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# Control of vibration suppression and motion control by piezo actuators

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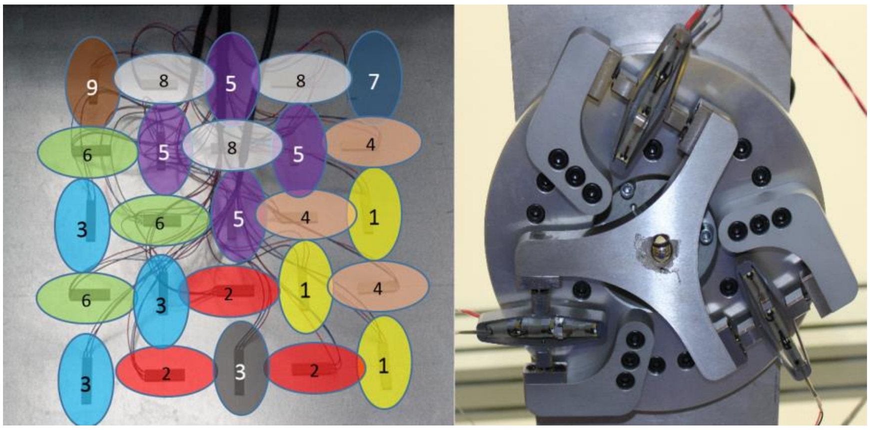
Piezoelectric materials are increasingly used in industry in various applications such as stabilization, micro-positioning, shakers etc. Two main disadvantages are high demand on the input voltages and relatively small range of motion. There are presented two type of piezoelectric elements implementation with respect to individual, above mention, problems and their solution. Firstly, usage piezo elements in smart materials. The price of piezo elements is still decreasing and it is not a problem to create material with heavily distributed grid of piezo patches Fig. 1 a). This material after applying voltage can modify his properties or can serve as vibration suppression element.




a) Heavily distributed grid of piezo patches b) Piezo platform for tracking task

Fig. 1. Examples of the use of piezoelectric elements

Such a heavily distributed grid is very demanding on control strategy and supply voltage. Normally there need to be one amplifier for one piezo patch. Therefore, several groups of the piezo patches is merged to ‘clusters’ see Fig. 1 a). Three concepts of clusters were proposed. Each cluster is powered with a single amplifier and single control voltage. From these clusters the optimal set of the piezo patches is tested to reduce the demands on the control strategy and control input voltage. Selection is based on the Henkel singular values [1] of the system, which represent a measure of energy for each mode

$$\gamma_{\mathrm{i}} = \sqrt{\lambda_i(W_c W_o)} = \sqrt{\lambda_i(W_{cb} W_{ob})}, \quad i = 1, .., N, \tag{1}$$

and controllability parameter. When our target is to suppress primary the first four modes of the system then with selected cluster (Fig. 1 a)) can be achieved the similar results as with fully distributed control with minimal loss of energy (on average approximately 4% ) for each mode with only 9 amplifiers instead of 25.

The second problem of piezo elements are their limited movement or stroke. An example of a solution to this problem is given on the example of a piezo platform perform the tracking task Fig. 1 b). Piezo elements are used as the micro positioning of the multilevel cable mechanism along the trajectory [2]. The control strategy is, because implementation obstacles, reduced to control just two degrees of freedom (x and y) with originally designed three Amplified Piezo Actuators (APA). For this reason, the redundant degree of freedom (rotation of the piezo driven platform) is used to minimize the individual APA stroke. The minimization function is based on the planar mathematical model of the platform which is delivered in the standard state space form. with inputs and outputs state as folowed

$$\boldsymbol{Y} = [x\ y]^T, \boldsymbol{u} = [u_1\ u_2\ u_3]^T. \tag{2}$$

Modeled system has not direct feedthrough. This mean, that the $\boldsymbol{D}$ matrix of the system is neglected and the static behaviour is considered $\dot{\boldsymbol{X}}$=0, then the system can be revriten as

$$\boldsymbol{Y} = \underbrace{-\boldsymbol{C}\boldsymbol{A}^{-1}\boldsymbol{B}}_{\boldsymbol{P}}\,\boldsymbol{u}. \tag{3}$$

Transformation matrix $\boldsymbol{P}$ has dimension 2x3. This system has two equations for three unknowns, therefore it has infinitely many solutions. But there are restrictions on the APA's stroke. They have maximum operating voltage 150 V. Based on this, one input voltage is set as variable parameter in the known range $\boldsymbol{u_3} = \langle 0{:}\,1{:}\,150\rangle$. Then the two vectors for inputs voltages $\mathbf{u_1}$ and $\mathbf{u_2}$ can be obtained in the specific position depending on the voltage $\mathbf{u_3}$

$$\begin{bmatrix}\boldsymbol{u_1}\\ \boldsymbol{u_2}\end{bmatrix} = \boldsymbol{P}(1{:}\,2,1{:}\,2)^{\boldsymbol{T}}\boldsymbol{Y} - \boldsymbol{P}(1{:}\,2,3)\begin{bmatrix}\boldsymbol{u_3}\\ \boldsymbol{u_3}\end{bmatrix}. \tag{4}$$

In form of the matrix with the given structure $\boldsymbol{F} = [\boldsymbol{u_1}\ \boldsymbol{u_2}\ \boldsymbol{u_3}]^T$ can be find maximum of absolute value in the term of the maximum use of APA

$$[V, I] = min(max(abs(\boldsymbol{F}))), \tag{5}$$

where $V$ is the value and $I$ is the index of the position in the vector. Then the $I$ represents the index of the optimal set of the input voltages in vector $\boldsymbol{F}$ to reach the desired position $\boldsymbol{Y}$ constrained by the operating voltage for APA 3. And the optimal voltage is selected as

$$u_{1optimal} = \boldsymbol{F}(1, I), u_{2optimal} = \boldsymbol{F}(2, I), u_{3optimal} = \boldsymbol{F}(3, I), \tag{6}$$

which achive the same results with only 80% of originaly APA's strokes.

Two main problems of usage piezoelectric material has been studied and an example was given to each problem. Solution on the first problem in the given example of heavily distributed grid of piezoelectric patches (high demand on input voltage) has been proposed as composing multiple piezo elements into one control unit. And second problem (restriction of the piezo element stroke) has been resolved by adding one piezo element which compensates for the movements of others. Both examples give promising results that will continue to be investigated and tested on real experiments.

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