Tool for designing motion profiles for servo motors

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Servo motors are used for many different application in the industry. Some examples are to drive a conveyor belt, move objects vertically or seal packages. To control the behaviour of the servo motors motion profiles are used, which can be created with our tool, CAMTool. This tool enables the user to design advanced motion profiles, which will make a smaller servo motor able to do the same work as a larger one.

Motion profiles are essential when designing mechatronic applications since they define the mechanic movement, i.e. the position, velocity, acceleration and jerk at a specified point in time and this is controlled by electronics. To have many possibilities when designing motion profiles are essential in three parts. Firstly, to reduce the amount of different servo motors that are used in different applications. Instead, servo motors of the same kind can be used for different motions so they can be acquired for a cheaper bulk price. Secondly, to have a good tool for designing motion profiles that can be used by both automation engineers and mechanical designers. The tool will then become a common reference point, which is beneficial in the development of new mechatronic applications as everything will originate from the same point. Thirdly and lastly, to have a quick and user friendly tool, which will work both offline as well as online when designing the motion profiles.

The tool calculating these motion profiles is called CAMTool and is an application which allows the designer to design motion profiles given a set of parameters. CAMTool is relatively new, which means it is still in the development phase. The tool has been evaluated and the application is in need of some improvements, which we have done as our Master Thesis project. The main focus is to make CAMTool be able to produce even more complex and advanced motion profiles, by calculating and utilise a motion profile with a non-zero jerk in different places. Jerk is the derivative of acceleration. The project will also make CAMTool able to calculate different kind of motion profiles with the focus to achieve an end velocity or an end position. The project ends up with a comparison between a motion profile calculated with CAMTool and one standard motion profile, which will be verified by running a servo motor connected through a gearbox to a conveyor belt.

Motion Profiles

Motion profiles describe how a servo motor should behave when it moves over time in terms of position, velocity, acceleration and jerk. This can be seen in figure 1 and figure 2, which are created by CAMTool. The first figure includes the position and its derivative, velocity. The second one shows the acceleration and its derivative, jerk. The figures are used to validate the motion profile and get a graphical representation of the motion profile.
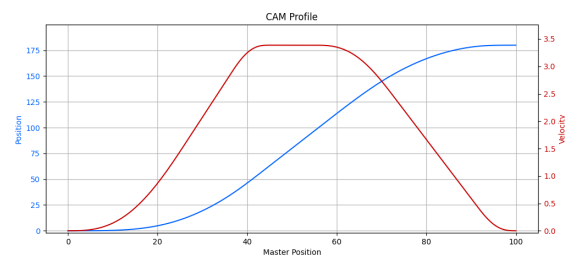

Figure 1: Shows an example of a motion profile, where the position is in blue and the velocity is in red
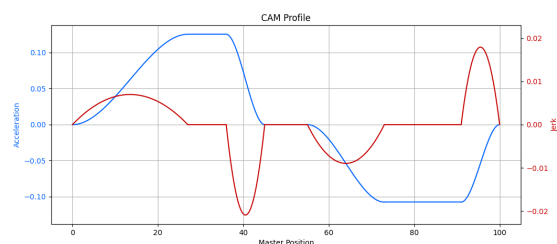

Figure 2: Shows the acceleration and jerk behaviour of the motion profile in figure 1. The acceleration is in blue and the jerk is in red

The requirements of the application puts some constraints on the motion profile. Some motions require the start velocity and end velocity to be controllable. Other types of motions require an end position and start position to be controllable. CAMTool can calculate such motion profiles given a specified acceleration behaviour.

