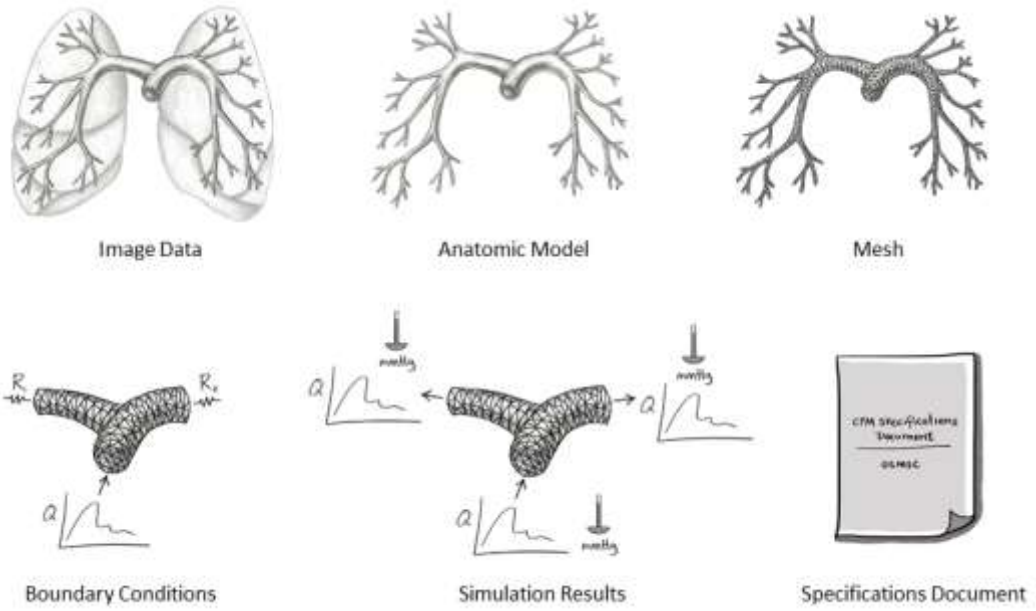

Figure 1: Schematic of Information Contained in a CPM Formatted Model.

Specification

The format has several required conventions. First a parent level directory must be created, and all the files and directories must adhere to the conventions specified in this document (i.e. the "Cardiovascular and Pulmonary Model Format Version 2.0"). It should be noted that the standard describes valid methodology for user and proprietary extensions to the data contained in the directory. For example, a vendor may implement a custom anatomic model representation. As long as the required representation is also created, both the proprietary and the standard anatomic representations can be created and stored in a single CPM directory structure. By convention, each "patient" or "subject" will have a given directory (e.g. "coronary_subject" and "carotid_subject").

Under the parent directory, a single CPM file (by convention <subject>.cpm) will contain the information to specify the contents of the "subject" directory. This CPM file utilizes the now-common Extensible Markup Language (XML) to store information. XML is a simple, very flexible text format derived from SGML (ISO 8879). While originally developed for electronic publishing, XML today is used in numerous applications for the exchange of a wide variety of data on the Web and elsewhere. See http://www.w3.org/XML/ for additional details on the XML standard.

Much of the content associated with a model (e.g. image data, finite element meshes, etc.) can be large and has data type-specific information. For large data structures, CPM relies on using data structures widely supported and standardized by the Visualization Toolkit (VTK). VTK has file formats for representing medical image data (vtkStructuredGrid), finite element analysis results (vtkUnstructuredGrid), and surfaces (vtkPolyData). It should be noted that these files are also stored by convention in XML format in the CPM directory structure. Additional information on the Visualization Toolkit and its supported file formats can be found elsewhere (e.g. http://www.vtk.org).

XML Tags (.CPM file)

Unique tags used in the XML formatted <subject>.cpm file are given in Table 1. Table 2 provides additional details regarding allowable variable values.

Table 1: Cardiovascular and Pulmonary Model Tags.

TAG	DETAILS
cardiovascular pulmonary model	<cardiovascular_pulmonary_model creation_date=TIMESTAMP modification_date=TIMESTAMP />
patient information	<patient_information creation_date=TIMESTAMP modification_date=TIMESTAMP patient_age=AGE patient_sex=GENDER />

image temporal data series	<image_temporal_data_series creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID > SERIES_ID_1 SERIES_ID_2 ... </image_temporal_data_series>
image data frame	<image_data_frame creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID time=REAL image_obj_identifier=REF_ID />
vessel centerline path	<vessel_centerline_path creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID name=NAME path_id=PATH_ID linear_path_obj_identifier=REF_ID spline_path_obj_identifier=REF_ID />
segmentation 2d	<segmentation_2d creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID spline_path_position_id=PATH_POS_ID segmentation_obj_identifier=REF_ID />
ordered vessel 2d segmentations	<ordered_vessel_2d_segmentations creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID name=NAME > SERIES_ID_1 SERIES_ID_2 ... </ordered_vessel_2d_segmentations>
anatomic model surface representation	<anatomic_model_surface_representation creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID name=NAME surface_obj_identifier=REF_ID />
associate pictures to anatomic model	<associate_pictures_to_anatomic_model creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID anatomic_model_identifier=REF_ID > SERIES_ID_1 SERIES_ID_2 ... </associate_pictures_to_anatomic_model>

