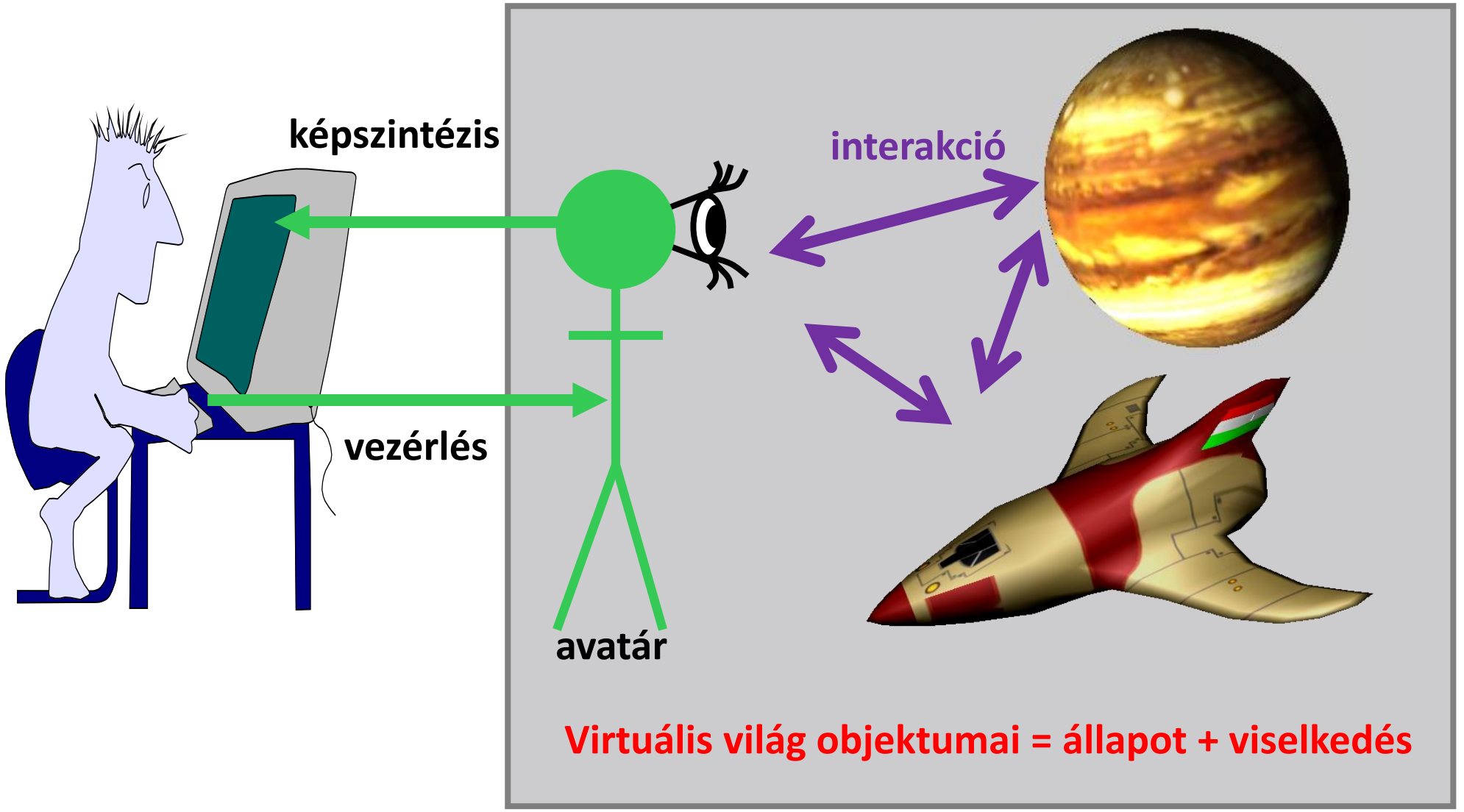
“The only legitimate use of a computer is to play games.”

Eugene Jarvis

Játékfejlesztés

Szirmay-Kalos László

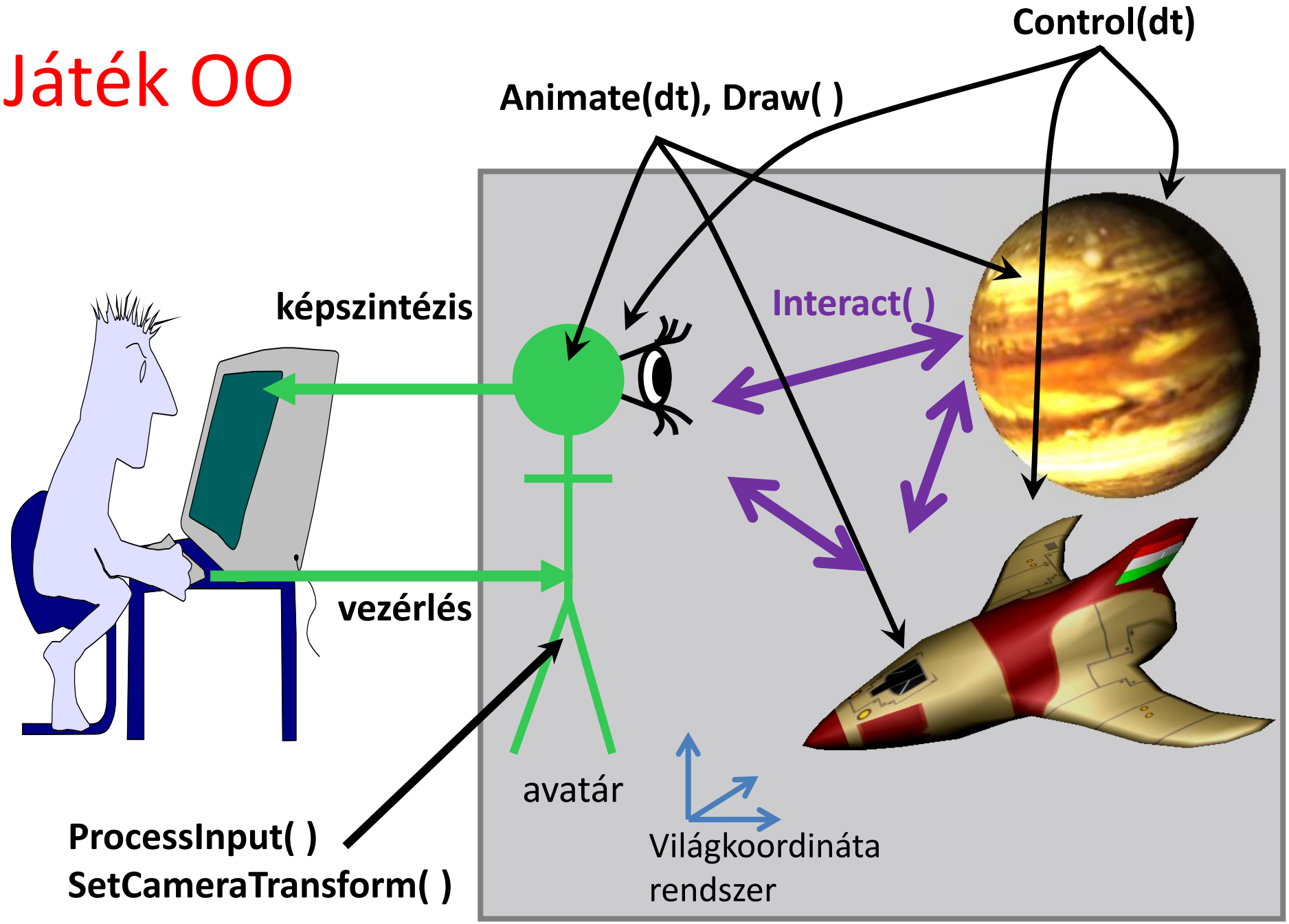
Virtuális valóság



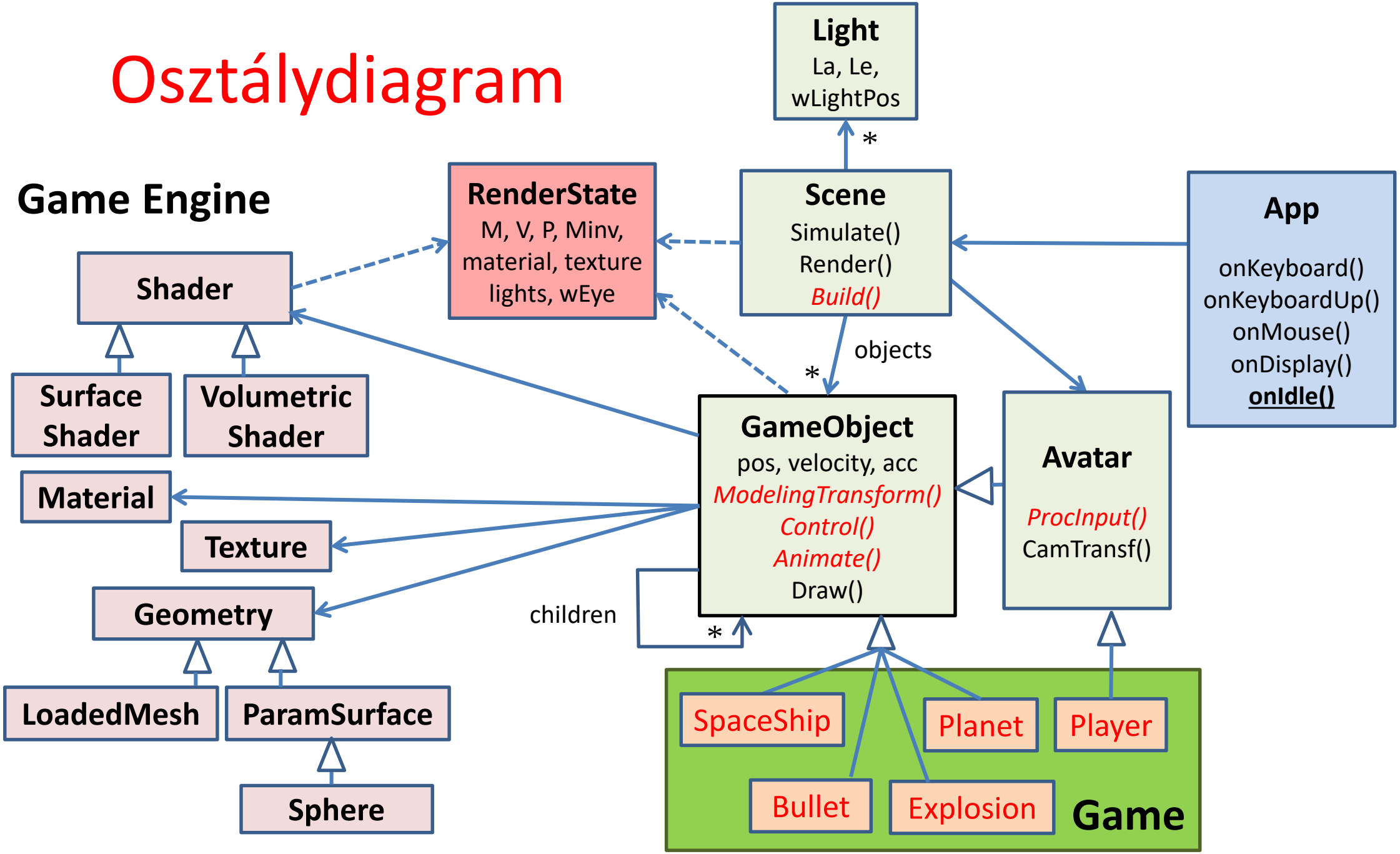
Játékok feladatai

- Képszintézis az avatár nézőpontjából:
  - 1 szem, sztereo, autosztereo
- Az avatár vezérlése a beviteli eszközökkel:
  - keyboard, mouse, Wii, gépi látás, Kinect, VR sisak, stb.
- Az „intelligens” objektumok vezérlése (AI)
  - állapotgép
- A fizikai világ szimulációja
  - Newtoni fizika

