Helping Middle School Teachers Create Problems and Analyze Student Performance Using Electrical Circuit Library Modeled in WebGME

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Scope and Motivation

- Creation of course modules often involves unnecessary tedious work on part of the teachers
- The WebGME environment supports instantiation of created models
- This feature can be used to easily develop more well structured course modules for middle school STEM classrooms
- For example, providing teachers a metamodel with a library of well-defined electrical circuit blocks can help them to easily create example problems related to particular circuit analysis concepts
- The model data generated using a plugin from WebGME can be exported to MATLAB for generation of correct solutions to the example problems

Scope and Motivation (Contd.)

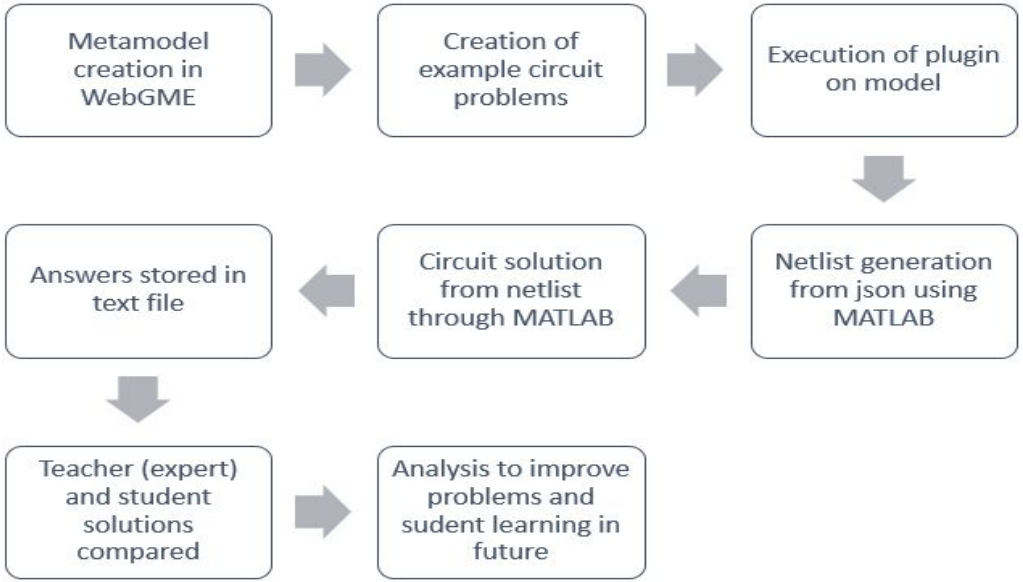
- Mathematical solution of the problem by students can also be scaffolded using a Matlab script, so that they can focus on learning concepts instead of losing time on calculations
- Students can check their own solutions against the expert (teacher) model solution
- Comparison of students' solutions with expert model solutions can help teachers keep track of students' class performance and thus measure their understanding of the problem, thereby gauging their change in learning over time
- Middle school teachers can apply this understanding to create future course modules which are more in accordance to the students' needs based on their class performance.

