GRAFIKA KOMPUTER

D10K-5C01

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GK05: Transformasi 3D

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TRANSFORMASI 3 DIMENSI

- Pendahuluan
- Skala
- Rotasi
- Refleksi
- Transformasi Majemuk

PENDAHULUAN

- Menggunakan koordinat 3 sumbu yaitu x, y dan z
- Sebuah titik pada ruang 3 dimensi dituliskan sebagai [x y z 1]
- Transformasi 3 dimensi dituliskan sebagai

  [x’ y’ z’ 1] = [x y z 1] [T]
- MTU 3 dimensi

$$\begin{bmatrix} a & b & c & p \\ d & e & f & q \\ g & h & i & r \\ l & m & n & s \end{bmatrix}$$

a, b, c, d, e, f, g, h, i adalah elemen yang berpengaruh terhadap transformasi linier

p, q, r adalah elemen yang untuk proyeksi dan perspektif

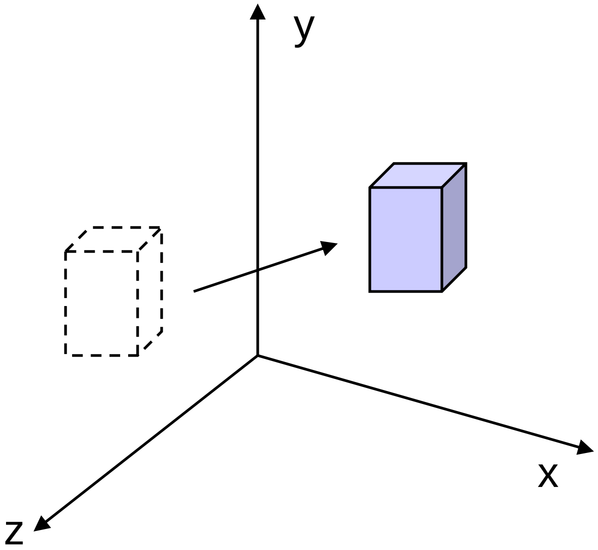
l, m, n adalah elemen untuk translasi pada sumbu x, y dan z

s adalah elemen untuk overall scaling

Translasi

- Translasi sebuah titik

$$x' = x + t_x\,, \quad y' = y + t_y\,, \quad z' = z + t_z$$



$$\begin{bmatrix} x' & y' & z' & 1 \end{bmatrix} = \begin{bmatrix} x & y & z & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ t_x & t_y & t_z & 1 \end{bmatrix}$$

SKALA 3D

- Terdapat 2 jenis skala yaitu **local scaling** dan **overall scaling**. Local scaling dipengaruhi oleh elemen a, e, dan `i`. Sedangkan overal scaling dipengaruhi oleh elemen `s`
- Contoh di bawah adalah MTU local scaling untuk faktor 1/3, 1/2 dan 1 serta overall scaling dengan faktor 2. Ingat bahwa nilai overall scaling adalah 1/s

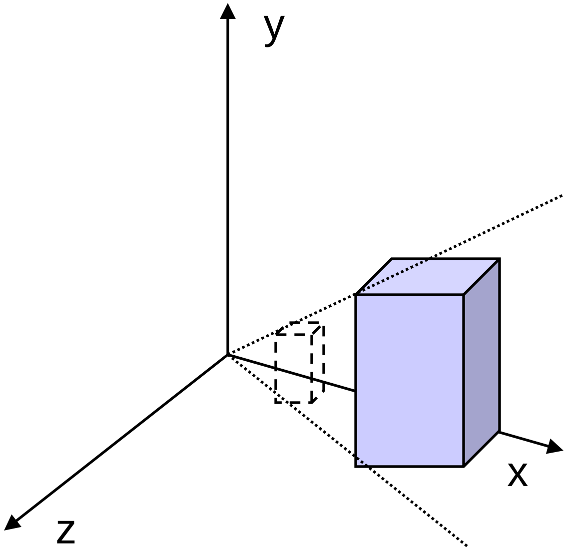
$$\begin{bmatrix} 1/3 & 0 & 0 & 0 \\ 0 & 1/2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1/2 \end{bmatrix}$$