Játék OO


Control(dt)
Animate(dt), Draw( )
képszintézis
Interact( )
vezérlés
avatár
ProcessInput( )
SetCameraTransform( )
Világkoordináta
rendszer

Osztálydiagram

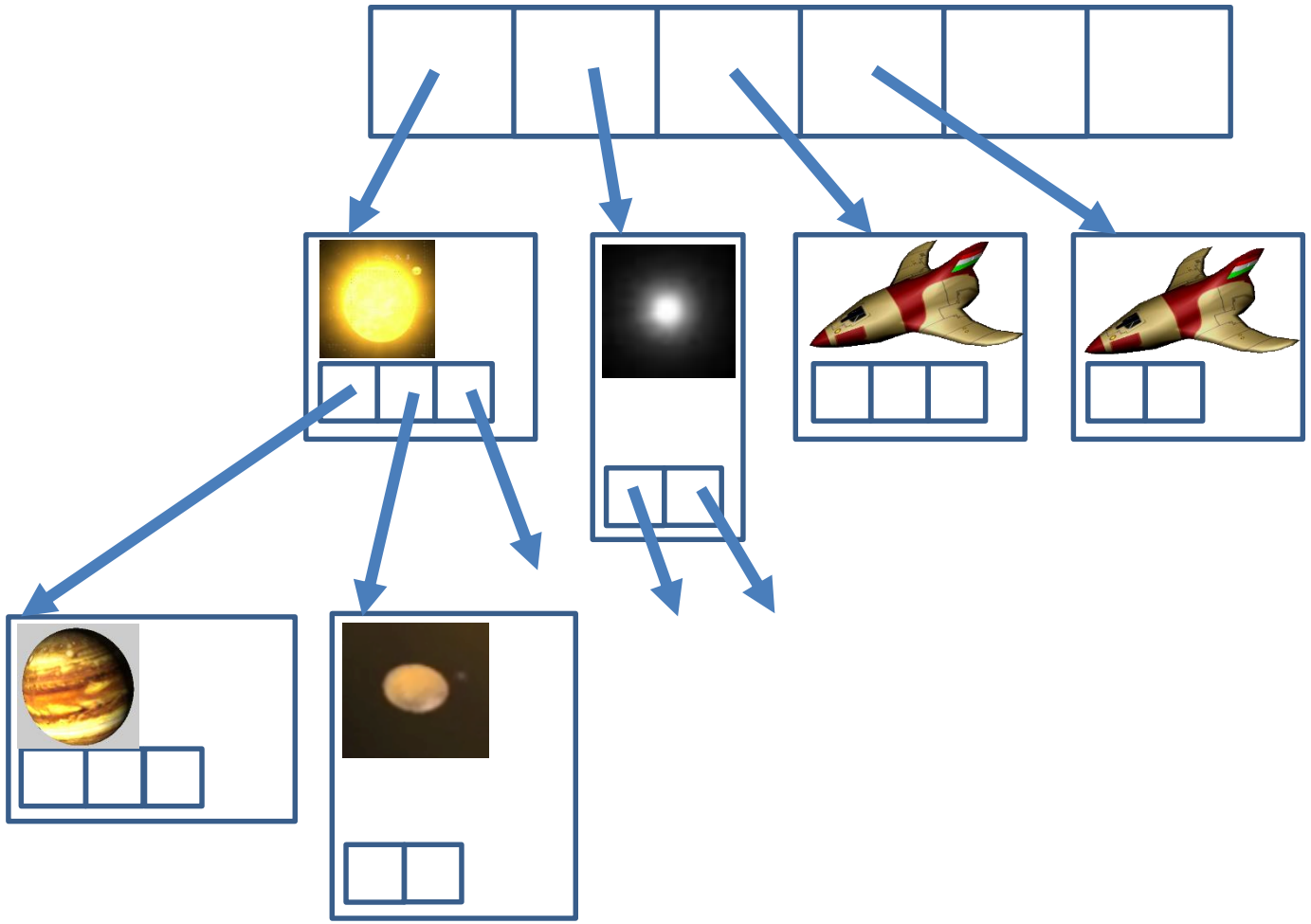


Játékobjektum (GameObject)

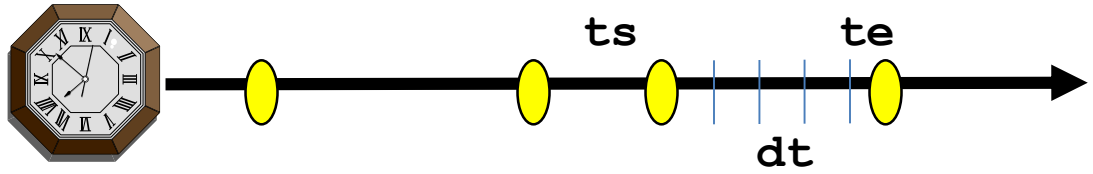
```
class GameObject {
protected:
   Shader *   shader;
   Material * material;
   Texture *  texture;
   Geometry * geometry;
   vec3 pos, velocity, acceleration;
   vector<GameObject *> children;
   virtual void ModelingTransform(mat4& M, mat4& Minv) { M = Minv = UnitMatrix();}
public:
   GameObject(Shader* s, Material* m, Texture* t, Geometry* g) { … }
   virtual void Control(float dt) { }
   virtual void Animate(float dt) { }
   virtual void Draw(RenderState state) { // parameter by value to separate objects
      mat4 M, Minv;
      ModelingTransform(M, Minv);
      state.M = M * state.M; state.Minv = state.Minv * Minv;
      state.material = material; state.texture = texture;
      shader->Bind(state); // uniform variable setting
      geometry->Draw();    // triangles go down the pipeline
      for (Object * child : children) child->Draw(state);
   }
};
```

Virtuális világ

```
vector<GameObject *> objects;
```



Szimulációs hurok (Game loop)




```
void onIdle ( ) { // idle call back
    static float tend = 0;
    float tstart = tend;
    tend = glutGet(GLUT_ELAPSED_TIME);
    scene.Simulate(tstart, tend, keys);
    glutPostRedisplay();
}
```

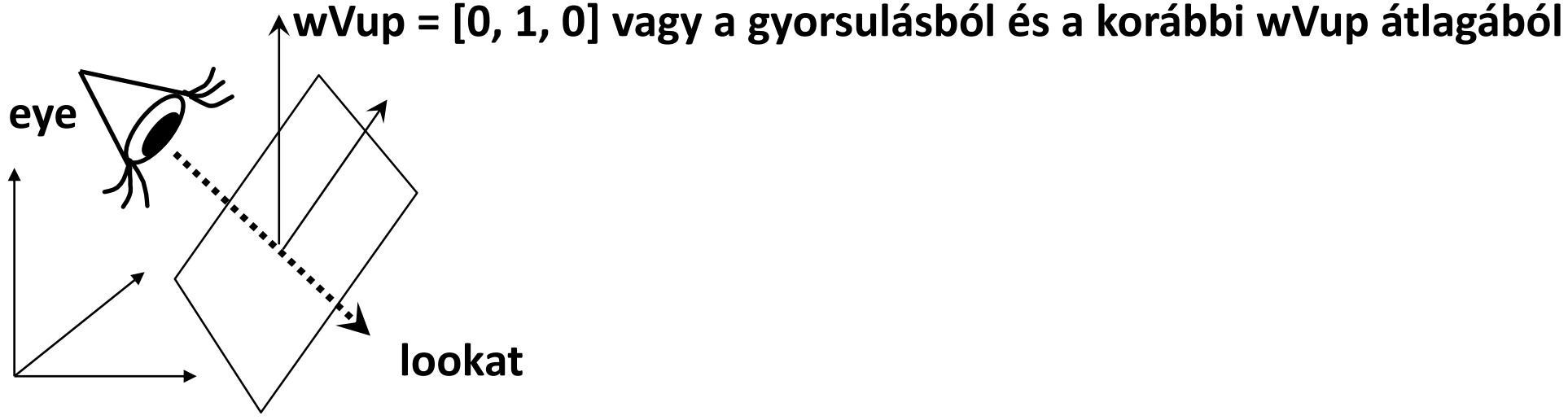
```
void Scene::Simulate(float ts, float te, bool keys[])
{
    avatar->ProcInput(keys);
    for(float t = ts; t < te; t += dt) {
        float Dt = min(dt, te - t);
        for (GameObject * o : objects) o->Control(Dt);
        for (GameObject * o : objects) o->Animate(Dt);
    }
}
```

```
void onDisplay(){
    glClear(GL_COLOR_BUFFER_BIT |
            GL_DEPTH_BUFFER_BIT);
    scene.Render();
    glutSwapBuffers( );
}
```

```
void Scene::Render( )
{
    RenderState state; // M=Minv=UnitMatrix();
    avatar->SetCameraTransform(state);
    for (GameObject * o : objects) o->Draw(state);
}
```

Avatar

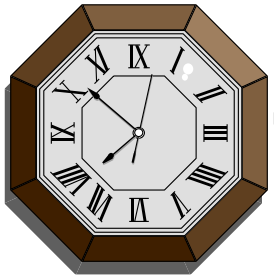
```
struct Avatar : public GameObject {
   virtual void ProcessInput() { }
   virtual vec3 wVup() { return vec3(0, 1, 0); }
   void SetCameraTransform(RenderState& state) {
      Camera camera(pos, pos + velocity, wVup());
      state.V() = camera.V();
      state.P() = camera.P();
   }
};
```



