NAME

Quantum Apprentice – visualization and execution for D-Wave System

SYNOPSIS

Quantum Apprentice is a Microsoft Excel application for visualizing and exploring some simple qubit systems, the D-Wave 128-qubit simulator and remote systems.

DESCRIPTION

Quantum Apprentice is designed to help users become familiar with the QUBO programming model and to also provide visualization and execution of quantum machine instructions on the D-Wave System. The functionality of Quantum Apprentice (QuApp) is organized around a set of worksheet tabs. The following description matches the seven tabs of QuApp:

TAB: Two Qubits

Displays a two-qubit system. Allows the user to adjust the two weights corresponding to the two qubits, plus the strength corresponding to the coupler which connects the two qubits. The objective values for the four possible states are automatically updated. The states which have the lowest objective value are highlighted.

TAB: Three Qubits

Displays a completely connected three-qubit system. Allows the user to adjust the three weights corresponding to the three qubits, plus the three strengths corresponding to the couplers which connect the qubits. The objective values for the eight possible states are automatically updated. The states which have the lowest objective value are highlighted.

TAB: Four Qubits

Displays a completely connected four-qubit system. Allows the user to adjust the four weights corresponding to the four qubits, plus the six strengths corresponding to the couplers which connect the qubits. The objective values for the sixteen possible

states are automatically updated. The states which have the lowest objective value are highlighted.

TAB: Chimera

Displays the 128-qubit D-Wave simulator and also remote systems. Supports the qubit and coupler numbering scheme used by dw. Select a qubit or coupler with your mouse and its label is displayed in the Excel Name Box. Once a qubit or coupler has been selected, click the View QMI button to change to the QMI tab. The cell corresponding to the qubit weight or coupler strength will be active. Use the Random button to generate random values for all qubit weights and coupler strengths. Use the Reset button to return all qubit weights and coupler strengths to their uninitialized state. The color legend indicates the dynamic range for weights and strengths: [-10,10].

TAB: QMI

Displays the entire set of weights and strengths available to the 128-qubit simulator or remote system. The yellow bars on the right side of the display show the qubit section and coupler section. The coupler section can be further divided into intra-cell and inter-cell. Intra-cell couplers connect two qubits within the same unit cell (group of eight qubits) and inter-cell couplers connect two qubits from neighboring unit cells. The inter-cell couplers can be further divided into the horizontal and vertical couplers, depending on whether the two unit cells are in the same row or column of the grid.

This tab allows the user to enter numeric values for qubit weights and coupler strengths. Remember to restrict values to the range [-10,10]. Once a weight or strength has been modified on this tab, the color code of the corresponding object on the Chimera tab will change to reflect the new coefficient.

In addition to the weights and strengths, each QMI contains two additional scalar fields: constant_offset and scale_factor. These values can be edited on this tab, and are saved and loaded along with the qubit weights and coupler strengths. These scalar values are used in computing the objective for each sample.

TAB: Solution

Displays individual qubit values in a solution file. Data from the solution file is displayed in the table on the upper right side of the tab, as well as in the individual qubit values. When

a solution is loaded (see Problem History), the first solution is displayed in the qubit values. The table also displays the total number of distinct solutions, the number of the displayed solution, the number of times the displayed solution appears in the solution file, and the objective of the displayed solution. Use the Next Solution button to advance through the solutions contained in a file. The Prior Solution button returns the user to an earlier solution. Use Clear Solution to reinitialize the Solution tab to its blank state. The solution displayed on this tab is also rendered on the Chimera tab with blue representing the value 0 and red representing the value 1.

TAB: Problem History

Displays information about QMI and SOL files that have been loaded into Quantum Apprentice.