(a) (b)

3D Scaling

- Global Scaling

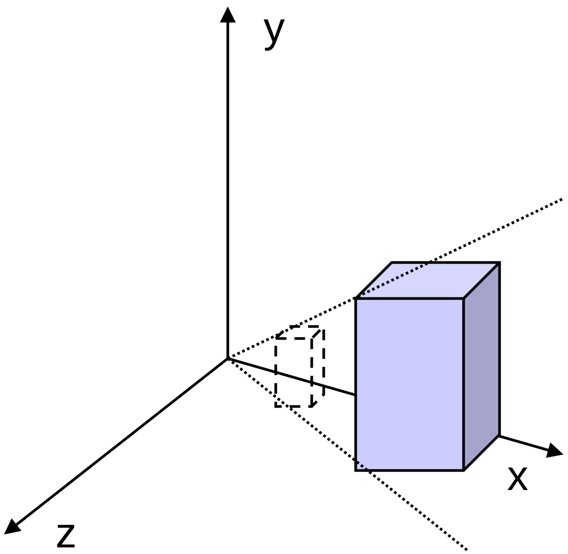
$$
\begin{bmatrix} x' & y' & z' & 1 \end{bmatrix} = \begin{bmatrix} x & y & z & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & \dfrac{1}{S_g} \end{bmatrix}
$$



3D Scaling

- Local Scaling

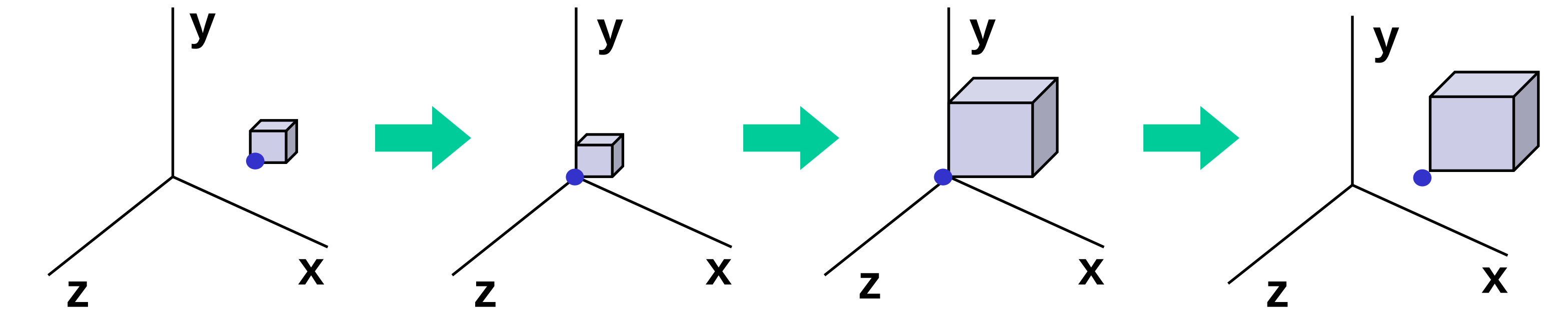
$$x' = x \cdot s_x\,, \quad y' = y \cdot s_y\,, \quad z' = z \cdot s_z$$



$$\begin{bmatrix} x' & y' & z' & 1 \end{bmatrix} = \begin{bmatrix} x & y & z & 1 \end{bmatrix} \begin{bmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Relative Scaling

- Scaling with a Selected Fixed Position



Original position **Translate** **Scaling** **Inverse Translate**

$$T(-t_x,-t_y,-t_z)\cdot S(s_x,s_y,s_z)\cdot T(t_x,t_y,t_z)=\begin{bmatrix}x' & y' & z' & 1\end{bmatrix}=$$

$$\begin{bmatrix}x & y & z & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ -t_x & -t_y & -t_z & 1\end{bmatrix}\begin{bmatrix}s_x & 0 & 0 & 0\\ 0 & s_y & 0 & 0\\ 0 & 0 & s_z & 0\\ 0 & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ t_x & t_y & t_y & 1\end{bmatrix}$$