Klaviatúra kezelés

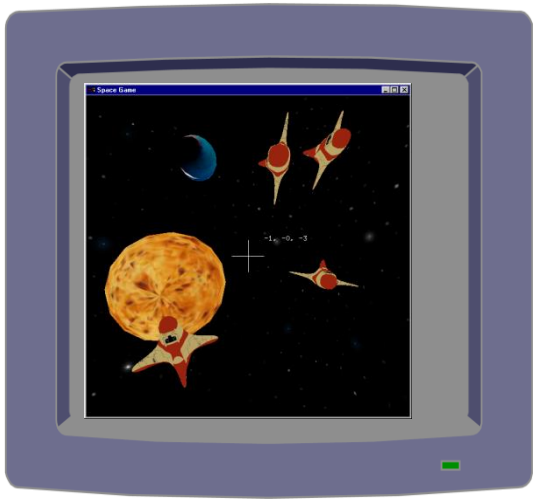
KeyboardFunc
KeyboardUpFunc
SpecialKeysFunc
SpecialKeysUpFunc

keys



onIdle:
Simulate

virtual
world



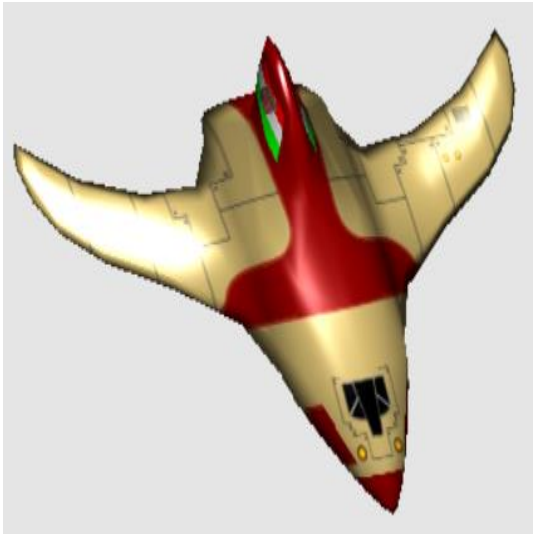
```
bool keys[256];      // is pressed?
void onKeyboard(unsigned char key, int pX, int pY) {
    keys[key] = true;
}
void onKeyboardUp(unsigned char key, int pX, int pY) {
    keys[key] = false;
}
```

“Be van fejezve a nagy mű, igen.
A gép forog, az alkotó pihen.
Évmilliókig eljár tengelyén,
Mig egy kerékfogát ujítni kell.”

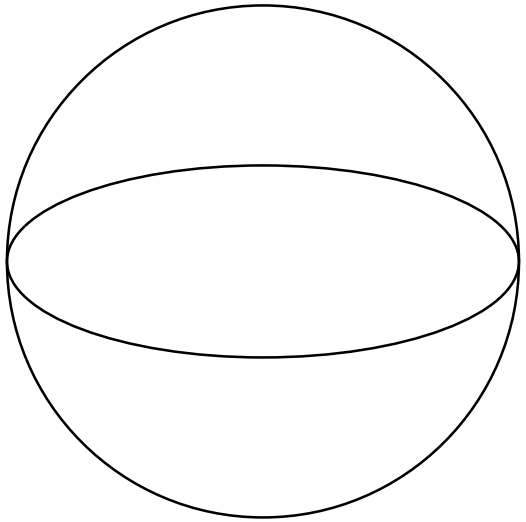
Madách Imre

Játékfejlesztés
2. Játékobjektumok

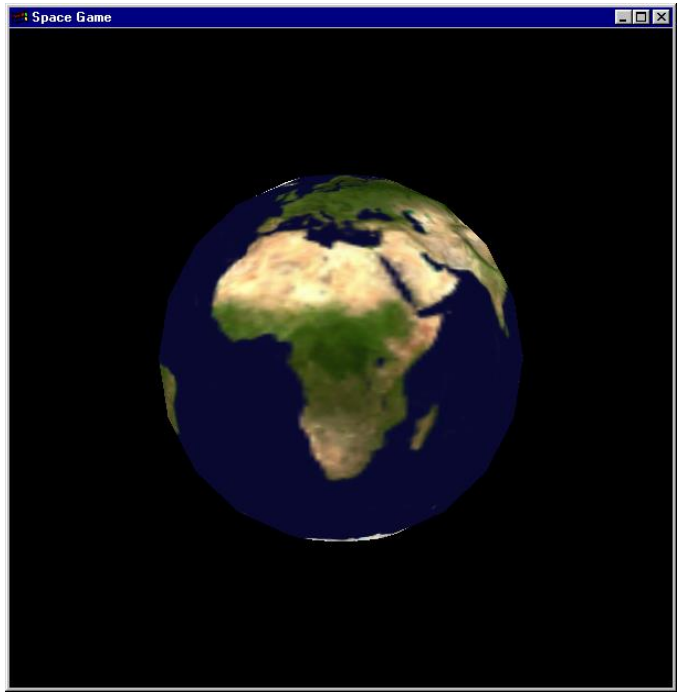
Szirmay-Kalos László



Bolygó: Planet



- Geometria: gömb
- Textúra
- Animáció:
  - Fizikai:
    - Tájékozódik majd követi a gravitációs törvényt
  - <u>Képletanimáció:</u>
    - „beégetett pálya”
    - Többiek érdektelenek
    - Nincs respektált törvény

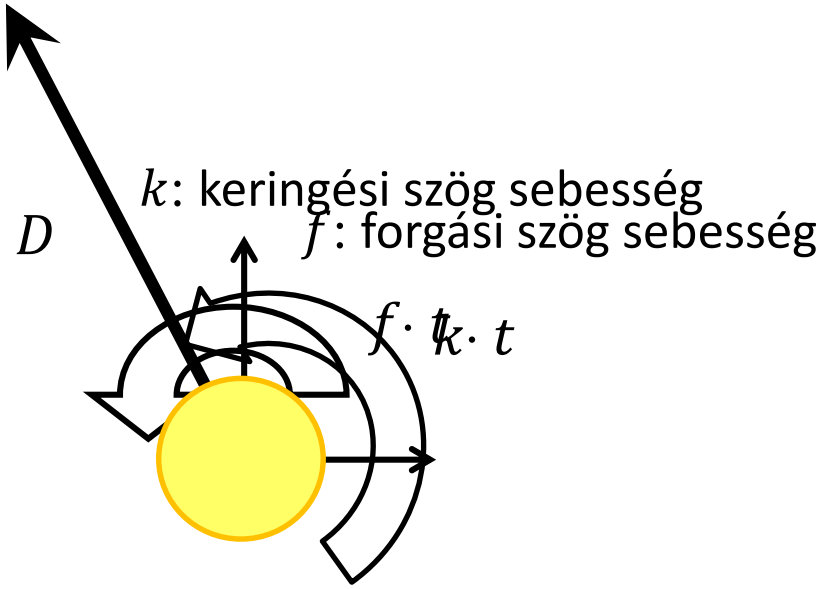


Animate:
A Föld forog és kering a Nap körül

$$M = \begin{bmatrix} \cos(f \cdot t) & \sin(f \cdot t) & 0 & 0 \\ -\sin(f \cdot t) & \cos(f \cdot t) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(23°) & \sin(23°) & 0 \\ 0 & -\sin(23°) & \cos(23°) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ D\cos(k \cdot t) & D\sin(k \cdot t) & 0 & 1 \end{bmatrix}$$



Planet

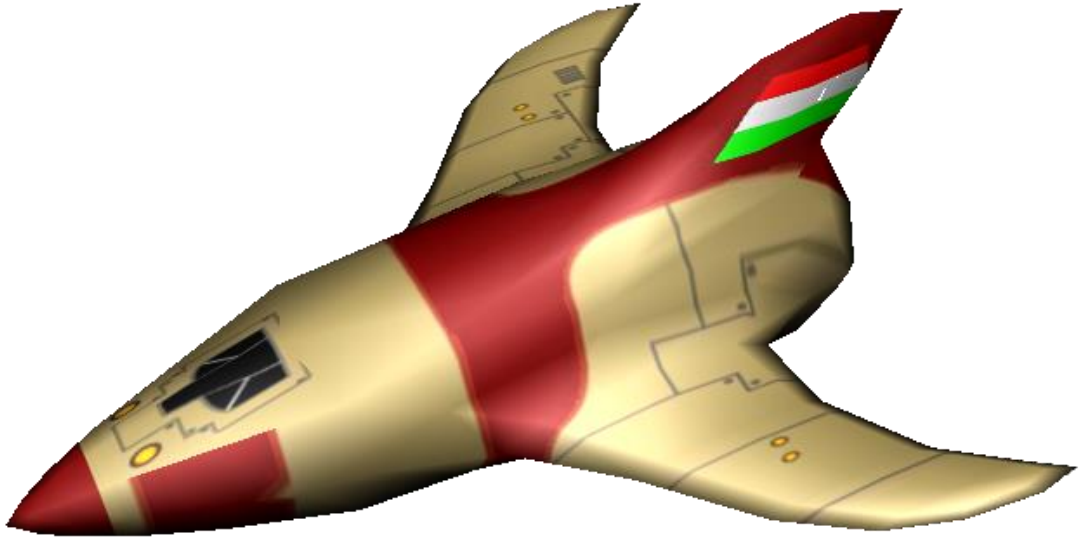
```
const vec3 X(1,0,0), Z(0,0,1);

class Planet : public GameObject {
   float rotAng = 0, revAng = 0;  // animation state
   float rotVel, revVel, tilt, D; // animation parameter
public:
   Planet(float _rotVel, float _revVel, float _tilt, float _D) { … }

   void Animate(float dt) {
      rotAng += rotVel * dt;
      revAng += revVel * dt;
   }

   void ModelingTransform(mat4& M, mat4& Minv) {
      vec3 p = vec3(cos(revAng), sin(revAng), 0) * D;
      M = RotationMatrix(rotAng, Z) * RotationMatrix(tilt, X) * TranslateMatrix(p);
      Minv = TranslateMatrix(-p) * RotationMatrix(-tilt,X) * RotationMatrix(-rotAng,Z);
   }
};
```

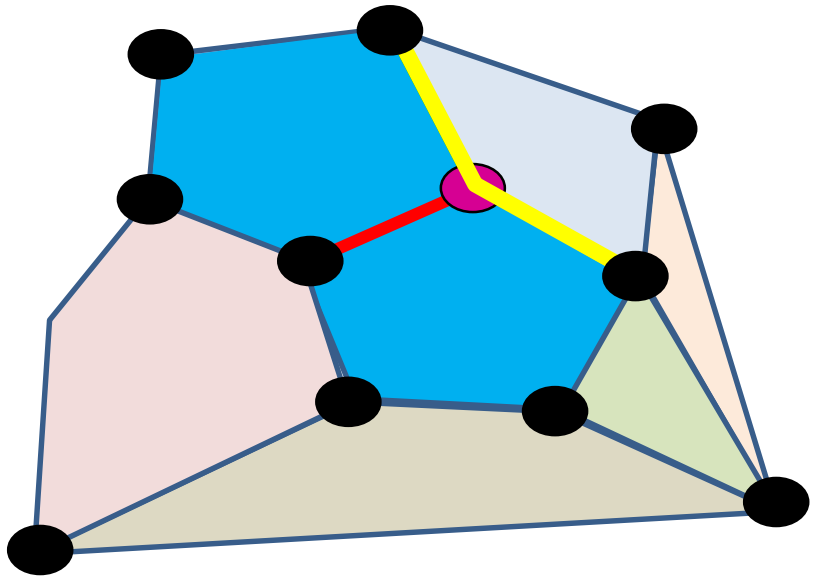
Az űrhajó



- Komplex geometria
  - négyszögháló
- Komplex textúra
- Fizikai animáció
  - erők (gravitáció, rakéták)
  - ütközések
- Viselkedés (AI)
  - A rakéták vezérlése
    - Ütközés elkerülés, avatártól menekülés, avatár üldözése

