Quantum Computing: Solving the Lipkin Hamiltonian Using Variational Quantum Eigensolver

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(Dated: May 27, 2023)

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I. INTRODUCTION

Quantum physics is all about solving the Hamiltonian. With the development of quantum computer, one would assume that it is only natraul to solve quantum problems with Hamiltonian.

II. METHODS

The algorithm

III. RESULTS

IV. DISCUSSION

V. CONCLUSION

APPENDIX

1. Consider the general 4x4 matrix M:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ m_{41} & m_{42} & m_{43} & m_{44} \end{bmatrix}$$

2. Express the tensor products of I and σ_z:

$$I \otimes I = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$I \otimes \sigma_z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$\sigma_z \otimes I = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$\sigma_z \otimes \sigma_z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3. Set up a system of equations by equating the corresponding elements of M and the tensor product combinations:

$$\begin{aligned} m_{11} &= a + b + c + d \\ m_{12} &= e + f + g + h \\ m_{13} &= i + j + k + l \\ m_{14} &= m + n + o + p \\ &\dots \end{aligned}$$

4. Solve the system of equations to find the values of the coefficients a, b, c, and d. This can be done analytically or using numerical methods such as matrix inversion or least squares.

By determining the specific values of the coefficients a, b, c, and d, you can rewrite any 4x4 matrix in the form:

$$M = (a \cdot I \otimes I) + (b \cdot I \otimes \sigma_z) + (c \cdot \sigma_z \otimes I) + (d \cdot \sigma_z \otimes \sigma_z)$$

Note that this representation is not unique, as different combinations of coefficients can represent the same matrix.