PGE Springs, Python and Internals

- examine the example code in the pge source tree:

PGE Springs, Python and Internals

$HOME/Sandpit/git-pge/examples/springs/bridge.py

```
left = placeBall (wood_light, 0.25, 0.45, 0.03).fix ()
right = placeBall (wood_light, 0.75, 0.45, 0.03).fix ()

prev = left
springs = []
for x in range (35, 75, 10):
    step = placeBall (wood_dark, float (x) / 100.0, 0.33, 0.03)\
           .mass (0.9)
    s = pge.spring (prev, step, spring_power, damping, 0.1)\
           .draw (yellow, 0.002)
    s.when (snap_length, snap_it)
    springs += [s]
    prev = step

s = pge.spring (right, prev, spring_power, damping, 0.1)\
       .draw (yellow, 0.002)
s.when (snap_length, snap_it)
```

PGE Springs, Python and Internals

- notice that two circles are fixed in position `left` and `right`
- now free moving circles are declared at positions: `35`, `45`, `55` and `65`.
- all of these circles are joined by a spring and each spring will snap if it exceeds `snap_length`
- each spring has a `k` value and also a damping value

PGE Springs, Python and Internals

```
s = pge.spring (prev, step, spring_power, damping, 0.1)\
        .draw (yellow, 0.002)
```

- here the `k` value is `spring_power` and uses `damping` and has an at rest length of `0.1` unit

- pge allows debugging (or visual showing of a spring `yellow` and `0.002` (width of the rectangle representing the spring)
  - this yellow visual cue has no effect in pge, it is simply drawn between the end points of a spring object

PGE Springs, Python and Internals

- a spring can be requested to call a callback function when it reaches a specific length
  - for example when it reaches `snap_length` it calls `snap_it`
- `snap_it` is a simple function
- ```
  def snap_it (event, object):
      object.rm ()
  ```
- and the spring is deleted, the event parameter (representing the function call) is ignored
  - as the only time this function is called is when a spring is to be deleted
  ```

PGE Spring Internals

- the main module of the physics engine is `$HOME/Sandpit/git-pge/c/twoDim.c`

- the `Spring` entity is declared as a `struct` called `Spring_r` and is defined as:

PGE Spring Internals

$HOME/Sandpit/git-pge/c/twoDim.c

```
struct Spring_r {
   unsigned int id1;  /* spring connects to object id1.  */
   unsigned int id2;  /* and id2.  */
   coord_Coord f1;    /* force of spring acting on id1.  */
   coord_Coord f2;    /* force of spring acting on id2.  */
   coord_Coord a1;    /* acceleration vector of spring operating on id1.  */
   coord_Coord a2;    /* acceleration vector of spring operating on id2.  */
   double k;  /* Hookes constant for the spring.  */
   double d;  /* Damping constant for the spring.  */
   double l0;  /* at rest length.  */
   double cbl; /* the call back length of the spring.  */
   double l1;  /* l1 is the current length of the spring.  */
   double width;  /* width of the rectangle used for drawing the spring.  */
```

PGE Spring Internals

$HOME/Sandpit/git-pge/c/twoDim.c

```
    unsigned int drawColour;  /* drawing colour.  */
    unsigned int endColour;   /* what colour to draw spring at the end?  */
    unsigned int midColour;   /* what colour to draw sprint in the middle?  */
    unsigned int draw;        /* should the spring be drawn at all?  */
    unsigned int drawEnd;     /* should it be redrawn at the end?  */
    unsigned int drawMid;     /* should it be redrawn in the middle?  */
    unsigned int hasCallBackLength;  /* is the call back length set?  */
    unsigned int func;   /* which function should we call for length?  */
};
```

PGE Internals

- one of the design decisions in building PGE was to assume that acceleration remains constant in between events

- velocity and position components of objects however will vary depending upon time
  - accelertion remains constant over time
  - but might change at the next event (collision or user input)

- this works well until springs are introduced!

- Hookes Law $F = -k(l_1 - l_0)$
- and Newtons Law: $F = ma$

PGE Internals

- can be combined to show that:
- $a = \frac{F}{m}$
- $a = \frac{-k(l_1 - l_0)}{m}$
- mass is constant, but l_1 changes with time
  - thus acceleration will also vary over time
- in effect adding a spring into PGE will potentially violate one of the core design parameters of PGE

PGE Internals

- however PGE can be adapted so that it adjusts the acceleration of each sprung object every time frame
  - this is an approximation - similar to numerical integration
  - a tradeoff, but it allows springs to coexist inside PGE

The data structures inside c/twoDsim.c

- **c/twoDsim.c**

```
typedef enum {polygonOb, circleOb, springOb} ObjectType;

typedef enum {frameKind, functionKind, collisionKind} eventKind;

typedef enum {frameEvent, circlesEvent, circlePolygonEvent,
              polygonPolygonEvent, functionEvent, springEvent} eventType;
```

- `ObjectType` defines the different kinds of object (ignore spring object)

- `eventKind` defines the three major classification of events

The data structures inside c/twoDsim.c

- `eventType` further subclassifies the event kind with the collision event info
  - we distinguish between a circle/polygon collision and a circle/circle collision and a polygon/polygon collision

object (typedef struct _T2_r)

c/twoDsim.c