Az Euler karakterisztika invariáns: csúcs - él + lap = χ

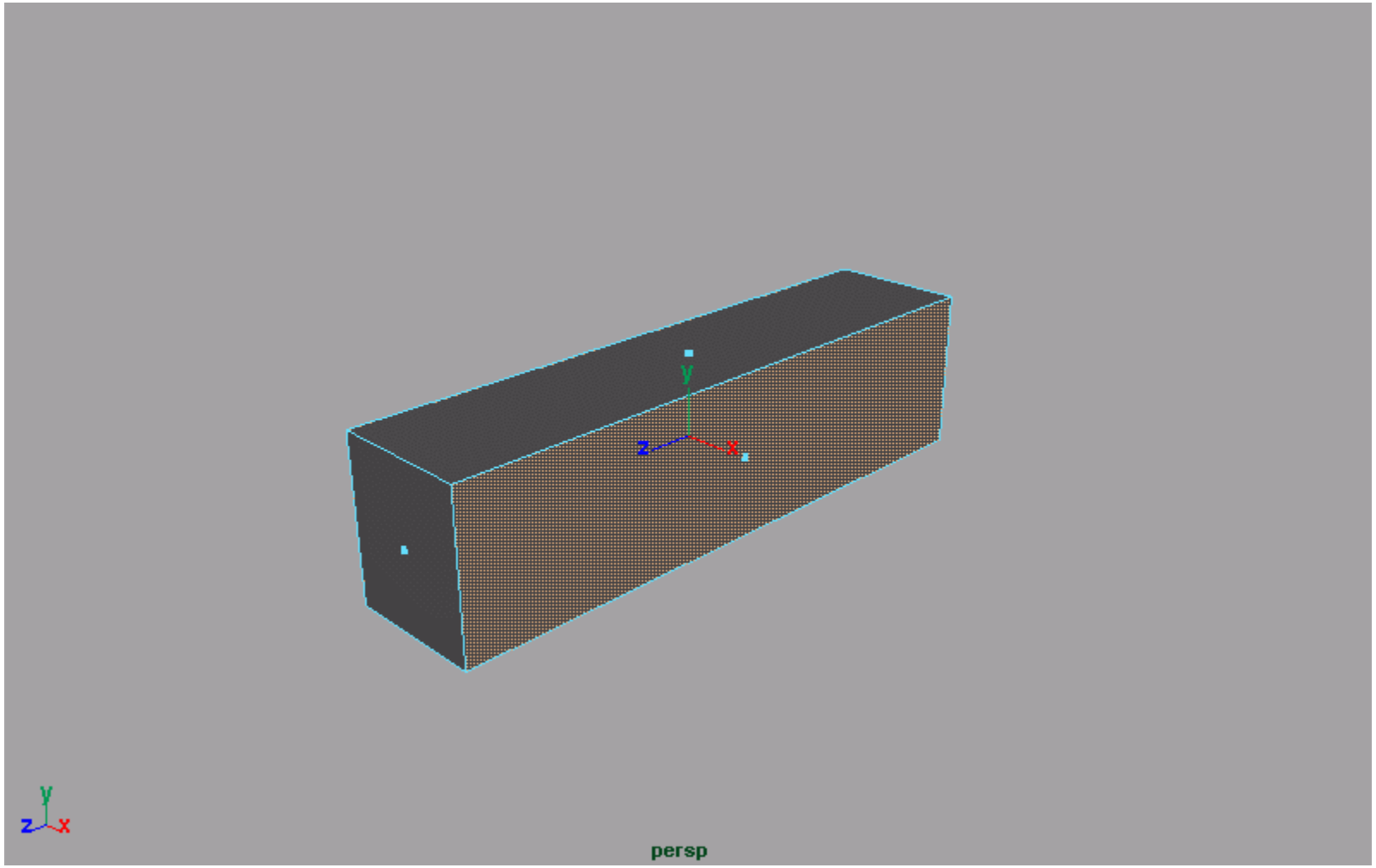
χ csak felület topológiájától függ, amelyre a csúcsokat, éleket és lapokat felrajzoltuk.



