COMPARSIONS

A Hybrid Numerical Solution to ARGESIM Comparison C11 'SCARA Robot' using Maple

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Simulator. Maple 9 is a Computer Algebra System which offers many routines for the exact solution of problems, although it's numerical capabilities are somewhat limited.

Task a - Modeling Method. This is the Task for which Maple is most suited. Transforming the implicit description of the system into an explicit one can be done at no time at all, as the commands for matrix and vector manipulation are intuitiv.

Task b - Simulation of the Controlled System. Adding another three ODEs is no problem in Maple. But implementing the restrictions for the armature voltages seemed to be impossible at first. Using the systematic approach

```
>kT3:=0.4:T3max:=0.6:
>I3max:=(sqrt(3)/2*kT3)^(-1)*T3max:
```

and replacing the -Imax<I<Imax condition by the term

```
>min(Imax,abs(I))*signum(I)
```

that, unlike a maple procedure, can be used for numerical integration, led to an error message:

```
Error, (in type/EvalfableProp) too many levels
of recursion".
```

Maple does not offer much help and / or support on error messages, so the user has to try to figure out what has gone wrong.

Manually calculating I3max – which yields sqrt(3) - and substituting this value instead of the variable worked. Apparently Maple was not able to get the correct value.

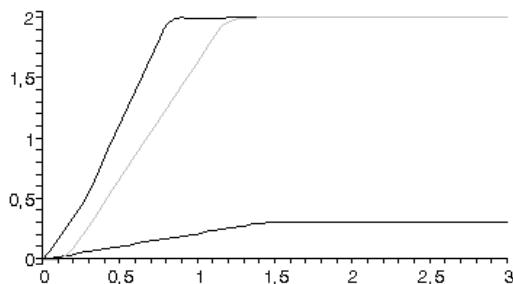Once the system is properly set up, simulating the system is easy. As already described above, the term used as limiter is properly handled by the numerical IVP solver. Plotting the solution is a bit more difficult, because the result is a set of procedures - one for each independent variable - neither alphabetically ordered nor like the initial conditions, the order changing every time the worksheet is executed. Therefore an 'eval' command has to be used before the plot (Fig. 1) can be obtained.

Task c - Collision Avoidance. The best course of action is defining two new ODEs for the PD-Controller in emergency situations together with joining the now two sets of ODEs into a hybrid loop. At the time where either the collision is immanent or the tip is again in a save distance from the obstacle, the transition between the two states takes place. Maple needs the stopping conditions for the ODE solver in the classic form of a function with a zero crossing at the desired state. The trouble is, that the condition, according to Maples Help, "should vary smoothly with the solution". The x-coordinate for the tip,

```
>L1*cos(q1(t))+L2*cos(q1(t)+q2(t)),
```

is not smooth enough for maple in case of the emergency situation, so the it switches back to normal mode only at the point where q3 is greater then the height of the obstacle.

Plotting the results also gets much more difficult. Depending on the movement of the SCARA unit, you have to join several procedures into one for plotting.

It is much more convenient to compute arrays of [t,x] coordinates, transform them into list and join the lists and create output. Given the rate at which especially q1 can change, a step size of 10^(-3) is required for a diagram which contains all the qualitative information about the SCARA units movement (Figure 2).
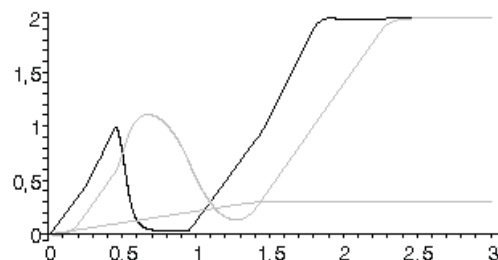
Fig. 2:movement with collision avoidance

C11 Classification: Hybrid Numerical Approach
Simulator: Maple 9, 2004

Fig. 1: movement without an obstacle