3D Rotation

- Coordinate-Axes Rotations
  - X-axis rotation
  - Y-axis rotation
  - Z-axis rotation

- General 3D Rotations
  - Rotation about Origin
  - Rotation about an axis that is parallel to one of the coordinate axes
  - Rotation about an arbitrary axis

ROTASI 3D

- Rotasi pada sumbu utama
- MTU $[T_x]$ untuk rotasi pada sumbu x sebesar θ°
- MTU $[T_y]$ untuk rotasi pada sumbu y sebesar o°
- MTU $[T_z]$ untuk rotasi pada sumbu z sebesar ψ°

$$[T_x] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$[T_y] = \begin{bmatrix} \cos\phi & 0 & -\sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ \sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$[T_z] = \begin{bmatrix} \cos\psi & \sin\psi & 0 & 0 \\ -\sin\psi & \cos\psi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

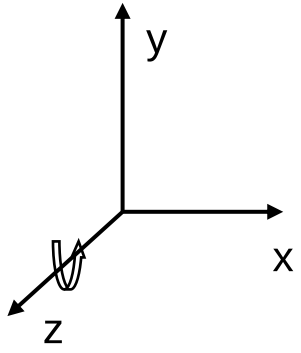
Coordinate-Axes Rotations

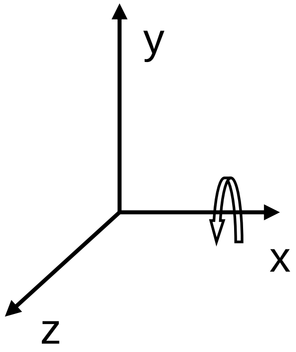
- **Z-Axis Rotation**
- **X-Axis Rotation**
- **Y-Axis Rotation**

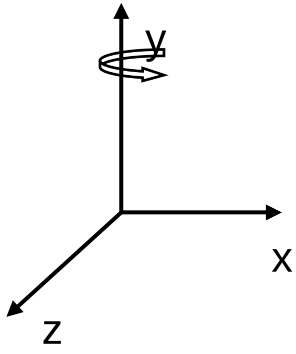
$$\begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos\theta & 0 & -\sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

