

ABSTRACT

Theoretical study on the control of spin-1/2 quantum system is an important matter for the development of quantum control theory. There are some approaches toward quantum control problem, e.g. optimal control, decoupling techniques, factorization techniques of the unitary group, filtering-based feedback design, and Lyapunov-based design. Lyapunov methods play vital role in quantum control because of their concise mathematical rigor, thus leading many researchers in quantum control field to use it. In some previous studies, using the Lyapunov methods, it has been shown that signum function control law can be employed to control spin-1/2 quantum system to achieve NOT quantum gate operation. The drawback of signum function is the occurrence of chattering, in which the control law values switches back and forth between two extremal values. It may cause problem in implementation of the control law.

The chattering problem caused by the usage of signum control law is the reason to use control laws that do not cause chattering. This study proposes other forms of control law that are continuous and differentiable. The control law is used to achieve the same NOT quantum gate operation in spin-1/2 quantum system. The control law is designed and analyzed using Lyapunov method. This study presents two examples of those other forms are provided, namely hyperbolic tangent (tanh) function and proportional multiplier. The proposed control laws are tested using numerical simulation in MATLAB. The results show that tanh and proportional multiplier function can also control spin-1/2 quantum system to achieve the NOT quantum gate operation and prevent the occurrence of chattering.

Keywords quantum control, spin-1/2 quantum system, quantum NOT gate, Lyapunov method

INTISARI

Studi teoretis untuk sistem kuantum spin-1/2 adalah hal yang penting untuk pengembangan teori kendali kuantum. Ada beberapa pendekatan untuk menyelesaikan permasalahan kendali kuantum, seperti kendali optimal, teknik *decoupling*, teknik faktorisasi dari grup *unitary*, desain umpan balik berdasarkan penapisan, dan desain berdasarkan metode Lyapunov. Metode Lyapunov memainkan peranan penting dalam kendali kuantum karena memiliki kejelasan matematis sehingga banyak peneliti di bidang kendali kuantum menggunakan metode Lyapunov. Dalam beberapa studi sebelumnya, telah ditunjukkan bahwa aturan kendali berbentuk fungsi signum dapat digunakan untuk mengendalikan sistem kuantum spin-1/2 guna melaksanakan operasi gerbang kuantum NOT. Kelemahan fungsi signum adalah munculnya fenomena *chattering*, di mana nilai fungsi kendali bergerak bolak-balik antara dua nilai ekstrem. Hal ini dapat menyebabkan masalah dalam implementasi aturan kendali.

Masalah *chattering* yang ditimbulkan oleh penggunaan fungsi signum merupakan alasan untuk menggunakan aturan kendali yang tidak menyebabkan masalah tersebut. Studi ini mengusulkan bentuk hukum kendali lain yang kontinu dan diferensiabel. Aturan kendali tersebut digunakan untuk melaksanakan operasi gerbang kuantum NOT dalam sistem kuantum spin-1/2. Adapun aturan kendali tersebut didesain dan dianalisis menggunakan metode Lyapunov. Studi ini mengajukan dua contoh aturan kendali bentuk lain tersebut, yaitu fungsi tangen hiperbolik (*tanh*) dan pengali proporsional. Aturan kendali yang diajukan diuji menggunakan simulasi numeris di MATLAB. Hasil simulasi menunjukkan bahwa fungsi *tanh* dan pengali proporsional juga dapat mengendalikan sistem kuantum spin-1/2 untuk melaksanakan operasi gerbang kuantum NOT dan mencegah munculnya *chattering*.

Kata kunci – kendali kuantum, sistem kuantum spin-1/2, gerbang kuantum NOT, metode Lyapunov