Defining a system symbolically.

```
syms s K;
gain = K;
feedback = 1;
plant = 1/(s*(s+1)*(s+2));  % Open-loop.
sys = gain * plant + feedback; % Closed-loop.
```

Characteristic equation representation of the system.

```
coeffs = ELAB.sd2ce(sys, true);
```

Original expression:

$$\frac{K}{s\ (s+1)\ (s+2)} + 1$$

Expanded form:

$$\frac{K}{s^3 + 3 s^2 + 2 s} + 1$$

Set equal to 0, then simplify:
$$s^3 + 3 s^2 + 2 s + K$$

Collect terms of equal power:

$$s^3 + 3 s^2 + 2 s + K$$

Routh array for stability analysis.

Routh Array

$$\begin{pmatrix} 1 & 2 \\ 3 & K \\ 2 - \frac{K}{3} & 0 \\ K & 0 \end{pmatrix}$$

Critical points, where system transitions between stable and unstable.

ELAB.critical(RA,true);

Solving equations for param:

$$2 - \frac{K}{3} = 0$$

$$K = 0$$

For stability, param (K) =]6;0[

From s^2 auxiliary equation:

$$(3 s^2 + 6 = 0 \quad 3 s^2 = 0)$$

Solved for s:

$$\begin{pmatrix} -\sqrt{2} & i & 0 \\ \sqrt{2} & i & 0 \end{pmatrix}$$

Breakaway points for root locus plot.

ELAB.breakaway(sys, gain, true);

Solving closed-loop for gain:

$$K = -s (s + 1) (s + 2)$$

Expanding expression:

$$K = -s^3 - 3s^2 - 2s$$

 $K = -s^3 - 3 s^2 - 2 s$ Derivative of gain of s:

$$-3 s^2 - 6 s - 2$$

Solving diff(gain) = 0 for s:

$$\left(s = -\frac{\sqrt{3}}{3} - 1 \quad s = \frac{\sqrt{3}}{3} - 1\right)$$

Sub s in 1st equation, solving for gain.

Breakaway points [s, gain]:

- -1.5774 -0.3849
- -0.4226 0.3849

plant = ELAB.sd2tf(plant); % Convert symbolic to tf-object for rlocus. rlocus(plant);

