Appendix B:  
The *rltool* Interactive Tutorial

The *rltool* (‘Root Locus Tool’) is a MATLAB guided user interface (GUI) used to perform the root locus analysis of linear and invariant single-input single-output systems.

This application provides a useful tool to realize both the design and the testing of controllers by using the root locus drawn. In this way, it is possible to change the gain or to add poles/zeros and see directly the results by viewing the system response when closed loop poles are moved throughout its root locus.

![Fig. B.1 The Control and Estimation Tool Manager of *rltool*.](image)

The *rltool* can be executed by typing

```
>> rltool
```
from the MATLAB command window or else

```matlab
>> rltool(G)
```

in case we have created a transfer function ‘G’ previously. In both cases, the ‘Control and Estimation Tool Manager’ is activated, showing the closed loop configuration actually used, where ‘F’, ‘C’, ‘G’ and ‘H’ stand for filter, controller, plant and sensor, all of these represented by linear and invariant transfer functions (fig. B.1)

These transfer functions can be imported from the MATLAB command window if they are previously created by selecting the ‘System Data’ option (fig. B.2).

For instance, if we execute

```matlab
>> s=zpk('s');
>> G = 5*(s+2)/(s*(s+1)*(s+5));
>> rltool(G)
```

then, the `rltool` GUI is opened showing the root locus for ‘G’ for the case of controller compensator C = 1 (fig. B.3). In this chart we can observe the closed loop pole location as pink squares, which can be moved by dragging them along the root locus. Note that the controller gain automatically changes in the ‘Current Compensator’ window (fig. B.4).
Fig. B.3 The window design of *rltool*, showing the root locus plot.

This ‘Compensation Editor’ toolbar allows to add poles, add zeros or to delete either for the controller by selecting the ‘Pole/Zero’ option. This operation can also be made by right clicking and accessing to the ‘Add Pole/Zero’ or ‘Delete Pole/Zero’ option.

For instance, we can add a zero at $s = -0.5$ and an integrator at $s = 0$ we get another root locus plot with moving closed loop poles (fig. B.5).
It can be seen how this proportional integral controller has moved the root locus graph to the right half plane, by impairing its transient performance (even causing unstability) but at the same time improving its steady state regime.

The rltool also enables to super-impose design constraints on the s-plane. For this, we have to right click and select “Design Requirements”, then ”New” in the ”Constraint type” menu. It is possible to choice between ‘Settling Time’, ‘Percent Overshoot’, ‘Damping Ratio’, ‘Natural Frequency’ and ‘Region Constraint’ requirements that can be viewed over an s-grid by right clicking ‘Grid’ (fig. B.6).

**Fig. B.5** The Compensator Editor window of rltool showing the effect of added poles/zeros

**Fig. B.6** The Design Requirements setting of rltool
For example, we can select a settling time $t_{set} < 2\ s$ and a percent overshoot $M_p < 20\%$. It can be seen that these specifications cannot be met with this controller, no matter what we set the proportional gain to. That is, the two dominant roots of the closed loop system will never be in the valid region (fig. B.7).

Fig. B.7 Imposing specific requirements in \textit{rltool}

Nevertheless, we can add a new the controller zero by using the toolbar in the \textit{rltool} main window and drag one of the closed loop poles until they are inside the

Fig. B.8 Fulfilling requirements by modifying the controller in \textit{rltool}
white region. Note how the new compensator transfer function designed meets the requirements in spite of the closed loop pole closer to the zero at $s = -0.5$ due to the cancellation effects (fig. B.8).

Besides we can see the time responses of the closed loop system by selecting the ‘Analysis’ at the toolbar and the ‘Response to Step Command’ option. Then, a new plot window is opened, showing the step response from the reference to the system’s output (fig. B.9). By right clicking, it can be shown that the time response characteristics (peak response, settling time, etc.) in order to test if the requirements have been effectively met.

![LTI Viewer for SISO Design Tool](image)

**Fig. B.9** Step response of the closed loop system designed by *rltool*