

Depth Control of an Underwater Vehicle Using Linear Parameter-varying Techniques

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ABSTRACT

The applicability of employing a linear parameter-varying (LPV) control to an underwater vehicle is investigated and compared to that of using a linear time-invariant robust control. The underwater vehicle is first modeled into a polytopic-type LPV system with speed variation. Then LPV controllers based on output feedback are designed which achieve specified performances such as bounded L_2 -induced norm and closed-loop pole clustering constraints for frozen linear time-invariant models. A parameter-dependent weight is investigated in the LPV synthesis. It is shown that the designed controller performs well over the entire operating range by computer simulation.

INTRODUCTION

As powerful tools for underwater activities, Autonomous Underwater Vehicles (AUV) have been intensively studied in the last decade. The vehicle, DELTA, discussed in this paper is a shuttle-species AUV that can swim freely without troubling with an umbilical cable. The vehicle can be lowered to the specified depth by changing the location of the center of gravity gradually. However, large transient responses could occur. For example, when the vehicle tries to avoid an obstacle or other swimming species, it has to deviate from its original moving path as soon as possible. In this emergency case, the change in vehicle dynamics is sudden and large, so a linear time-invariant (LTI) controller cannot guarantee performance over the entire range. Then a parameter-dependent controller with the advance speed as the scheduling variable is a possible control candidate.

LPV systems depend on on-line, measurable, time-varying parameters, such that the measurement of these parameters provides real-time information on the variations of the plant's characteristics. It is then desirable to design controllers that are scheduled based on this information. The LPV control has many advantages over conventional gain-scheduled control (e.g. Apkarian et al., 1995; Leith and Leithead, 2000), while the main drawback of the LPV technique is its conservatism (e.g. Wu et al., 1995; Bendotti et al., 1999).

When the loop-shaping technique is adopted to LPV synthesis, which is widely used and successful in robust control, the fixed weight function—which means the same performance specification over the entire parameter range—is sometimes rigid and makes the problem unsolvable. Although the time-varying weight is thought to be conservative (Apakrian et al., 1996), it may provide a comparatively appropriate performance specification for an LPV plant. Thus, if a time-varying weight function is employed properly in synthesis, the performance over the entire parameter range may be improved. It is desirable to use a parameter-dependent weight function and at the same time make the augmented plant parameter-dependent. As regards tractability, it is preferable that the augmented plant remain affinely dependent on the parameter. This is difficult in general, but for this application, we use a diagonal structure sensitivity weight function consisting of integrators, demonstrated to be simple and effective in many other applications, to acquire related parameter-dependent property. An additional benefit of using this simple weight function is that it facilitates the digital implementation due to the low order of controller.

Concentrating on rapid depth control, our goal in this paper is to control the vehicle to continuously dive with a speed ranging from 55% to 122% of its nominal value. We show the difficulties on LTI controller encounters because of the changing dynamics and the manner in which the LPV controller solves them.

The paper is organized as follows. First, the problem statement is given, followed by a brief review of the multi-objective-based LPV synthesis techniques. After describing the LPV modeling of the underwater vehicle, we describe the full design procedure, including a linear time-invariant robust controller design and 2 LPV controllers' design. Next are simulations and evaluation of these control methodologies. Concluding remarks end the paper.

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