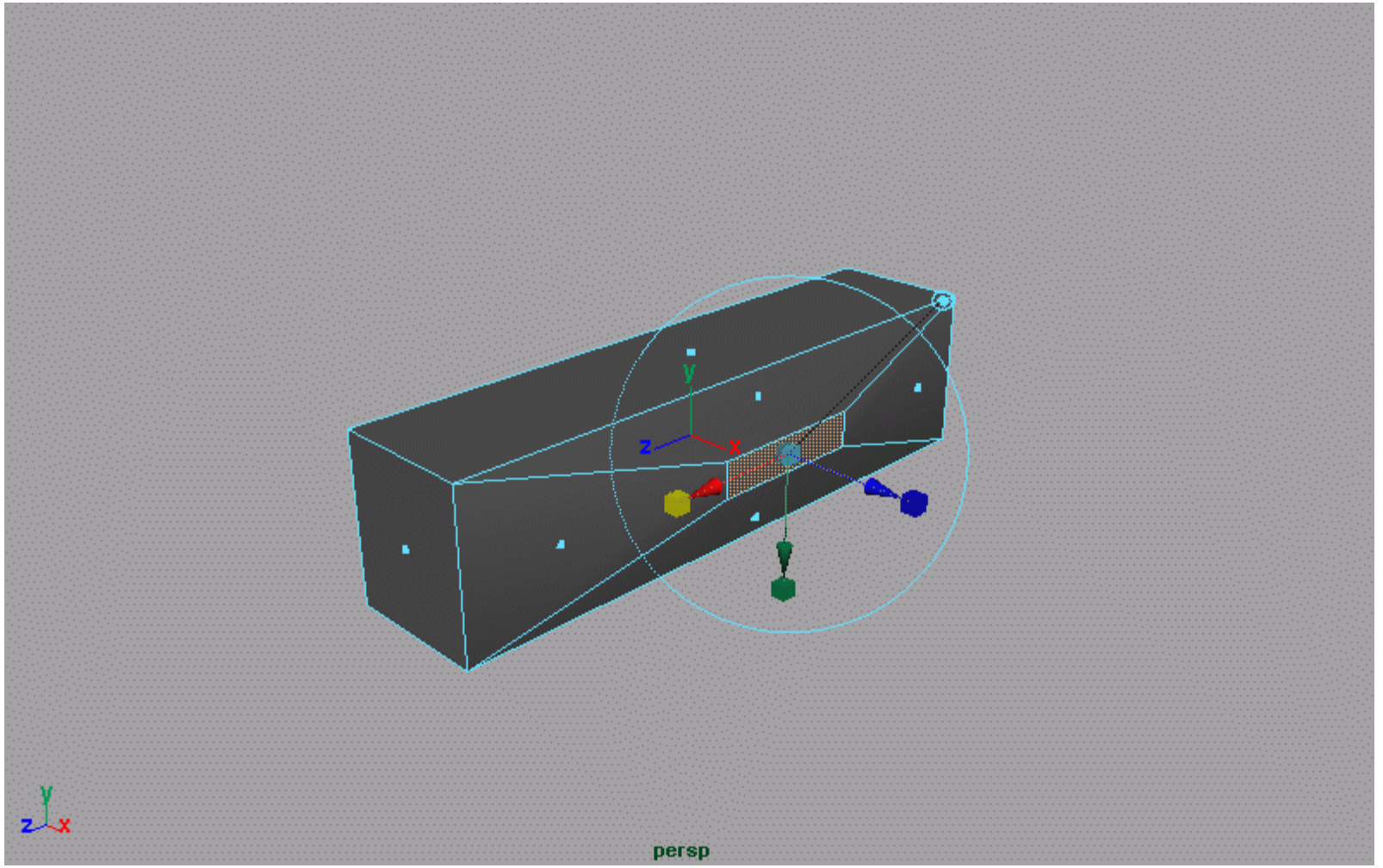
csúcs - él + lap
$+1\ -1$
$-1\ +1$

Űrhajó geometria

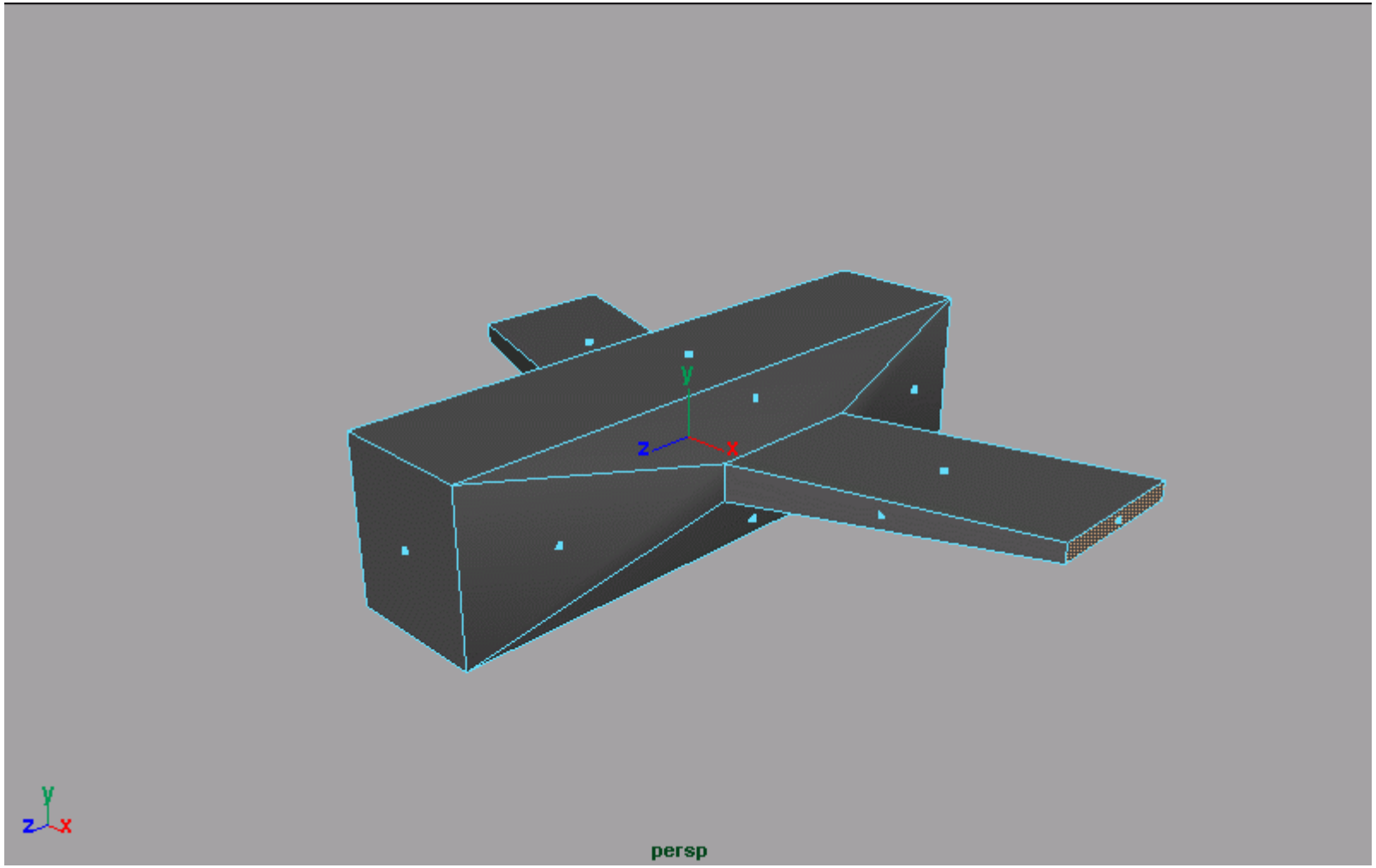
Euler műveletek: csúcs + lap = él + 2



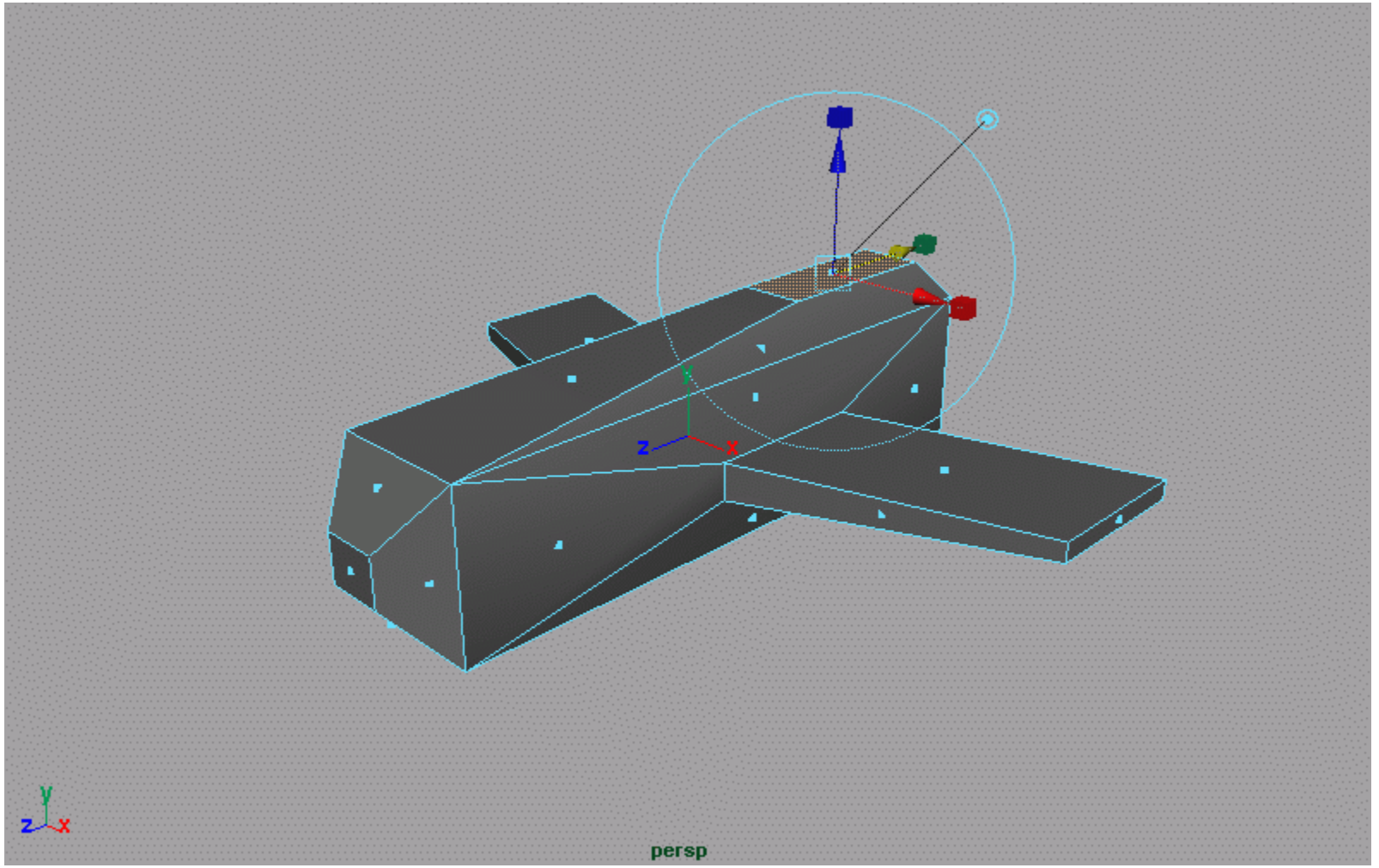
Űrhajó geometria



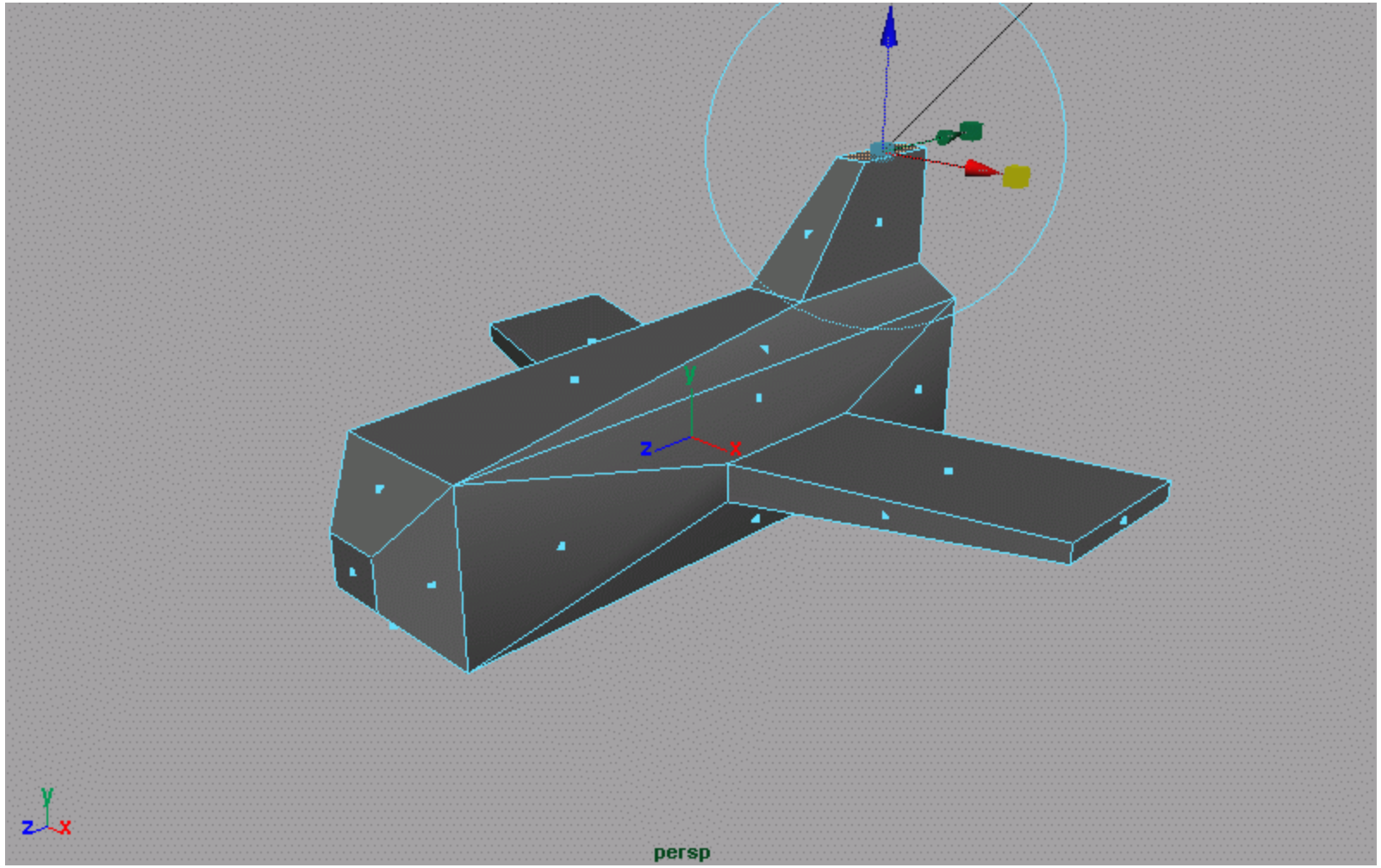
Űrhajó geometria