Model Description

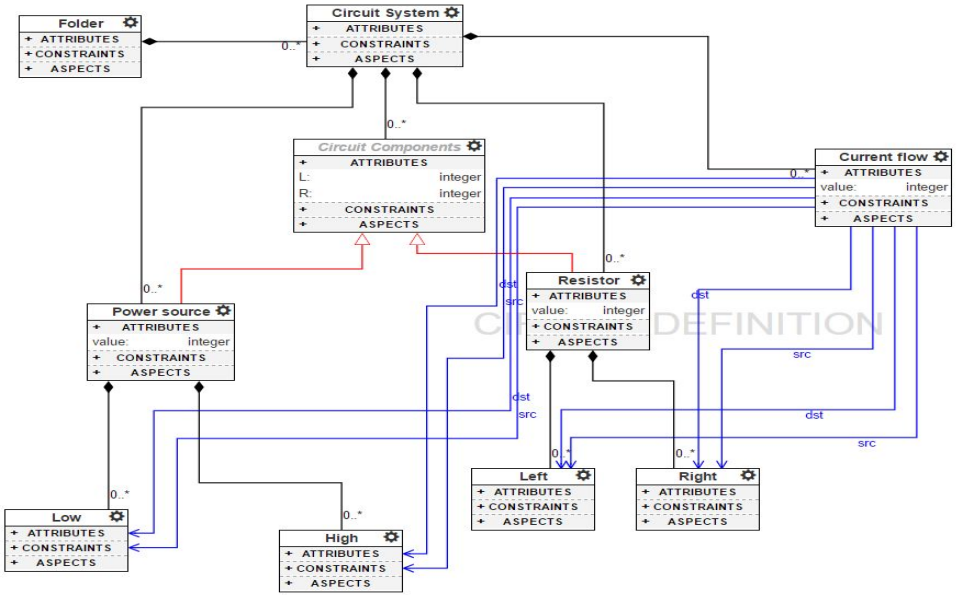
Expert Model

- Passive electrical circuit elements are modeled and integrated into a design library within WebGME.
- Accurate representation of the schematic would imply that the teacher can export the data (for example, values of the source voltage and load resistance if a simple resistive circuit is considered).
- MATLAB has been used here to intercept the model data.
- The teacher can solve for the desired system variables (say, value of current in different branches) and create an expert model that can act as a reference point for validating students' work.

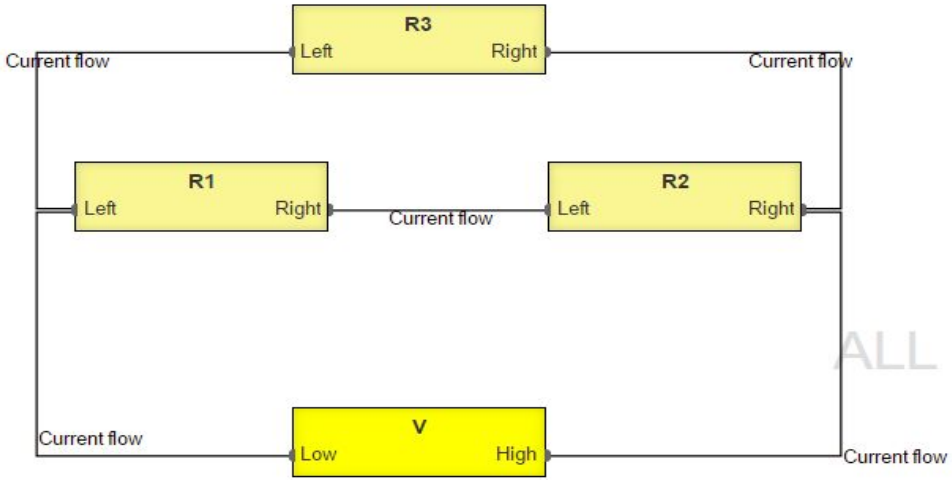
Project Work Flow



Metamodel


Folder
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
Circuit System
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
Circuit Components
+ ATTRIBUTES
L: integer
R: integer
+ CONSTRAINTS
+ ASPECTS
Current flow
+ ATTRIBUTES
value: integer
+ CONSTRAINTS
+ ASPECTS
Resistor
+ ATTRIBUTES
value: integer
+ CONSTRAINTS
+ ASPECTS
Power source
+ ATTRIBUTES
value: integer
+ CONSTRAINTS
+ ASPECTS
Low
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
High
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
Left
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
Right
+ ATTRIBUTES
+ CONSTRAINTS
+ ASPECTS
0..*
dst
src

An example circuit



Netlist Generation

```
V1 0 1 30
R1 0 2 10
R2 2 1 5
R3 0 1 5
```

The above netlist is a 4-tuple of {Component Name, Node 1, Node 2, Value}.

