

Supplementary Materials

# Computer Animation Education Online: A Tool to Teach Control Systems Engineering throughout the COVID-19 Pandemic

Anna Patete <sup>1\*</sup> and Ronald Marquez <sup>2,3\*</sup>

<sup>1</sup>Departamento de Sistemas de Control, Facultad de Ingeniería, Universidad de Los Andes; 5101; Venezuela.

<sup>2</sup>Escuela de Ingeniería Química, Facultad de Ingeniería, Universidad de Los Andes; 5101; Venezuela.

<sup>3</sup>Now at École Supérieure de Physique et de Chimie Industrielles de la ville de Paris (ESPCI), 10 rue Vauquelin, F-75231 Paris, France

\*Correspondence: annapatete.ula.ve@gmail.com; marquezronald.ula.ve@gmail.com;

## Supplementary Information: Code to Graph the Watt Governor

### 1. First Function for the dynamics of the Watt Governor base

```
BeginPackage["ControlAnimation`FlywheelBase`"]
Needs["Graphics`Graphics3D`"]

Base::usage = "Flywheel's Base";

Unprotect[Base];

Begin["ControlAnimation`FlywheelBase`Private`"]

(*****)

Base[i_] :=
  ParametricPlot3D[{(Cos[t] (Cos[u]))/2, (Sin[t]
(Cos[u]))/2,
    (Sin[u]/10) - 0.1, Hue[0.43]}, {t, -i/100, -Pi - i/100},
{u, 0, Pi}, Axes -> \
  False,
    Boxed -> False, DisplayFunction -> Identity]

(*****
**)
End[]
Protect[Base];
EndPackage[]
```

## 2. Second Function to graph the elements that make up the Watt Governor

```

BeginPackage["ControlAnimation`FlywheelGraph`"]
Needs["Graphics`Graphics3D`"]

Flywheel::usage = "Centrifugal's Graphics";

Unprotect[Flywheel];

Begin["ControlAnimation`Flywheel`Private`"]
(*****)

Flywheel[px1_,px2_,px3_,L_,vertices1_,vertices2_,vertices3_,v
ertices4_,\
    vertices5_] :=

    Graphics3D[{
        Line[{{0, 0, 0}, {2, 0, 0}, {0, 0, 0}}],
        Line[{{0, 0, 0}, {0, 2, 0}, {0, 0, 0}}],
        Line[{{0, 0, 0}, {0, 0, 2*L}, {0, 0, 0}}],
        Text["eje Z", {0, 0, 2*L}, {-1.3, 0}],
        Text["eje X", {2, 0, 0}, {1.3, 0}],
        Text["eje Y", {0, 2, 0}, {-1.3, 0}],
        RGBColor[0, 1, 0], Cuboid[{-0.025, -0.025, -0.05 +
2*px3}, {0.025, \
    0.025, 0 + 2*px3}],
        RGBColor[1, 0, 0], PointSize[0.0575], Point[{-px1, -
px2, px3 + L}],
        RGBColor[0, 0, 1], PointSize[0.0575], Point[{px1,
px2, px3 + L}],
        Thickness[.009], RGBColor[0, 0, 1], Line[vertices1],
        Thickness[.009], RGBColor[1, 0, 0], Line[vertices2],
        Thickness[.009], RGBColor[0, 0, 1], Line[vertices3],
        Thickness[.009], RGBColor[1, 0, 0], Line[vertices4],
        Thickness[.009], RGBColor[0, 1, 0], Line[vertices5]

    }]

(*****
**)

End[]