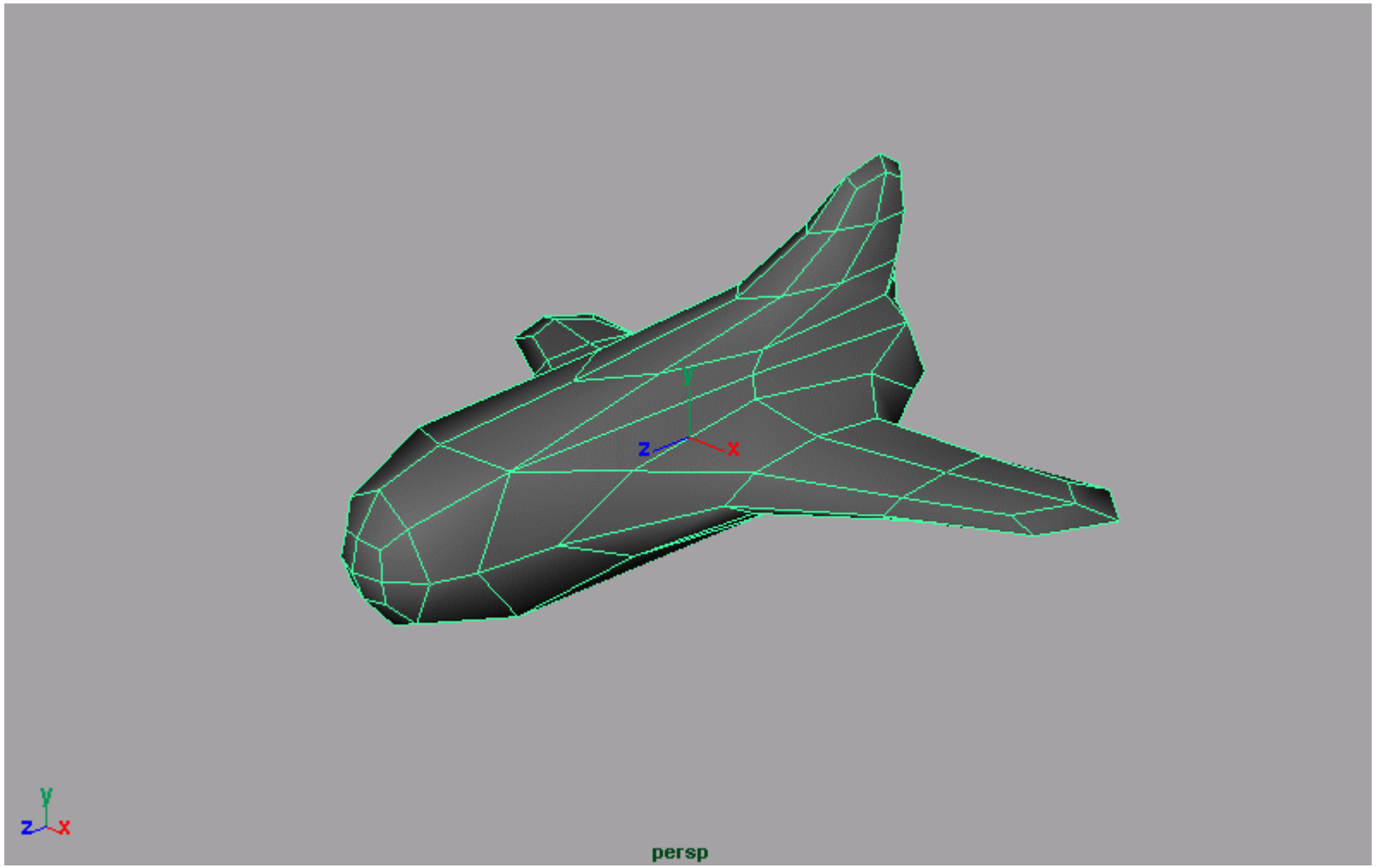
Űrhajó geometria



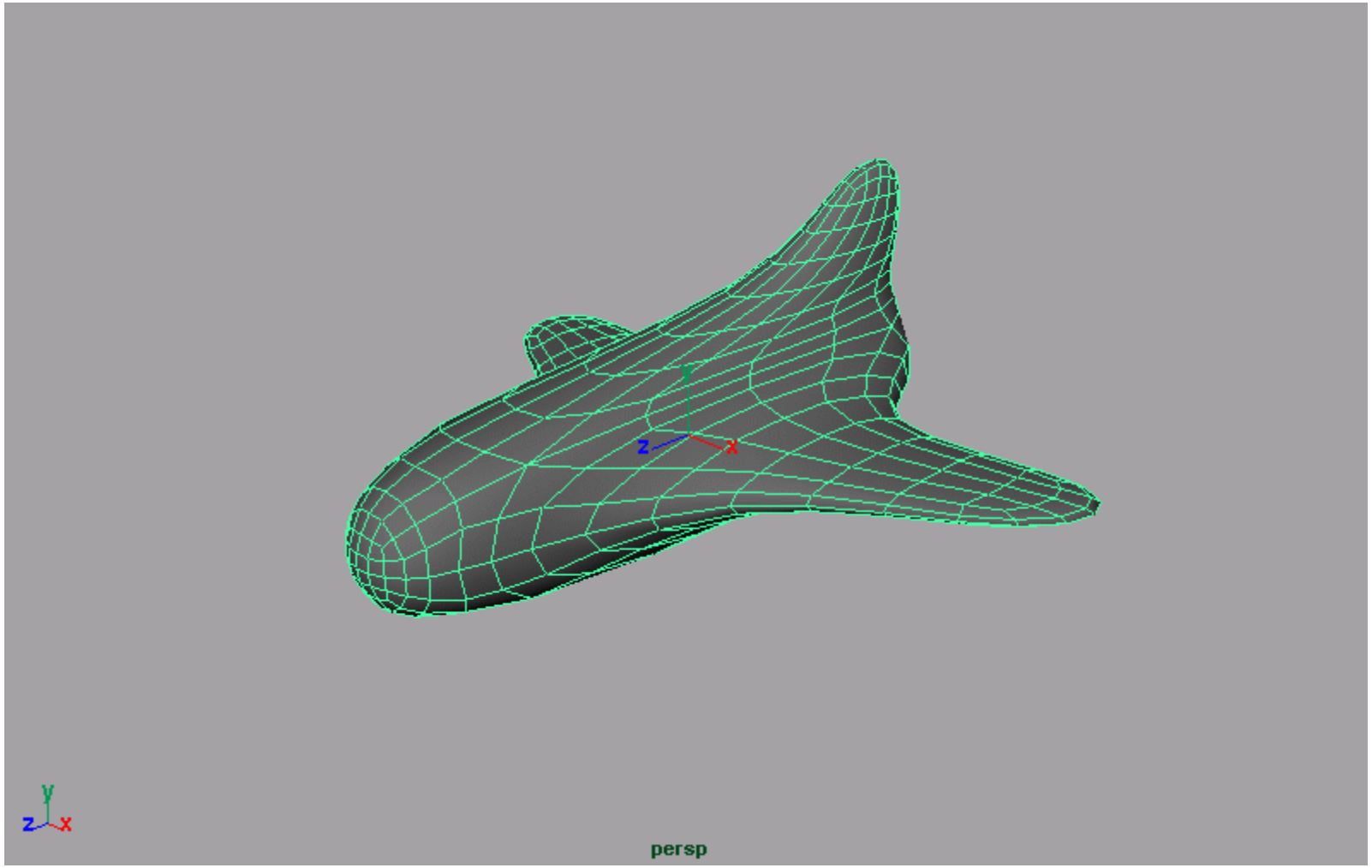
Űrhajó geometria



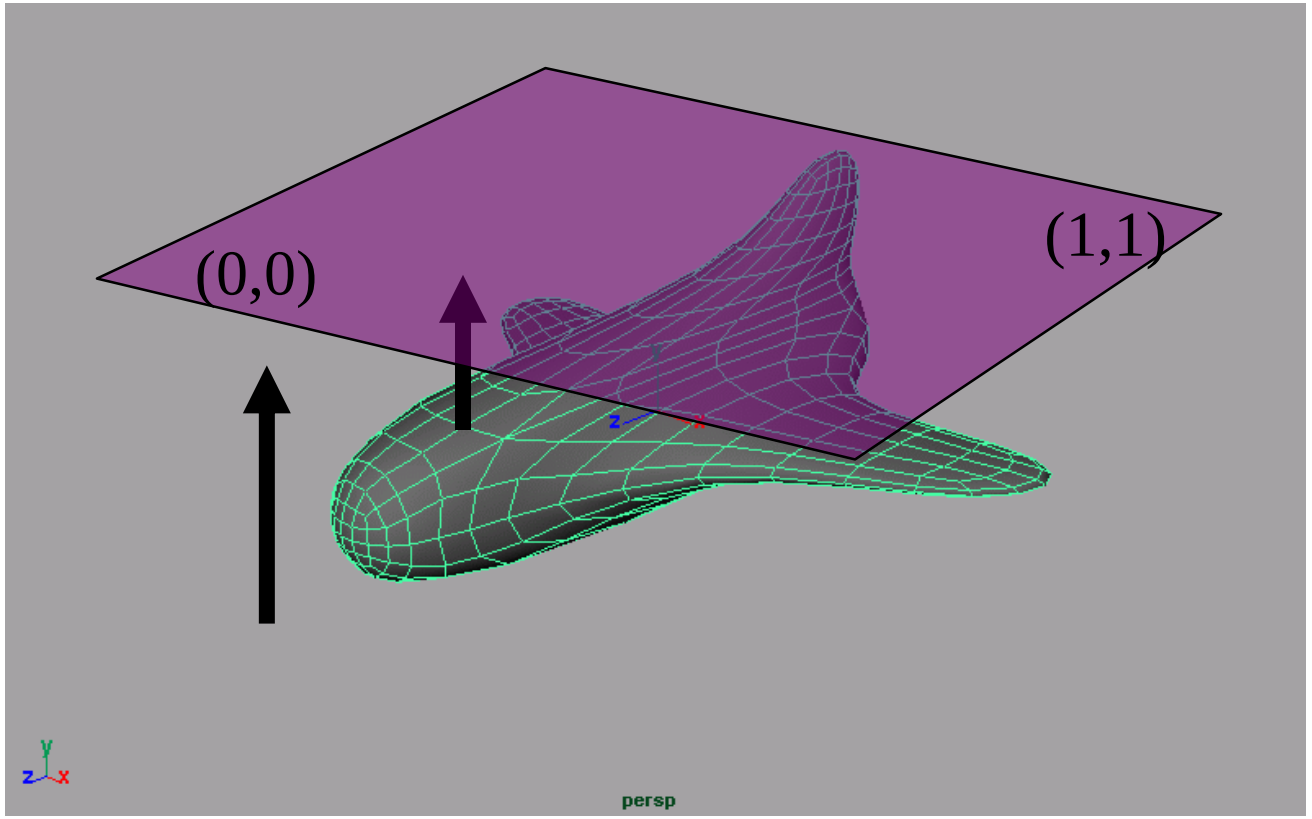
Űrhajó geometria:
Catmull-Clark subdivision

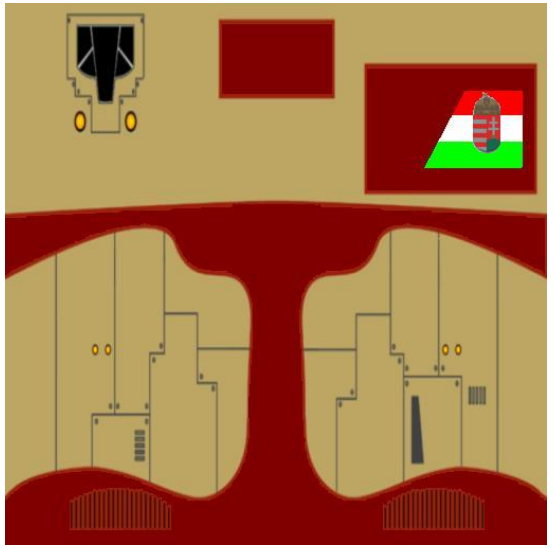


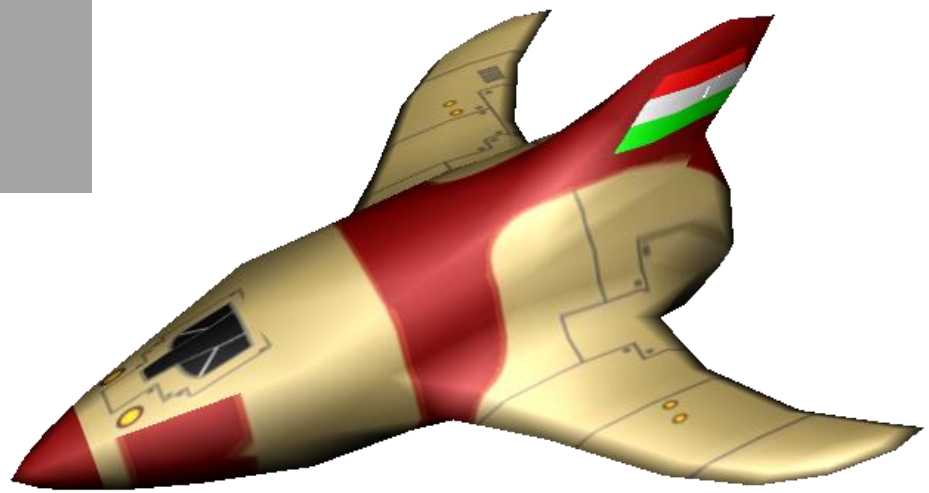
Űrhajó geometria:
Catmull-Clark subdivision