As mentioned above, the approach of CAMTool is to design the motion around the acceleration behaviour. This introduces a lot more flexibility around the motion itself. CAMTool needs to know the amount of time the acceleration should increase, be constant and decrease. These parameters should sum up to 100%. The same holds for the deceleration part, it needs to know the amount of time the deceleration should increase, be constant and decrease. The parameters for the deceleration part should also sum up to 100%. In between the acceleration part and the deceleration part, the constant velocity takes place. It tells how much of the total motion should have constant velocity. For example, the motion shown in figure 1 and figure 2 has the parameters: 60% acceleration increase, 20% acceleration constant, 20% acceleration decrease, 20% constant velocity, 40% deceleration increase, 40% deceleration constant and 20% deceleration decrease. These parameters are specified by the design engineer in the graphical user interface, GUI, of CAMTool, which is shown in figure 3. The symmetry of the motion profiles can also be specified, which gives either the acceleration part or deceleration part more time. This is used for example when the gravity is affecting the movement, or there is a lot of friction in the system.
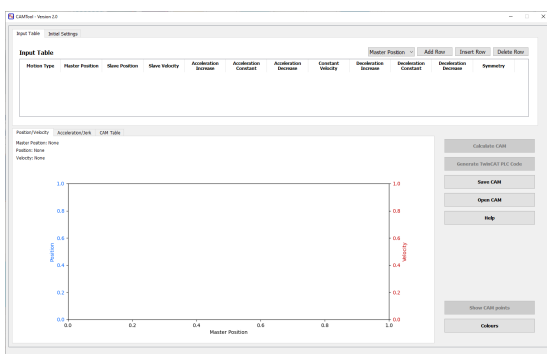

Figure 3: Shows the GUI of CAMTool including input table and graph area

Result

Besides ending up in a zero velocity as in figure 1 and figure 2, it is now also possible to design other more complex motion profiles meeting other requirements. The only motion profile existing before are now able to have non-zero jerk at four independent locations, see figure 4 and figure 5. These benefits are neces-

sary when the acceleration should not be ramped up as in figure 2, but rather have a stronger acceleration change. The same holds for the deceleration part.
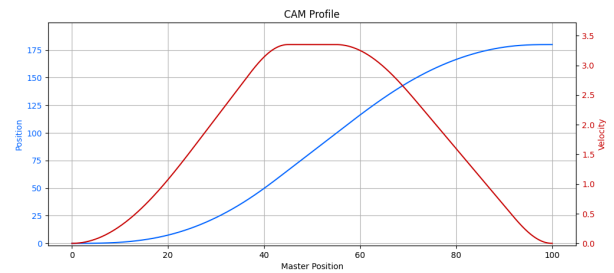

Figure 4: Shows an example of motion profile where the end velocity is predefined and the end position is zero. Position in blue and velocity in red
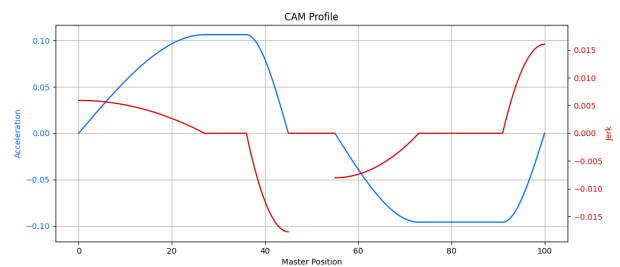

Figure 5: Shows the acceleration and jerk behaviour of the motion profile in figure 4. Acceleration is in blue and jerk is in red

Another feature CAMTool got are to end up in a predefined velocity, given a initial velocity and position as well as the acceleration behaviour. This is shown in figure 6 and figure 7. It is also possible to end up in a predefined position given the same constrains as the predefined velocity, which is shown in figure 8 and figure 9. The first benefit is necessary to control the speed, for example a conveyor belt. The second one is necessary if two motions have to line up where the position have to be specified.
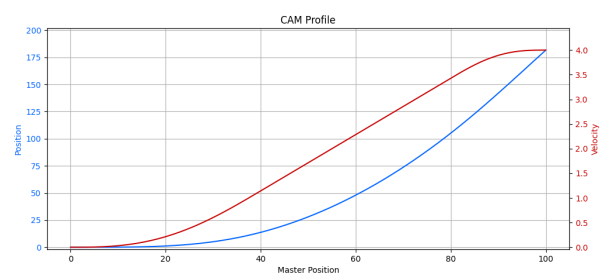

Figure 6: Shows a example of motion profile where the start and end positions are predefined. Position in blue and velocity in red.
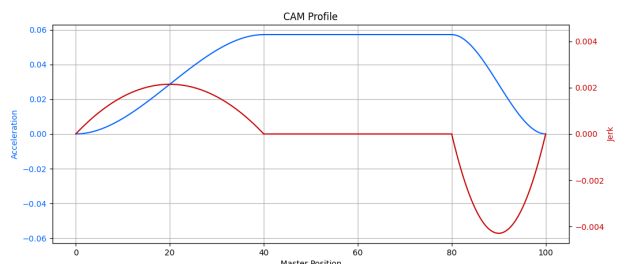