```

```
Protect[Flywheel];
EndPackage[]
```

### 3. Third Function to receive the dynamics (in open loop or closed loop) and give movement to the Watt Governor

```
BeginPackage["ControlAnimation`FlywheelPendulum`"]
Needs["ControlAnimation`FlywheelGraph`"]
Needs["ControlAnimation`FlywheelBase`"]
Needs["Graphics`Graphics3D`"]

WattGovernorAnimation::usage = "Flywheel's Animation";

Unprotect[WattGovernorAnimation];
Begin["ControlAnimation`WattGovernorAnimation`Private`"]

(*****)

WattGovernorAnimation[salidax1_, X_, xl10_, L_, muestras_,
paso_, zise_, view_] \
:=

Block[{hsalx1, lis, vu, ci, tci, tol, lpts1, p, de, pa},

lis = {{101, 0.1864242}, {201, 0.0932121}, {301, 0.0621414},
{401, 0.04660605}, {501, 0.03728484}, {601, 0.0310707},
{701, 0.026720802}, {801, 0.023303025},
{901, 0.0208795104}, {1001, 0.01864242},
{1101, 0.0164242}, {1501, 0.0125060},
{1701, 0.010558494}, {2001, 0.00932121},
{2501, 0.00710}, {3001, 0.00621414},
{4001, 0.004660605}, {5001, 0.0037284884},
{6001, 0.00310707}, {7001, 0.0026720802},
{8001, 0.0023303025}, {9001, 0.00208795104},
{10001, 0.001864242}};

de = Interpolation[lis];
Plot[de[x], {x, 101., 10001.}, PlotRange-
>All, DisplayFunction->Identity];
pa = If[muestras < 101, 0.1864242, de[muestras]];

hsalx1 = salidax1/(Pi/2);

ci = xl10*10;
```

```

vu = ci+6*Pi;

For[i = 1, i <= muestras, i += paso,

    lpts = Table[{L*(Cos[p]*p/30), L*(Sin[p]*p/30),
hsalx1[[i]]}, {p, \
    ci,vu, pa}];

    px1 = lpts[[i]][[1]];
    px2 = lpts[[i]][[2]];
    px3 = lpts[[i]][[3]];

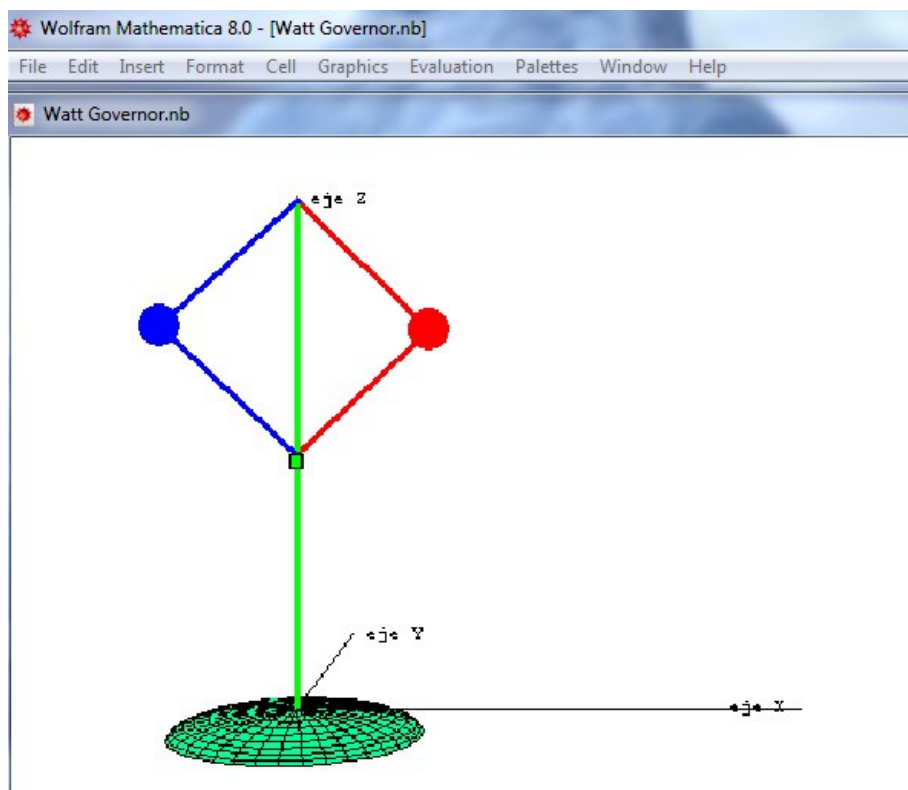
    vertices1 = {{0, 0, 2*L}, {px1, px2, px3 + L}};
    vertices2 = {{0, 0, 2*L}, {-px1, -px2, px3 + L}};
    vertices3 = {{0, 0, 2*px3}, {px1, px2, px3 + L}};
    vertices4 = {{0, 0, 2*px3}, {-px1, -px2, px3 + L}};
    vertices5 = {{0, 0, 2*L}, {0, 0, 0}};

    F =
        Show[Base[i], Flywheel[px1, px2, px3, L, \
vertices1,vertices2,vertices3,
            vertices4, vertices5], PlotRange -> All,
ImageSize -> zise,
            Boxed -> False, Axes -> False, view, Lighting-
>False, \
            DisplayFunction->$DisplayFunction];
        ];
]

(*****)

End[]
Protect[WattGovernorAnimation];
EndPackage[]

```



**Figure S1.** Watt Governor computer animation: position at 45 degrees.