THE INFORMATION OF DOCTORAL THESIS

Thesis title: **Study on the control solution of trajectory tracking for the ship with constraint signal and uncertain input function**

Major: **Control Engineering and Automation** Code: **9520216**

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THESIS SUMMARY

1. The urgency of the topic

Resolution No. 36-NQ / TW on the strategy for sustainable development of Vietnam's marine economy by 2030 with a vision to 2045 points out: "on the issue of science and technology, the development of marine human resources is the approach, taking full advantage of advanced scientific and technological achievements and being one of the leading countries in ASEAN, that owns a number of advanced and modern marine science and technology fields. Training and developing marine human resources for forming highly qualified marine science and technology staff". According to above policy, research institutions, shipyards, domestic shipping enterprises have continuously improved their design capacity, technological innovation in recent years. Using the most advanced science and technology to design and build a series of cargo ships with large tonnage, marine research ships, fishery control ships, specialized coast guard ships and border guards, ...

Along with the development of science and technology, the explosion of electronic technology - informatics and the industrial revolution 4.0 results in the application of advanced and modern technical equipment and automation technology on ships such as ship's autopilot system (Auto Pilot), ship's motion control system in orbit, ship's positioning system DP (Dynamic Position), maritime comfort system - satellite navigation , GPS navigation system (Global Positioning System), Radar, engine room automation system, power station
automation system ... to improve the quality of ship operation.

In this field of research, domestic and foreign scientists have constantly paid attention to researched synthesized controllers applied to ships such as:

- Classical controllers: PID, linear control LQR - Linear Quadratic Regulator, LQG - Linear Quadratic Gaussian, ...

- Nonlinear controllers: Backsteppin, sliding SMC – Sliding Mode Control, Dynamic Surface Control DSC - Dynamic Surface Control, adaptive control or the nonlinear controllers combined with the fuzzy, Neural, SMC - Backstepping, SMC - adaptive controls…

to solve the complex uncertainty of the ship model to improve control quality.

The problem of controlling ship movement poses many difficulties and challenges for scientists when researching because of some main following reasons:

i) Ships are maritime vessels operating in complex and unstructured environments, which results in unpredictable disturbances to control systems, such as ocean currents and waves. and wind ...

ii) Ship dynamics model is nonlinear and uncertain, the parameters of the ship model depend on the control state variables. The mathematical equations describing ship motion is a high-level differential equations. Considering the ship dynamics, the object has properties such asoscillation process, long time-span, low stable reserve.

Overview of ship motion control shows that topical nonlinear controllers have been studied and applied for ship control. The synthesis of nonlinear controllers is based on the Lyapunov control function but how to determine the Lyapunov control function is complex and always challenges the control designers. The research works on ship motion control have just solved single control problems but haven't combined trajectory attachment, credit binding, control signals, using models with uncertain components and random impact interference ... in a controller.

As a result, a new control method to control ship movement to meet the above problems will enrich the control methods and improve the quality of ship motion control.

2. Purpose of the research

The purpose of the research is to study the application of model predictive control (MPC) with the principle of vertical sliding on the RHC (Receding Horizon Control) time axis,

based on the linearization of each nonlinear model segment along axis of time to design the ship trajactory tracking controller with constraint signal and uncertain mathematical model.

To accomplish this goal, the thesis points out the following main tasks:

Study mathematical model describing ship motion and different types of mathematical model. On that basis, an overview of controlling ship movement method has been published inland and abroad in recent years, from which giving the research direction for the thesis.

Study constraint optimal controller theory with MPC model.

Study and propose state observer and new estimators to compensate uncertain components.

Apply the MPC by linearizing each nonlinear model segment to design underactuated ship trajectory tracking controller when input signals have constraint and uncertain.

Simulate and experiment using HIL (Hardware In the Loop) method to verify the controller.

3. The object and the scope of the research

The object of the research:

The research object of the thesis is displaced surface ship with mathematical underactuated model in the control trajectory tracking problem.

The scope of the research:

Study on designing the trajectory tracking ship controller for the underactuated, displaced, three degrees of freedom (3-DOF) ship model on horizontal axis with constraint control signals and uncertain input (do not study actuated structure model). The mathematical model describing ship dynamics on the horizontal axis containing uncertain components, influenced by the random interference factors from the external environment. The ship operates in running mode to check maneuverability, rotation under limited conditions of waves, wind, flow ... (smaller than level 5). This means the environment random disturbance is not great.

4. Research Methodology

Using methods from analysis, evaluation and synthesis, as follows:

Research, analysis mathematical models describing ship dynamics on the horizontal plane. Analysis and evaluation of published research works at home and abroad in articles,

magazines, reference documents on ship motion control. Especially, the control methods applied to surface underactuated ships.

Research theory of model predictive control and application MPC based on the linearization of each nonlinear model segment to synthesize and design the controller.

Verify the research results by Matlab - Simulink simulation and experiment by Hardware In the Loop method.

5. Scientific and practical significance of the topic

Scientific significance of the topic

The thesis proposes a methodology, proposing the application of a new nonlinear controller to control trajectory tracking ship. Specifically, the controller includes the RHC principle (sliding along the time axis), based on the ship Model Prediction Control, with a mathematical underactuated ship model based on linearization techniques each nonlinear model segment. The thesis will contribute to supplement and enrich methods of controlling ship movement.

Practical significance of the topic

The results of the thesis will realize the problem of controlling the movement of objects with mathematical underactuated models to control trajectory tracking. Specifically, the ship, the object has a large nonlinearity, the model contains more uncertain components and only two control effects are the steering gear and the main propeller behind the steering.

6. New contributions to the thesis

The thesis has solved the following contents:

1. Having studied and developed the MPC algorithm based on the linearization of each nonlinear model segment for underactuator ship model when the ship model is determined and uncertain Ship model. The thesis proves that the controller proposed is asymptotic stability. A new feature of this algorithm is to use the linear MPC principle to control nonlinear object (ship), based on the linearization of each nonlinear model segment along the time axis. The advantages of this controller are few calculation commands, fast calculating time, and simple optimization solution.

2. Studying and proposing a new state observer with a direct observer method from 3-DOF ship model on a horizontal plane without measurement noise.
3. Studying and proposing a method of estimating and compensating new uncertain components (the method of approximating uncertain components based on optimizing deviations from the model) to solve ship motion problem when the ship model contains uncertain components.
4. Building an experimental model based on Harware In the Loop method to test the quality of the proposed controller with the real ship model in MSS-GNC.

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