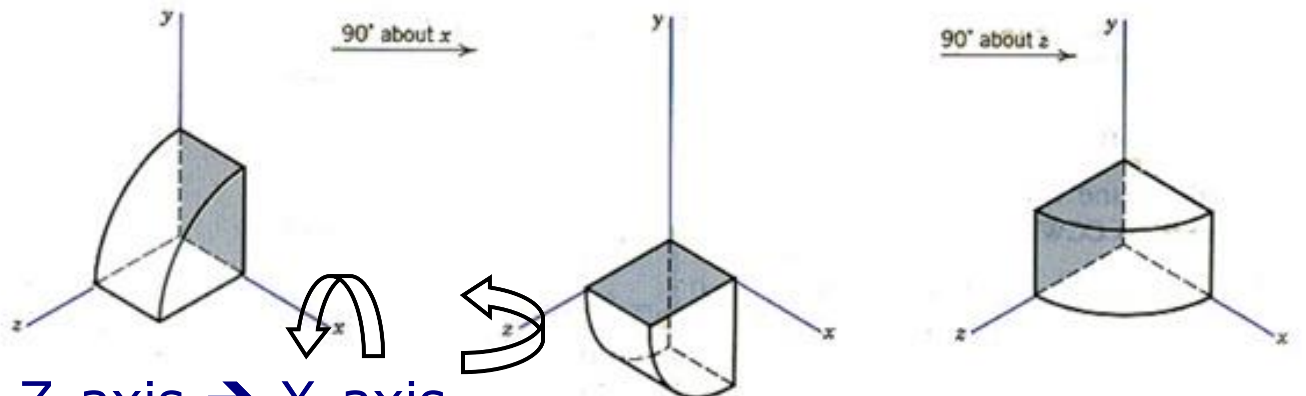




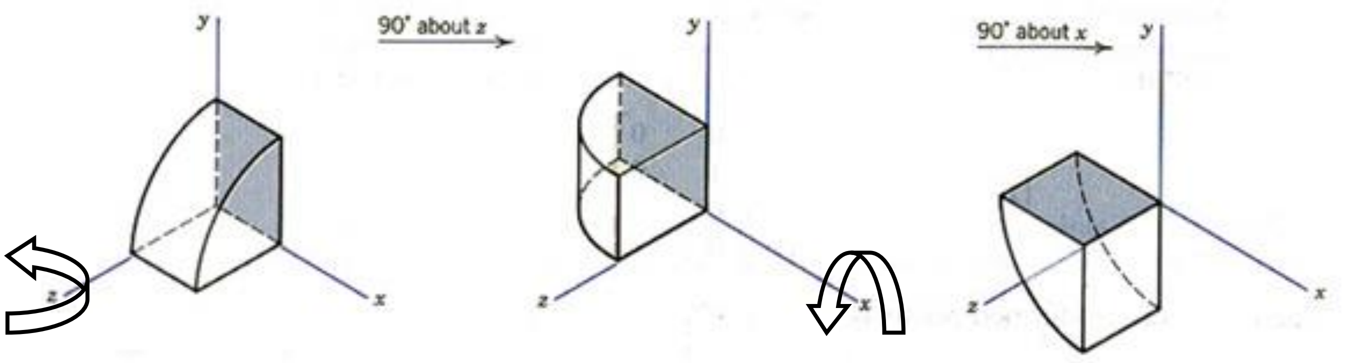


Urutan Rotasi

- Urutan rotasi mempengaruhi hasil akhir
  - X-axis ➔ Z-axis

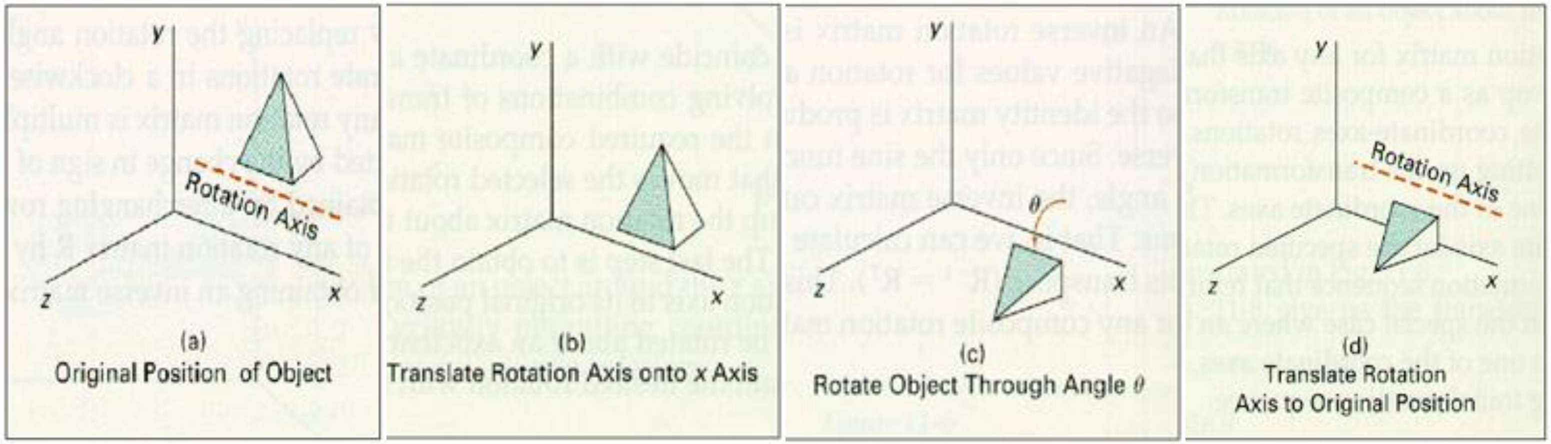


  - Z-axis ➔ X-axis



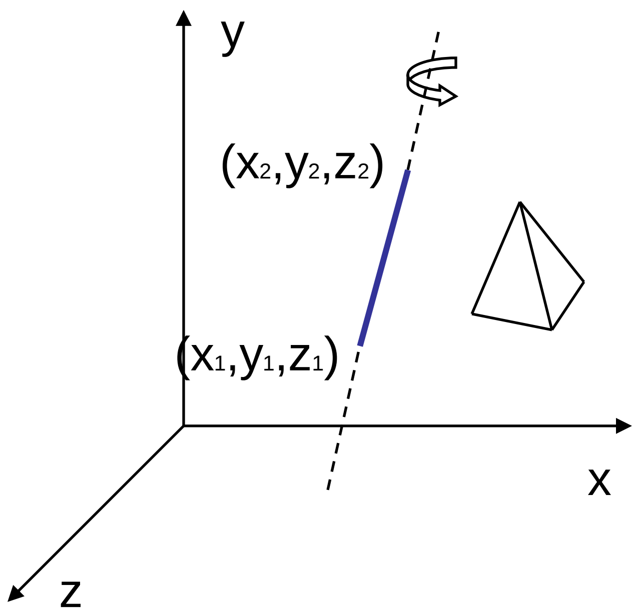
Rotasi 3D Secara Umum

- Rotasi pada sebuah sumbu yang paralel dengan sumbu utama
  - **Translate** objek sehingga sumbu rotasi berimpit dengan sumbu koordinat yang paralel
  - Lakukan **rotation** yang diinginkan pada sumbu tsb
