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INPUT SHAPING CONTROL OF ELECTRONIC CAMS

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Abstract: *The paper deals with the input shaping control of electronic cams that eliminates their residual vibrations. The models of several different kinds of electronic cams are described, i.e. the simple traditional one, the serial one, the parallel one, the multi-input one. Then the input shaping control and its generalization is described. The generalization means the shaper of arbitrary time length and/or of arbitrary rate combined with the set of shaping functions of reentry kind. It is demonstrated and explained that some more complex shaping functions in comparison with the simple Heaviside pulse shapers are more robust against model misalignment. This generalized input shaping control is applied to different kinds of electronic cams*

Keywords: ***Input shaping, electronic cams, residual vibration, reentry commands***

1. Introduction

Conventional cam drives in modern machines can be replaced by properly controlled servomotors. This concept is generally called an electronic cam and can be further divided into several groups according to system structure – e.g. serial, parallel or multi-input electronic cams. The demand for fast and precise positioning is crucial in all mentioned cases but it could be easily corrupted by the residual vibration. To suppress the unwanted dynamics of flexible system the standard control input can be reshaped in such a way that it doesn't excite flexible modes or, more generally, that all the energy put into flexible modes is completely relieved at the end of the travel (Miu, 1989). The difference between original unshaped and shaped signal as well as the response of the two-mass model is shown in Fig. 1.

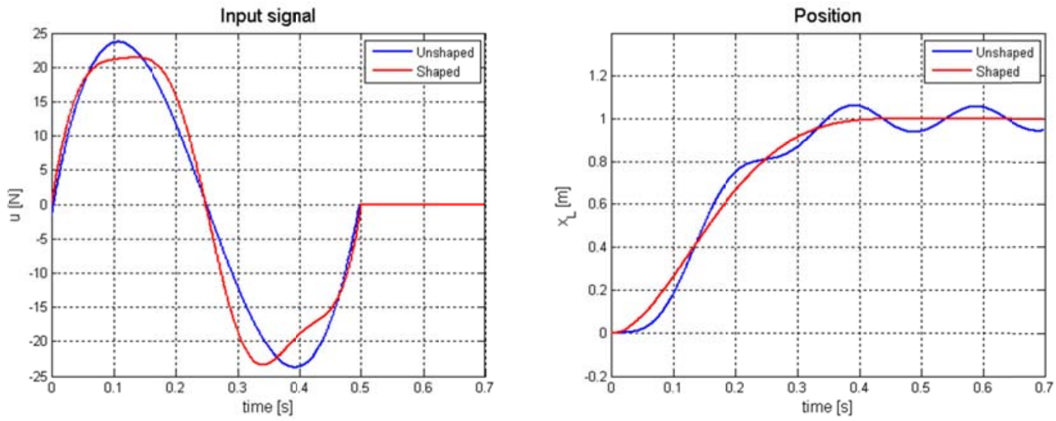

Fig. 1:Comparison of shaped and unshaped control input.

2. Control input shaping

The control input that ensures no-vibration positioning has to fulfill some necessary conditions. For the system described using state space formulation as

$$\dot{\boldsymbol{y}} = \boldsymbol{A}\boldsymbol{y}(t) + \boldsymbol{B}\boldsymbol{u}(t), \tag{1}$$

these conditions can be derived in the form

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$$\sum_{l=1}^{n} U_l(s)|_{s=\boldsymbol{A}} \cdot \boldsymbol{b}_l = e^{-\boldsymbol{A}T}\boldsymbol{y}(t_2) - e^{-\boldsymbol{A}T}\boldsymbol{y}(t_1), \tag{2}$$

where $U_l(s)$ is the finite time Laplace transform (Miu, 1989) of the l-th input, $\boldsymbol{b}_l$ is the corresponding column of $\boldsymbol{B}$ matrix, t_1 and t_2 is the start and the finish time, n is the number of inputs. The solution $u_l(t)$ in the time domain is the inverse Laplace transform of $U_l(s)$.

This approach leads to the control input in the form of pre-computed curve. However if it is rewritten to the form of a dynamical block it acts like a filter that transform any arbitrary signal to no-vibration one (Beneš & Valášek, 2008). And in contrast with patented input shaping technique by Singhose & Seering (1990) the length of this shaper is not dependent on the system natural frequency and can be set arbitrary.

3. Robustness

Being a feed-forward method all control shaping techniques need precise system models. The vibration suppression is in fact caused by placing zeros of the control input into the poles of the system. Therefore incorrect system model causes that the control input is not design properly and vibrations are not canceled. To increase robustness to modeling errors it is possible to formulate additional constrains that either introduced more zeros to the control input or increase the order of existing ones. The price for that is the increase of necessary acting force or longer settling time. Comparison of spectral analysis of a standard shaper and a robust one is in Fig. 2.

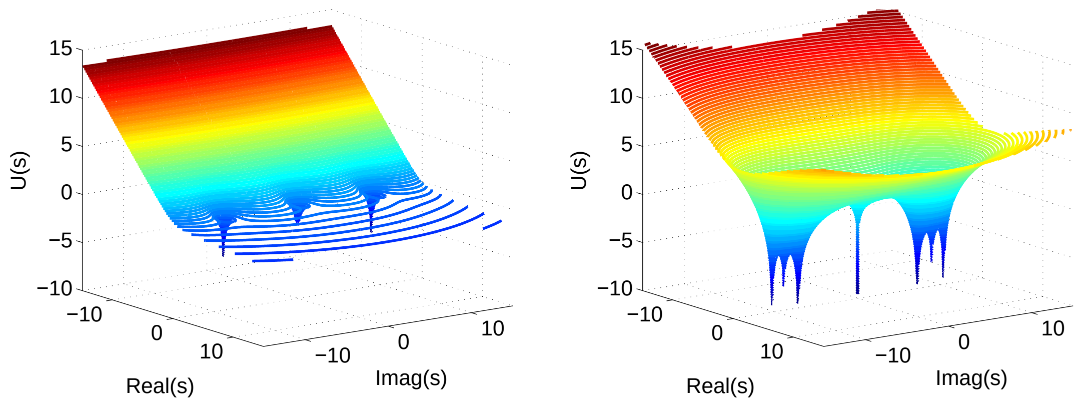

Fig. 2: Spectral analysis of a) standard shaper b) robust shaper.

4. Conclusions

The presented approach to control of electronic cams and other flexible systems combines advantages of two different control shaping techniques. It produces command shapers of arbitrary length with reentry property as well. It is opened to formulation of additional constrains that ensure robustness to modeling errors.

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