```
unsigned int id;           /* the id of the object.  */
unsigned int deleted;      /* has it been deleted?   */
unsigned int fixed;        /* is it fixed to be world?  */
unsigned int stationary;   /* is it stationary?  */
double gravity;            /* the gravity for this object.  */
coord_Coord saccel;        /* the acceleration due to a spring.  */
coord_Coord forceVec;      /* the aggregate force this object generates.  */
double vx;                 /* velocity along x-axis.  */
double vy;                 /* velocity along y-axis.  */
double ax;                 /* acceleration along x-axis.  */
double ay;                 /* acceleration along y-axis.  */
double inertia;            /* a constant for the life of the object used for rotation.
double angleOrientation;   /* the current rotation angle of the object.  */
double angularVelocity;    /* the rate of rotation.  (Rotation per second).  */
double angularMomentum;    /* used to hold the current momemtum after a collision.  */
unsigned int interpen;     /* a count of the times the object is penetrating another ob
ObjectType object;  /* case tag */
union {
        Polygon p;  /* object is either a polygon, circle or string.  */
        Circle c;
        Spring s;
      };
```

object (typedef struct _T2_r)

- **c/twoDsim.c**

```
typedef struct _T2_r _T2;
typedef _T2 *Object;
```

- notice you can ignore the `inertia`, `angleOrientation`, `angularVelocity` and `angularMomentum` as these are used to implement rotation

Circle

c/twoDsim.c

```
typedef struct Circle_r Circle;

struct Circle_r {
      coord_Coord pos;    /* center of the circle in the world.  */
      double r;           /* radius of circle.  */
      double mass;        /* mass of the circle.  */
      deviceIf_Colour col;  /* colour of circle.  */
};
```

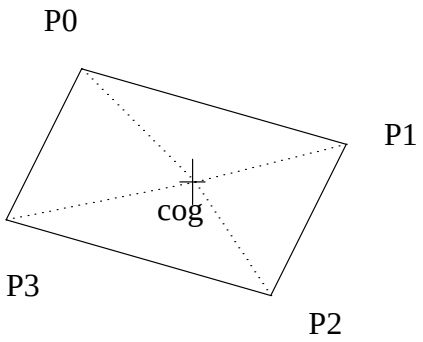
Polygon

c/twoDsim.c

```
typedef struct Polygon_r Polygon;
struct _T3_a { polar_Polar array[MaxPolygonPoints+1]; };
struct Polygon_r {
                   unsigned int nPoints;
                   _T3 points;
                   double mass;
                   deviceIf_Colour col;
                   coord_Coord cOfG;
                 };
typedef struct _T3_a _T3;
```

Polygon

- the polygon has an array which is used to contain each corner
  - a corner is a polar coordinate from the centre of gravity



Polar coordinates

- remember that a polar coordinate has a magnitude and an angle
  - an angle of 0 radians is along the x-axis
  - magnitude of, r and an angle of ω
- so we can convert a polar to cartesian coordinate by:
- $x = \cos(\omega) \times r$
- $y = \sin(\omega) \times r$

Polar coordinates

- in our diagram
- $P0 = (p0, 135/360 \times 2\pi)$
- $P1 = (p1, 45/360 \times 2\pi)$
- $P2 = (p2, 315/360 \times 2\pi)$
- $P3 = (p3, 225/360 \times 2\pi)$
- where p1, p2, p3, p4 are the lengths of the line from the CofG to the corner
  - dotted lines in our diagram

Polar coordinates

- the angle values in the polar coordinates for our polygon are the offset of the angle for the particular corner
  - the angularVelocity is used to determine the rotation of the polygon, this is added to each corner to find out the corner position at any time

- this allows rotation of the polygon to be modelled at a later date

Polar coordinates

- at any time in the future, t we can determine the polygons corner, i by:
- $\Omega = angleOrientation + angularVelocity \times t$
- $x_i = cofg_x + r_i \times \cos(\omega_i + \Omega)$
- $y_i = cofg_y + r_i \times \sin(\omega_i + \Omega)$

Polar coordinates

- we can see how this data structure represents a polygon by following the `dumpPolygon` function

Polar coordinates

- see how each corner is defined by following through the function `box`
  - into `poly4`
- how it calculates the box CofG
- how it defines each corner relative to the CofG and as a polar coordinate
  - each corner is orbiting the CofG

dumpPolygon

c/twoDsim.c

```
static void dumpPolygon (Object o)
{
  unsigned int i;
  coord_Coord c0;

  libc_printf ((char *) "polygon mass %g colour %d\\n", 27,
               o->p.mass, o->p.col);
  libc_printf ((char *) "  c of g  (%g,%g)\\n", 19,
               o->p.cOfG.x, o->p.cOfG.y);
  for (i=0; i<=o->p.nPoints-1; i++)
    {
      c0 = coord_addCoord (o->p.cOfG,
           polar_polarToCoord (polar_rotatePolar
           ((polar_Polar) o->p.points.array[i], o->angleOrientation)));
      libc_printf ((char *) "  point at (%g,%g)\\n", 20, c0.x, c0.y);
    }
}
```

dumpPolygon

- follow through the function `doDrawFrame` and see how the corners of a polygon are updated dependant upon the `angularVelocity`, `angleOrientation` and the acceleration and velocity components

- examine `newPositionRotationCoord`, `newPositionRotationSinScalar` and `newPositionRotationCosScalar`