Using the node numbers, all components of a circuit can be connected.

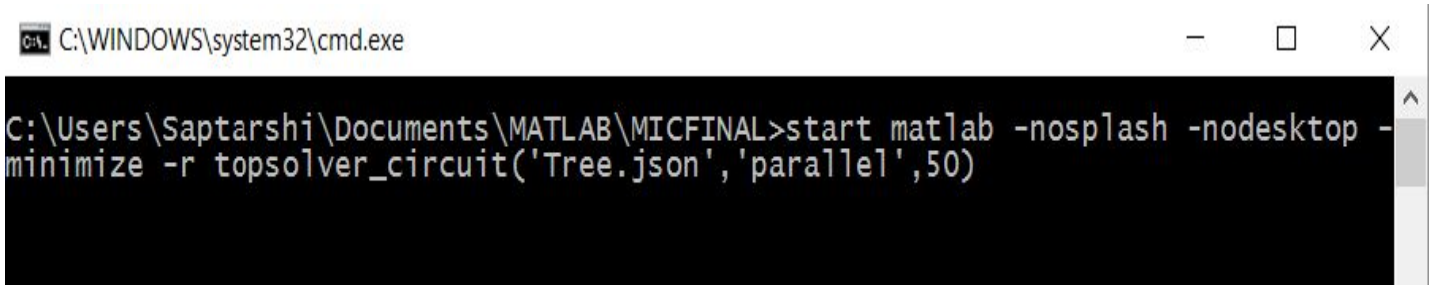
Solution to Node Voltage and Branch Current using a SPICE-like solver in MATLAB

- Solver takes netlist as input
- Solves in accordance to Kirchoff's Voltage and Current Laws
- Returns node voltage and current expressions as well as evaluations
- Logs the results in a text file

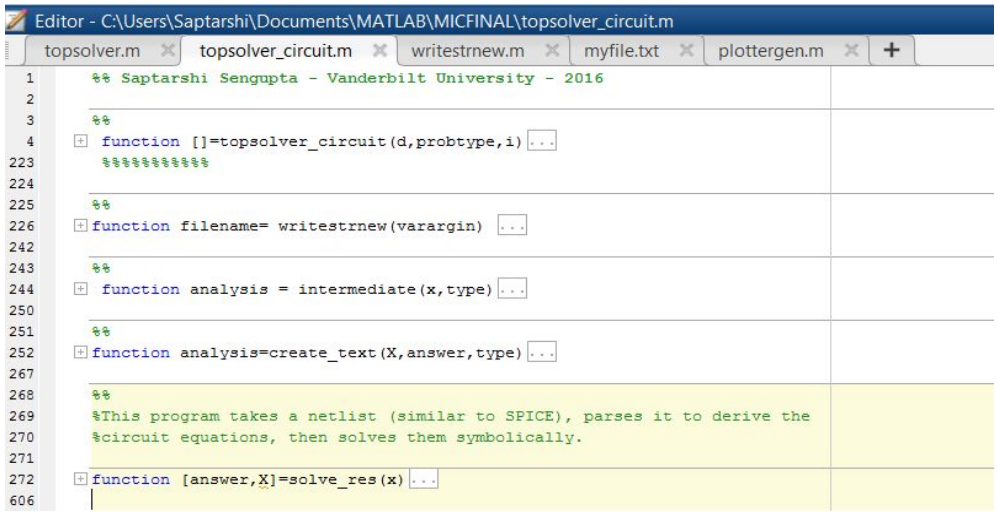
Solver Workflow - Top Level

The top level function takes three input arguments:

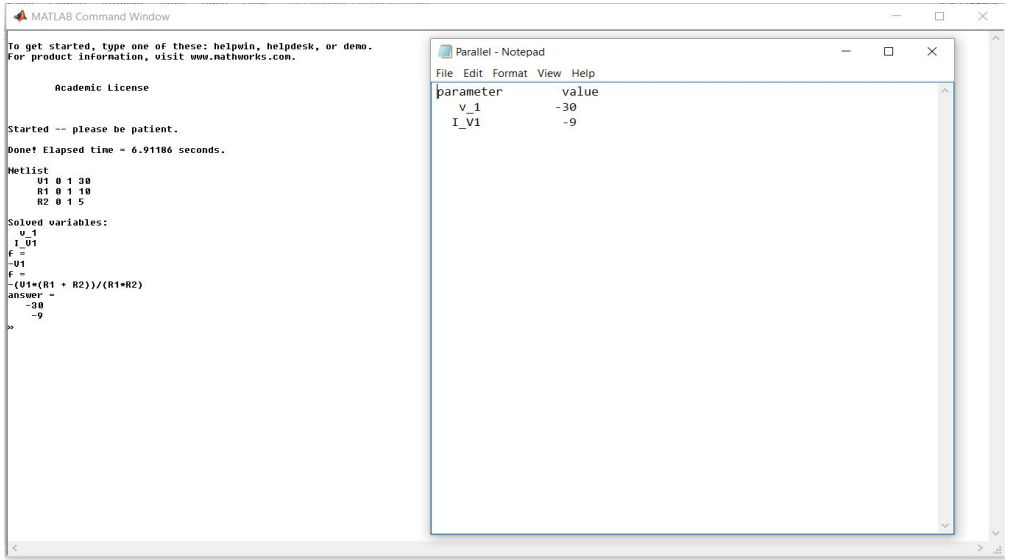
Tree.json
Type of Circuit
No of students in the class



Solver Workflow - Background

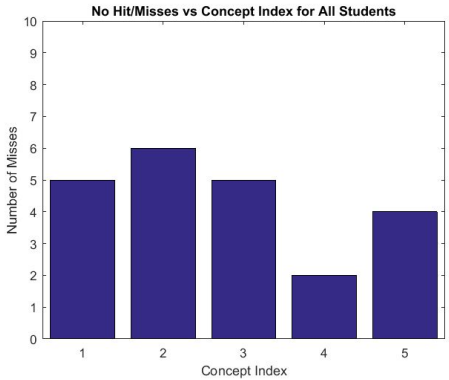


Solver Workflow - Results

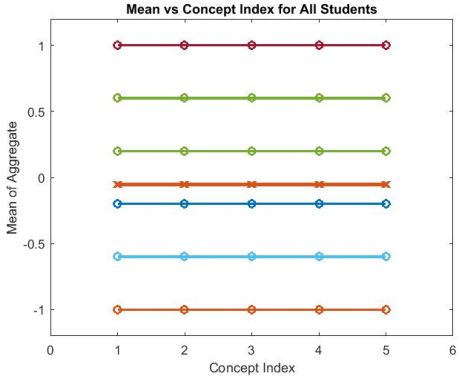


Student Performance Analysis

Relevant Sample Analysis Results generated using data drawn randomly from a uniform distribution



Concept 2 was least excelled in & Concept 4 was most



Student Standing wrt Mean Performance

Summary of Work Done

- Creation of a test circuit metamodel
- Definition of example circuit problems using several types of combinations of V-R components
- Generation of the json file containing problem data using a plugin in WebGME
- Exporting the problem data from the json to a MATLAB script to compute expert model solution, which is saved in a text file
- Relevant sample analysis of the solutions generated by different students and comparison with expert model solutions over some circuit design concepts, to identify potential shortcomings in understanding concepts
- This analysis can help the teacher to give student-specific feedback and also analyse any possible changes in future teaching methodologies

Resources Used / References

- Lecture Notes and WebGME Github Resources, CS 6388, Vanderbilt University School of Engineering
- MATLAB R2016a
- MATLAB Documentation
- Symbolic Circuit Analysis in MATLAB (SCAM) © Swarthmore College
- JSONLAB: A Toolbox to encode/decode JSON Files

Thank you