At start-up the selected workspace is $DWAVE_HOME/workspace.c4 in single-user mode or $DWAVE_WORKSPACE/workspace.c4 in multi-user mode. This is the built-in workspace for the 128-qubit simulator. To change to a different workspace, click Select Workspace and use the "Select a workspace directory" dialog to navigate to a new workspace. Note that the workspace *must* be located beneath $DWAVE_HOME/workspace.* or $DWAVE_WORKSPACE/workspace.* depending on mode. Use dw(1) commands to create new workspaces. The Geometry field on this tab displays the geometry name given to the workspace when it was created.

If two solvers have identical geometries as specified by the parameters L, M and N and the set of active qubits, then dw will assign these two solvers to the same workspace. In this case there are multiple configurations for the workspace. Each configuration is identified by a connection name and solver. When executing a QMI, the current configuration specifies the connection and solver to use. To change to a new configuration for a given workspace, use the Select Configuration button. The Connection and Solver fields on this tab display information from the current configuration.

Click Refresh History to load Quantum Apprentice with the newest set of QMI and SOL files. These files are binary format files, typically read and written by Quantum Apprentice and dw(1). The location of these files is determined by the $DWAVE_HOME or $DWAVE_WORKSPACE environment variable and the current workspace.

QMI and SOL files contain quantum machine instructions and solutions. These files have a binary format which is very close to the sapi_Problem and sapi_IsingResult data structures defined in dwave_sapi.h. When Refresh History is clicked, Quantum Apprentice scans the current workspace directory, lists the files with .qmi suffix under ***QMI name***, and lists the files with .sol suffix under ***Solution name***.

The Clear History button clears the entries under ***QMI name*** and ***Solution name***. Pressing this button does not delete any of the contents of the current workspace directory, so it is perfectly safe to press Clear History followed by Refresh History at any time to ensure that you have an up-to-date view.

After editing qubit weights and coupler strengths via the Chimera and QMI tabs, you can save the resulting QMI via the Save QMI button. Pressing this button pops up a dialog box in which you can specify the name for the generated QMI file. Do not include the .qmi suffix when you specify the name for the QMI. When you save the QMI, the Chimera and QMI tabs will not be cleared. To see the newly saved QMI under ***QMI name*** you will need to press the Refresh History button.

To load a QMI that you have created and saved earlier, use the Load QMI button. First, select a QMI from the ***QMI name*** column and then press the Load QMI button. The qubit weights and couplers strengths from the saved QMI will be loaded into Quantum Apprentice and displayed as numeric values in the QMI tab and as color-coded values on the Chimera tab.

To execute a QMI, first select a QMI from the ***QMI name*** column, then press the Execute QMI button. You will be prompted to provide a name for the solution file which will contain the results of executing this QMI. Do not include the .sol suffix when providing the solution file name. To see the new solution file, press Refresh History. You may then select the solution under ***Solution name*** and press the Load Solution button. The sample with the lowest objective value will be displayed in the Solution tab. You may use buttons on that tab to see the distinct samples generated while executing the QMI.

Finally, the Generate C button will write out a C source file in the current workspace directory. This C source file contains the QMI that you have currently loaded into the Chimera and QMI tab. Press Generate C and supply the name for the output file –

without the .c suffix. Use a text editor to look at the generated file in the current workspace directory. The C source file begins with a comment which contains instructions for compiling and linking the generated problem. Execute the compiled program to see the qubit values for each solution.

By default, simulator executions triggered from Quantum Apprentice cause 10 samples to be generated from each QMI. To change this number, use the cell labeled Solutions on the Problem History tab. Enter the number 1000 into this cell to cause Execute QMI and Generate C to generate 1000 samples.

FILES

$HOME/.dwrc

See the dwrc(5) man page for a description of the contents of the $HOME/.dwrc file. This file names the connections available to the user.

BUGS

Please report bugs to dwsupport@dwavesys.com.

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SEE ALSO

The Execute QMI feature relies on an external utility named quapp which is not intended to be used directly by users. Correctly installing and configuring the D-Wave Simulator is necessary so that Quantum Apprentice will link with the quapp utility.

dw(1), dwrc(5)