  - **Translate** objek kembali ke posisi semula



Rotasi 3D Secara Umum

- Rotasi pada Sumbu Sembarang



T

R

R^{-1}

T^{-1}

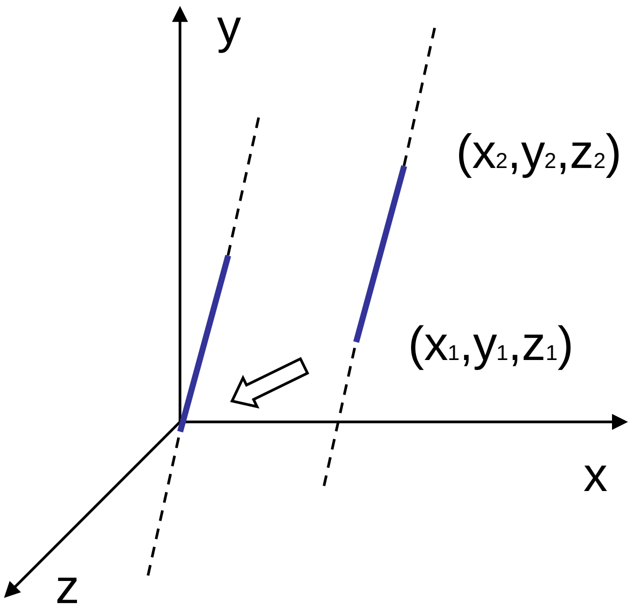
Basic Idea

1. **Translate (x1, y1, z1) to the origin**
2. **Rotate (x’2, y’2, z’2) on to the z axis**
3. **Rotate the object around the z-axis**
4. **Rotate the axis to the original orientation**
5. **Translate the rotation axis to the original position**

$$[T_R]_{ARB} = [T_{TR}]^{-1}[T_R]_x^{-\alpha}[T_R]_y^{-\phi}[T_R]_z^{\theta}[T_R]_y^{\phi}[T_R]_x^{\alpha}[T_{TR}]$$