surface results	<surface_results creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID surface_obj_identifier=REF_ID field_name=STRING text_description=STRING display_min_data_range=REAL display_max_data_range=REAL />
associate surface results to anatomic model	<associate_surface_results_to_anatomic_model creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID anatomic_model_identifier=REF_ID > SERIES_ID_1 SERIES_ID_2 ... </associate_surface_results_to_anatomic_model>
saved state	<saved_state creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID name=NAME selected_image_temporal_data_series=REF_ID selected_image_temporal_data_series_frame=FRAME_ID />
vtkpolydata object	<vtkpolydata_object creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID file=RELATIVE_FILENAME units=LENGTH_UNITS />
vtkstructuredgrid object	<vtkstructuredgrid_object creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID file=RELATIVE_FILENAME units=LENGTH_UNITS />
picture object	<picture_object creation_date=TIMESTAMP modification_date=TIMESTAMP identifier=ID file=RELATIVE_FILENAME text_description=STRING />

Table 2: Variable Types

Data	Definition	Type	Values
AGE	patient age	integer	ge in years
GENDER	patient gender	char	values: "M" Male values: "F" Female values: "O" Unknown/Omitted
NAME	Human readable string	string	Typically unique among object types
RELATIVE_FILENAME	File name relative to CPM directory	string	Valid system filename for Windows & Linux
ID	unique identifier	integer	Unique
REF_ID	Reference to an ID	integer	Id
SERIES_ID_xxx	Reference to an ID	integer	Id
PATH_ID	unique among paths	integer	unique among paths
PATH_POS_ID	Position along a spline path	integer	path positions are numbered sequentially starting at 0
FRAME_ID	ID reference to an image frame	integer	Image frames are number sequentially starting at 0

Representative Implementation

OSMSC has created a software application (**cpmViewer**) to serve as a representative example of utilizing the CPM file format. **cpmViewer** enables the user to visualize the image data, anatomic model, and selected simulation results for a particular model (see Figure 2). In particular, it supports storing and displaying surface based results (e.g. TAWSS, mean pressure, etc.). The left side of Figure 2 shows the surface plot of TAWSS embedded in the volume rendered image data. In addition, result "plots" can be stored in the CPM. The plots are stored as bitmap images, so this enables the inclusion of X-Y style plots as well as select simulation result images as shown in the lower right corner of Figure 2.

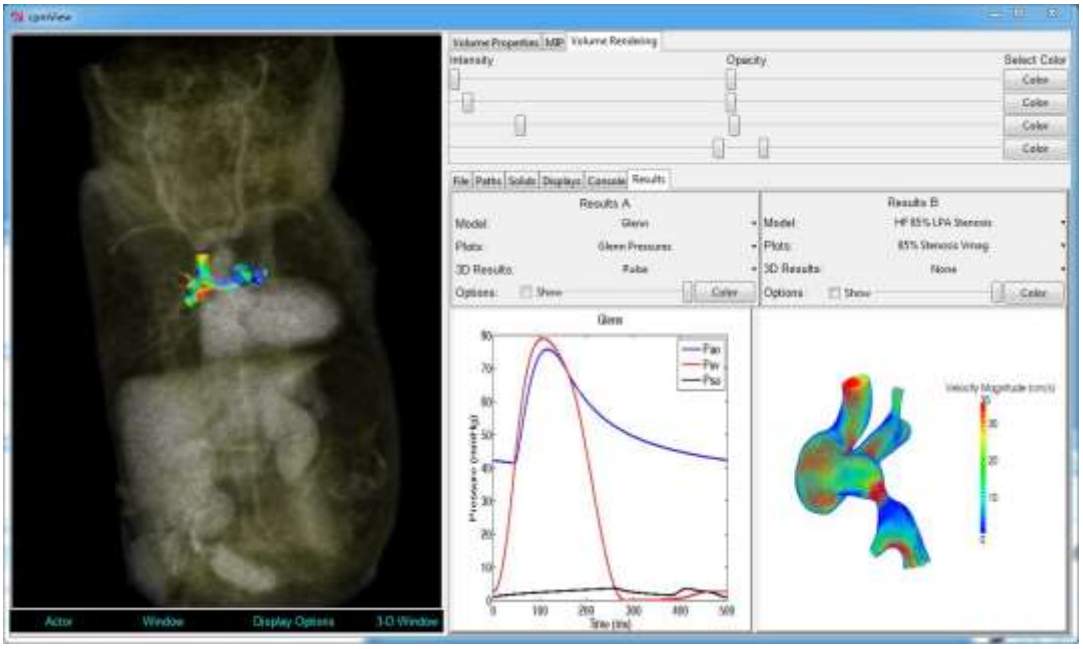

Figure 2: cpmViewer results interface. The figure shows a volume rendering of image data with the TAWSS results included. In addition, cpmViewer has been extended to include results "plots."