Prevention of Servo-Induced Vibrations in Robotics

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Vibrations, or oscillations, are present everywhere around us. Sound arises due to oscillation of air masses, tree branches oscillates in the wind, the water in the sea oscillates and the movement of a swing in the park is also a type of oscillation. These oscillations are most of the time not problematic but there are of course also those that are, for example earthquakes. Another problematic oscillation could for instance be the shaking hand of a surgeon. The surgeon needs to be precise in his/her movements in order not to hurt the patient. It is the same case with a robot or another machine that should perform movements with precision. The worst thing that could happen if a machine vibrates too much is of course in most cases not a human getting hurt, but expensive material damage can very well occur.

Almost all industrial machines, like robots, are made up by metal parts. The machine builder wants the design to be robust but at the same time not too heavy and expensive. A balance between these factors is usually made but there is almost always room for optimization. For example, if it is possible to find a way to make vibrations disappear other than adding more metal to the construction, it is perhaps also possible to reduce the total cost of the machine. Vibrations in a machine increase the mechanical wear, therefore maintenance costs can also be reduced by treating the vibrations. Production in a plant can also be made more time efficient by treating the vibrations but before explaining how, let us consider a portal robot. Portal robots are often used in industry for so called pick-and-place tasks. The robot can roughly be said to consist of three (most often) metal beams and three electric motors. A tool is attached on one end of one of the three beams. The beams are located so that the angle between them is ninety degrees. Each beam is connected to one of the three electric motors. A portal robot is shown in Figure 1. By driving the motors we can move the tool back and forth, to the left and to the right and up and down. The movements are usually performed rapidly with a lot of power, therefore vibrations of the arms (or metal beams) are likely to appear. Let us consider a pick-and-place task where the tool should enter a narrow opening in another machine to pick up a product and then place it on a conveyor belt. If the movements of the robot arms are too fast, vibrations can make the tool miss the narrow machine opening and as a consequence the tool may break. Robot tools are often very expensive. To avoid such a scenario, there are two obvious and straight forward methods. One method is to move the arms much slower so that no vibrations appear and another method is to move the arms rapidly and then wait for the vibrations to fade before entering the narrow machine opening.

-Fine, no tool will be broken. The problem is however that time is money. In production plants, even one tenth of a second longer for one single "pick" means hours longer in total

Figure 1. *A portal robot. The tool is usually located on the vertical arm where the black cuboid is located in this photograph.*

production time every day when tens of thousand "picks" are conducted. It is therefore very important to create a more efficient method to treat the vibrations. So how could such a method look like? Let us consider the surgeon with a shaky hand again. If the shaking hand is not a consequence of a medical condition which makes the surgeon unable to control his/her shaking hand, he/she both sees and feels the shaking and stops it. In other words, the eyes and the sensory nerves sends signals to the brain that the hand is shaking. The brain then sends new signals to the muscles so that the shaking stops. This control method is called feedback, in this case feedback from the eyes and the sensory nerves to the brain. The brain can be considered as the "controller". The job of a controller is to calculate signals, in this case nerve signals, to the "process" which in this case is the shaking hand. The controller knows how the process should behave. By letting the controller see how the process is behaving in reality, the controller computes new signals to the process. A so called feedback loop for signals between controller and process is closed. There are many feedback loops in the human body and in nature. There are of course also feedback loops in many everyday gadgets such as DVD-players and cars and also in advanced industrial machines. So how would a feedback method for treating vibrations in a robot arm look like? Well, a sensor would be needed. The surgeon has his/her eyes and sensory nerves. In a machine a sensor for detecting vibrations could be a so called accelerometer which measures accelerations of the arm, or a strain gauge which measures bending of the arm. The sensor signal would be sent to the "robot computer" (the controller) which based on these signals would compute new signals for the motors so that the vibrations would be canceled on the arm (the process). The biggest drawback with this solution is that sensors add to the total cost of the machine. As the goal in industry is to keep the cost down as much as possible, it may be a good idea to consider another method which is not dependent on sensors. But how could such a method look like? Once again, consider the surgeon. It would be like blindfolding him/her and giving him/her anesthetics so that he/she would not be able to see or feel anything. How could he/she know if the hand is shaking? The truth is that he/she would not know that, but if the surgeon has full ability to move his/her muscles the shaking can be prevented. The surgeon knows how to move the hand so that it is shaking and by not moving it that way, hopefully it will not shake. It sounds simple and there is no need for eyes or sensory nerves. But how could this method be implemented in a robot? Like the surgeon, the robot computer knows what movements it wants the arm to do. The difference is that we would have to tell the robot how not to move so that vibrations appear, the surgeon hopefully knows this. A method that goes under the name "command shaping" has been tested. This method does exactly what the name suggests. The signal that tells how the robot should move is reshaped in a way so that vibrations will not appear. This can be achieved through different mathematical signal treatment algorithms or through mathematical models. More about this can be read in the master thesis with the same title and author as for this article. In this way the arm moves rapidly and effectively without vibrating. Figure 2 shows vibration measurements of the tool when no command shaping is active and Figure 3 shows measurements when command shaping is active. The measurements have been gathered with an accelerometer.

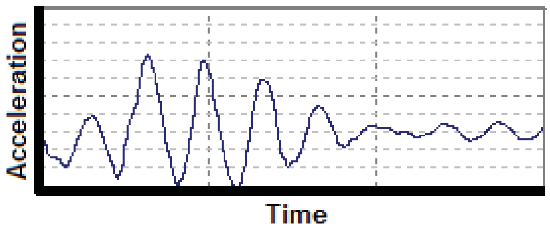

Figure 2. *Measurements on the tool when no command shaping is used. Vibrations become very clear.*

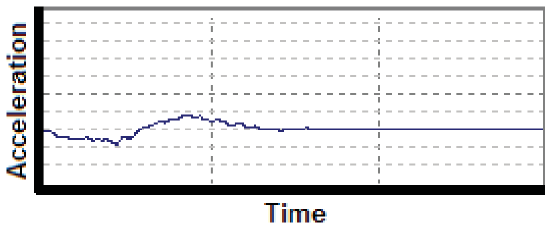

Figure 3. *Measurements on the tool when command shaping is active. Vibrations do not appear.*