Figure 7: Shows the acceleration and jerk behaviour of the motion profile in figure 6. Acceleration is in blue and jerk is in red
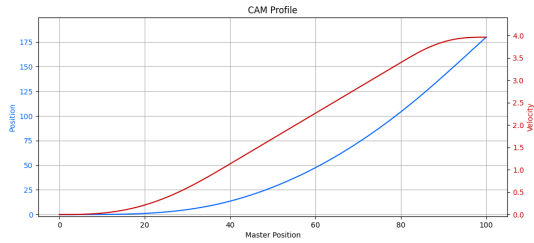
Figure 8: Shows an example of motion profile where the start and end velocities are predefined, Position in blue and velocity in red
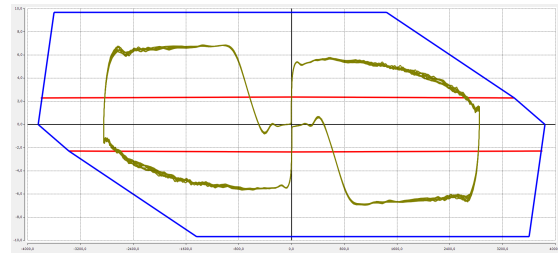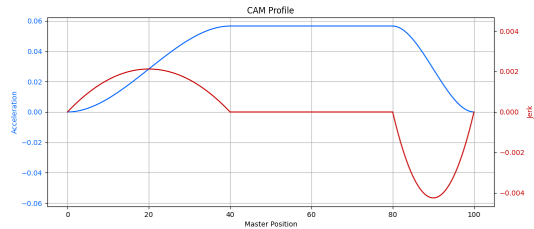

Figure 9: Shows the acceleration and jerk behaviour of the motion profile in figure 8. Acceleration is in blue and jerk is in red
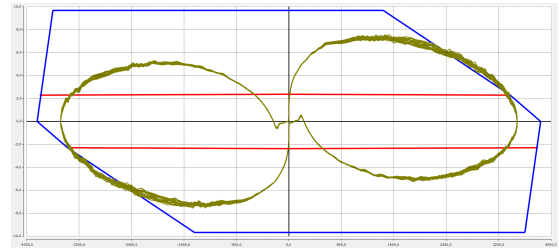
Verification

The verification was done by comparing a motion profile designed and calculated using CAMTool with a standard motion profile, which was then run on an experimental setup consisting of a servo motor, a gearbox and a small conveyor belt shown in figure 10.
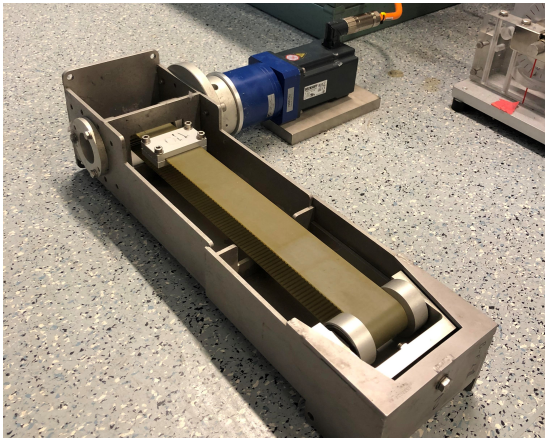

Figure 10: Shows the setup of a servo motor in black, a gearbox in blue and a conveyor belt in light gray

The result of the operating path calculated with CAM-Tool is shown in figure 11, while the standard motion profile is shown in figure 12. The blue line in the figures are the limits for the servomotor, the red ones are the RMS limits and the green ones are the operating paths. The verification shows with a standard motion profile the servomotor is outside the limits of the servomotor, but by using CAMTool the operating path have margins to it.

Figure 11: Shows the performance of the servo motor running a CAM profile designed in the CAMTool

Figure 12: Shows the performance of the servo motor running a standard CAM profile

Conclusion

By using CAMTool more advanced motion profiles can be design such as non-zero jerk, specify the end position or specify the end velocity. This means servo motors can be used in more advanced applications where the motion profiles have to be designed in more detail. It is also shown that using CAMTool a smaller servo motor can be used to drive a bigger load when using a motion profile designed and calculated in CAMTool compared to using a standard motion profile.