Textúrához paraméterezés



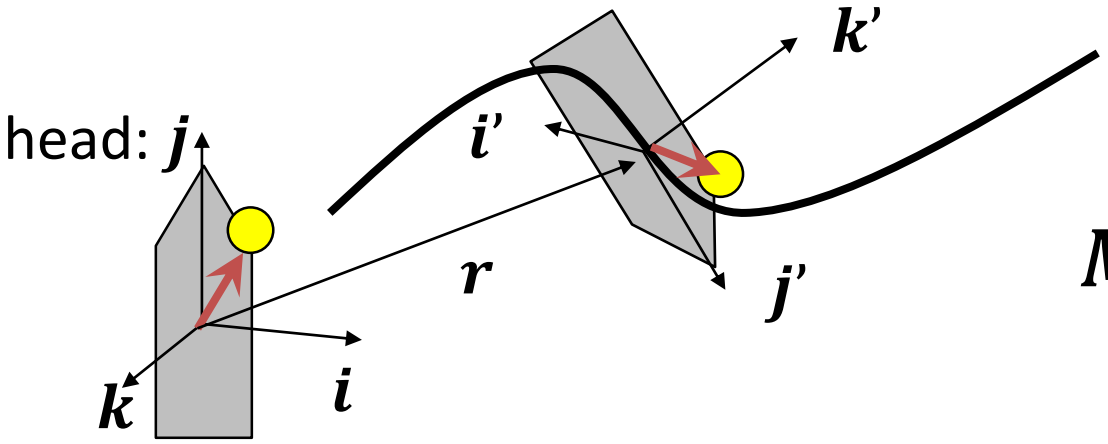




OBJ fájlformátum

```
v -0.708698 -0.679666 2.277417
v  0.708698 -0.679666 2.277417
v -0.735419  0.754681 2.256846
...
vt 0.510655 0.078673
vt 0.509594 0.070000
vt 0.496429 0.079059
...
vn -0.843091  0.000000 0.537771
vn -0.670151 -0.543088 0.505918
vn -0.000000 -0.783747 0.621081
…
f 65/1/1 37/2/2   62/3/3   61/4/4
f 70/8/5 45/217/6 67/218/7 66/241/8
f 75/9/9 57/10/10 72/11/11 71/12/12
...
```

Animate: Frenet frame + Newton 2



$$\boldsymbol{M} = \begin{bmatrix} \boldsymbol{i}' & 0 \\ \boldsymbol{j}' & 0 \\ \boldsymbol{k}' & 0 \\ \boldsymbol{r} & 1 \end{bmatrix}$$

Orientáció, nem ortonormált:

$$\boldsymbol{j}' = \boldsymbol{v},$$
$$\boldsymbol{k}^* = \boldsymbol{k}'(\mathbf{1} - \boldsymbol{\alpha}) + \boldsymbol{a}\boldsymbol{\alpha},$$
$$\boldsymbol{i}' = \boldsymbol{j}' \times \boldsymbol{k}^*$$

Gram-Schmidt ortogonalizáció:

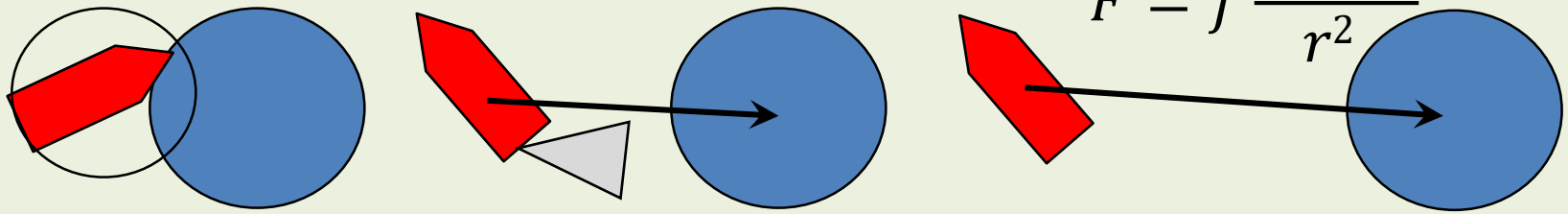
$$\boldsymbol{j}' = \boldsymbol{v}/|\boldsymbol{v}|,$$
$$\boldsymbol{i}' = \boldsymbol{j}' \times \boldsymbol{k}^*/|\boldsymbol{j}' \times \boldsymbol{k}^*|,$$
$$\boldsymbol{k}' = \boldsymbol{i}' \times \boldsymbol{j}'$$

Dinamikai szimuláció:

$$\boldsymbol{F} = m\boldsymbol{a}, \quad \boldsymbol{a} = \frac{\mathrm{d}\boldsymbol{v}}{\mathrm{d}t}, \quad \boldsymbol{v} = \frac{\mathrm{d}\boldsymbol{r}}{\mathrm{d}t} \Rightarrow \boxed{\boldsymbol{a} = \frac{\boldsymbol{F}}{m}, \quad \boldsymbol{v} \mathrel{+}= \boldsymbol{a}\Delta t, \quad \boldsymbol{r} \mathrel{+}= \boldsymbol{v}\Delta t}$$

Ship :: Control

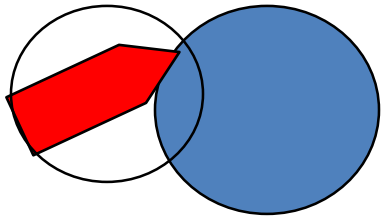
```
void Ship :: Control( float dt ) {
    force = vec3(0, 0, 0);
    for (GameObject * obj : objects) {
        if (dynamic_cast<Planet*>(obj)) {
```




```
        }
        if (dynamic_cast<Avatar*>(obj)) {
```

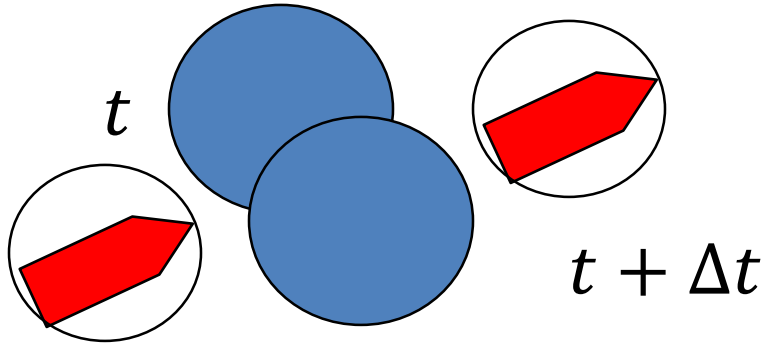

```
        }
    }
}
```

Ütközésdetektálás: lassú objektumok



adott t

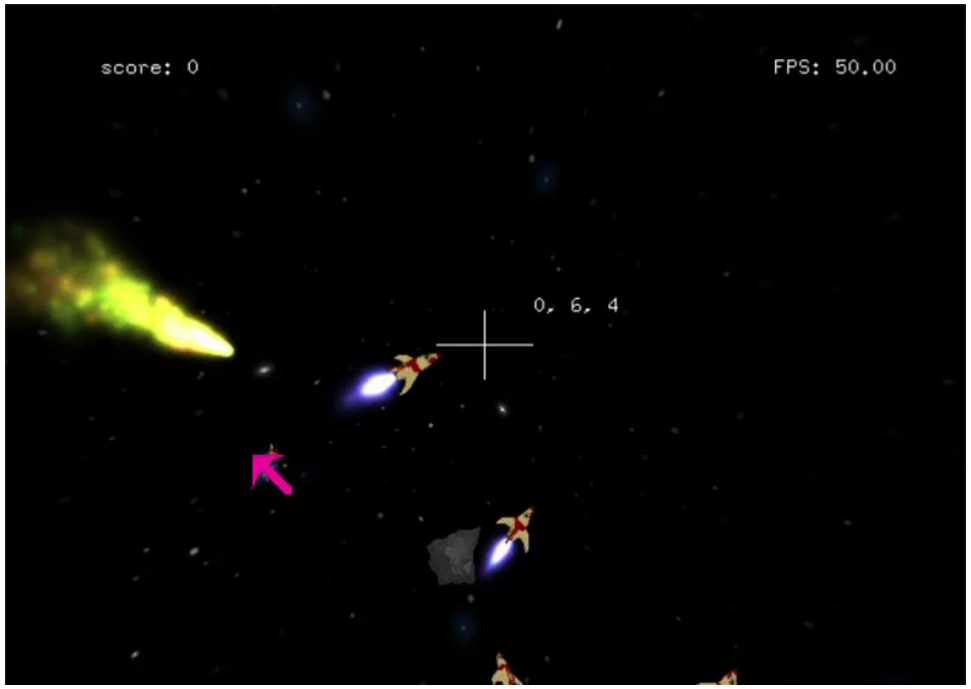
Probléma, ha az objektum gyors




```
dist = length(obj1.pos - obj2.pos)
minDist = obj1.BoundingRadius() + obj2.BoundingRadius()
if (dist < minDist) Collision!
```

Foton torpedó

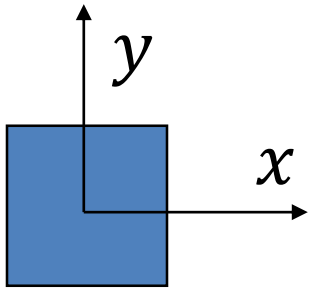
- Nagyon komplex geometria
- Hasonló kinézet minden irányból
- Könnyebb a képét használni

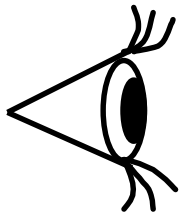


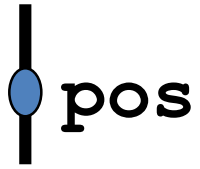
- Ütközésdetektálás = gyors mozgás

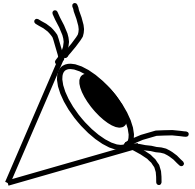
Billboard

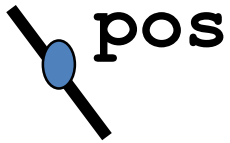
Egyetlen félig átlátszó textúra egy téglalapon

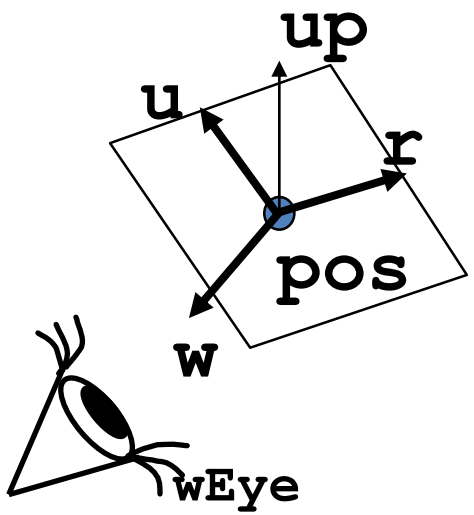










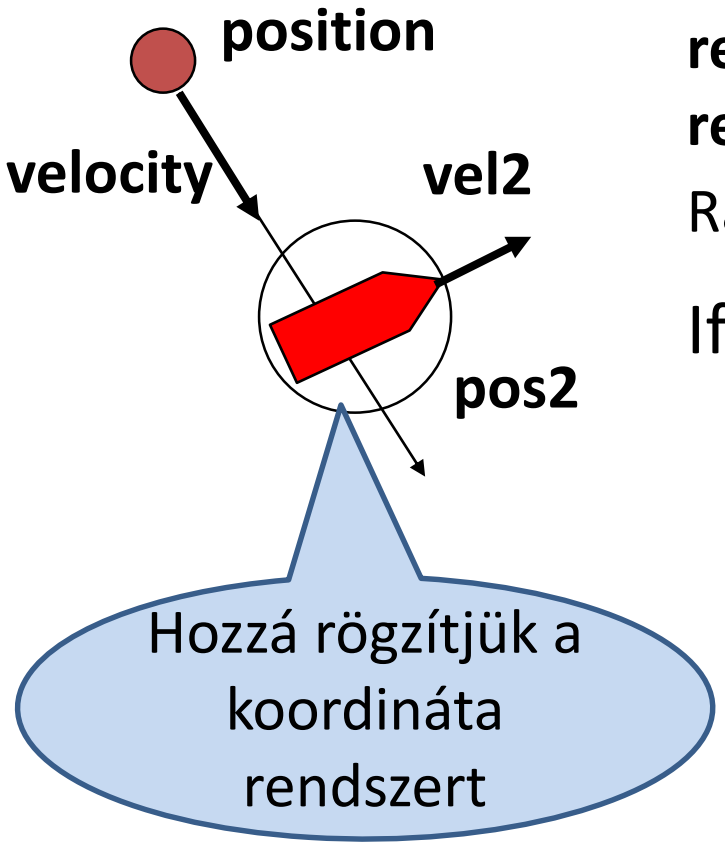



```
vec3 w = wEye - pos;
vec3 r = cross(w, up);
vec3 u = cross(r, w);
r = normalize(r) * size;
u = normalize(u) * size;
```

Billboard

```
void Bullet :: ModelingTransform(mat4& M, mat4& Minv) {
    vec3 up = vec3(0, 1, 0);
    vec3 w = state.wEye - pos;
    vec3 r = cross(w, up);
    vec3 u = cross(r, w);
    r = normalize(r) * size;
    u = normalize(u) * size;
    M = mat4(r.x,   r.y,   r.z,   0,
             u.x,   u.y,   u.z,   0,
             0,       0,     1,   0,  // z is zero: don't care
             pos.x, pos.y, pos.z, 1);
    Minv = …;
}
void Bullet :: Draw(RenderState state) {
    glEnable(GL_BLEND);          // transparency
    glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
    GameObject::Draw(state);
    glDisable(GL_BLEND);
}
```

Gyors (folytonos) ütközés detektálás



rel_pos = **position** - **pos2**

rel_velocity = **velocity** - **vel2**

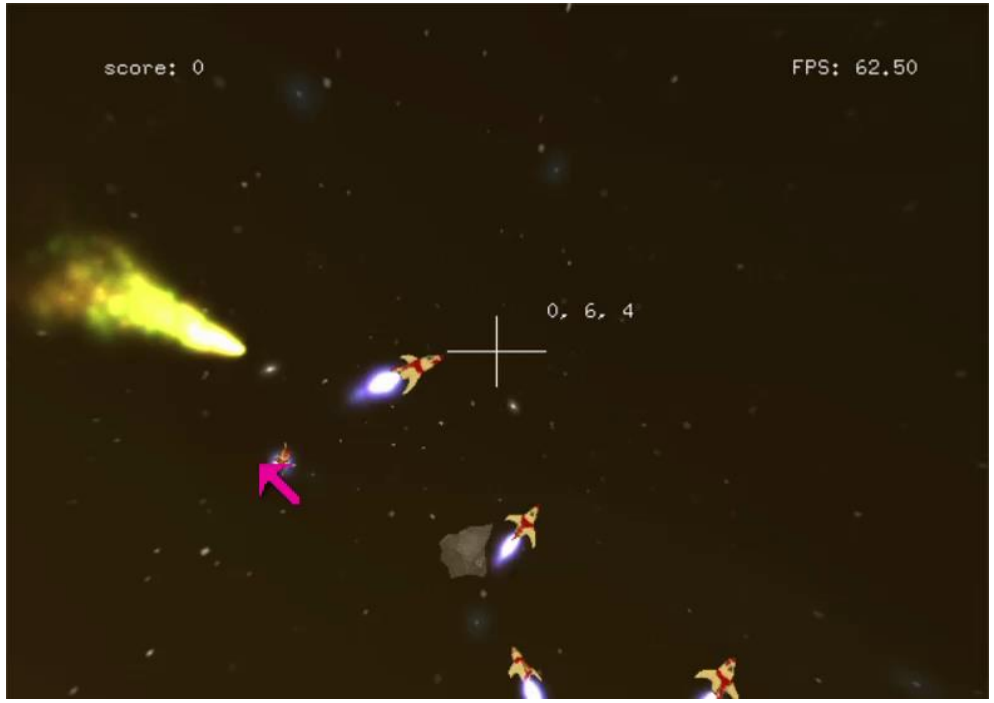
Ray: **rel_pos** + **rel_velocity**·*t*

If (ray intersects bounding sphere first
&& tintersect < dt) ***Collision!***

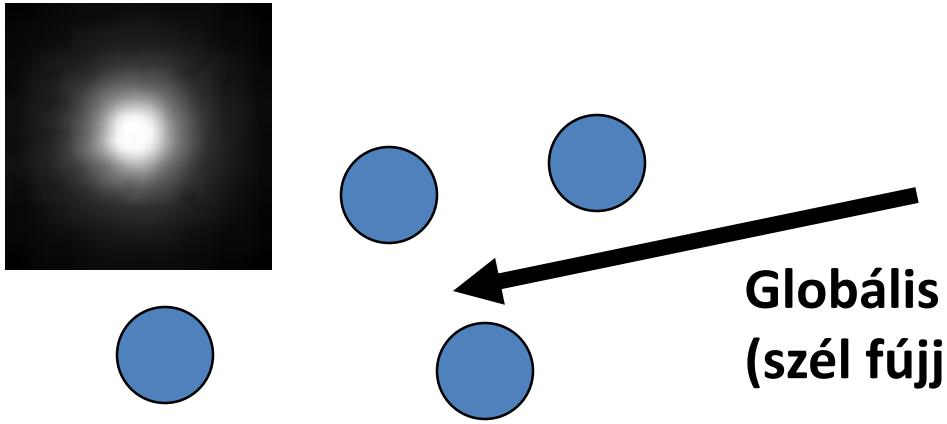
Robbanás

- Nagyon komplex geometria
- Hasonló kinézet minden irányból
- Plakátgyűjtemény

- Részecske rendszer



Részecske rendszerek

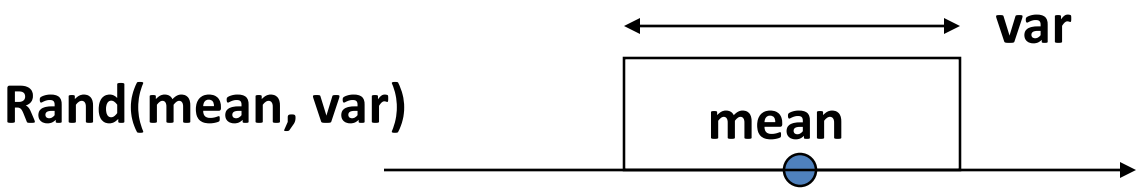


Globális erőtér
(szél fújja a füstöt)

Véletlen
Kezdeti
értékek

pos:	pos += velocity * dt
velocity:	velocity += acceleration * dt
acceleration:	acceleration = force / weight
lifetime	
age:	age += dt; if (age > lifetime) Kill();
size, dsize:	size += dsize * dt;
weight, dweight:	weight += dweight * dt
color, dcolor:	color += dcolor * dt

Robbanás paraméterei



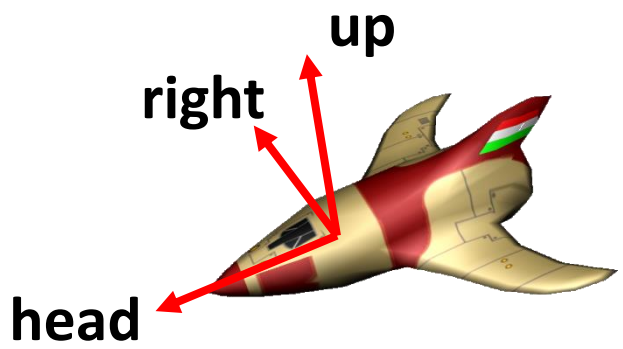

```
pos = center;                          // kezdetben fókuszált
lifetime = Rand(2, 1);

size = 0.001;                                  // kezdetben kicsi
dsize = Rand(0.5, 0.25) / lifetime;

velocity = Vector(Rand(0,0.4), Rand(0,0.4), Rand(0,0.4));
acceleration = Vector(Rand(0,1), Rand(0,1), Rand(0,1));

                       // Planck törvény: sárga átlátszatlanból vörös átlátszóba
color = Color(1, Rand(0.5, 0.25), 0, 1 );
dcolor = Color(0, -0.25, 0, -1) / lifetime;
```

Player




```
class Player : public Avatar, public Ship {
  void ProcInput(bool keys[]) {
     if ( keys[' '] ) // Fire!
        objects.push_back(new Bullet(pos, velocity));

     // Kormányzás: az avatár koordinátarendszerében!
     vec3 head = normalize(velocity);
     vec3 right = normalize(cross(wVup(), head));
     vec3 up = cross(head, right);

     if (keys[KEY_UP])    force -= up;
     if (keys[KEY_DOWN])  force += up;
     if (keys[KEY_LEFT])  force -= right;
     if (keys[KEY_RIGHT]) force += right;
  }
};
```