General 3D Rotations

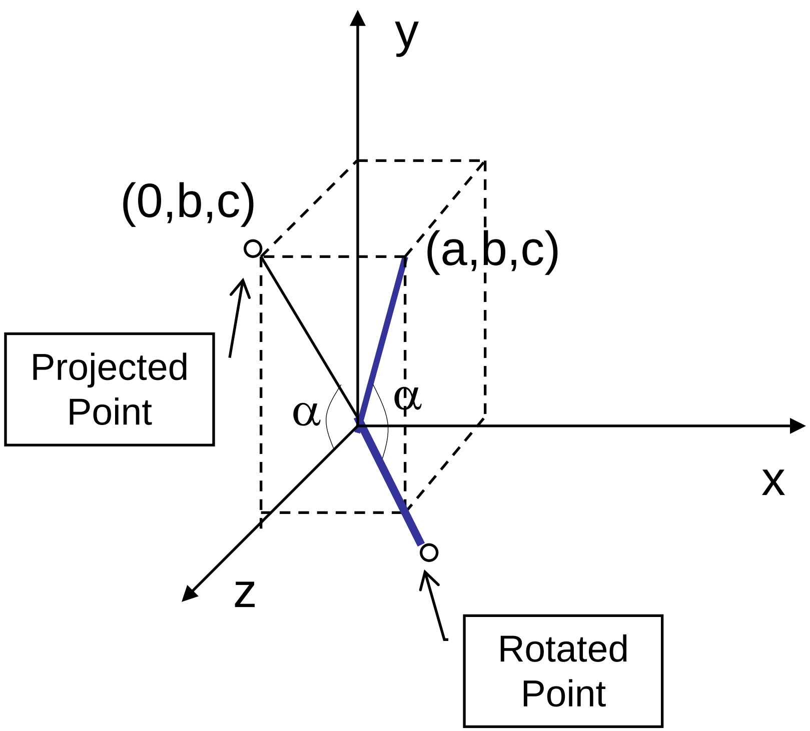
- Step 1. Translation



$$T_{TR} = \begin{bmatrix} 1 & 0 & 0 & 0_1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_1 & -y_1 & -z_1 & 1 \end{bmatrix}$$

General 3D Rotations

- Step 2. Establish $[\ T_R\ ]^{\alpha}_{x}$ x axis



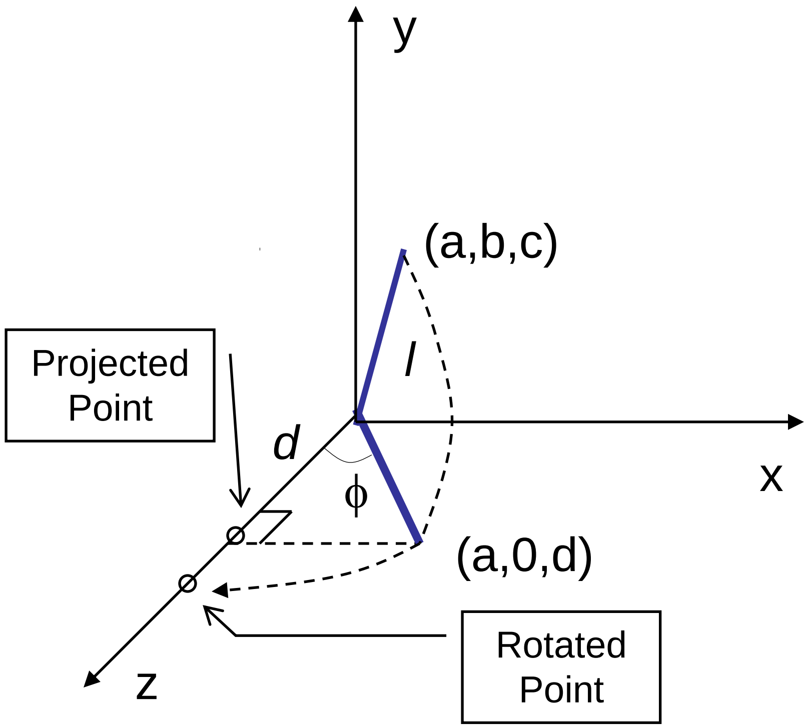
$$\sin\alpha = \frac{b}{\sqrt{b^2 + c^2}} = \frac{b}{d}$$

$$\cos\alpha = \frac{c}{\sqrt{b^2 + c^2}} = \frac{c}{d}$$

$$[T_R]^{\alpha}_{x} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha & 0 \\ 0 & \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & c/d & -b/d & 0 \\ 0 & b/d & c/d & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Arbitrary Axis Rotation

- Step 3. Rotate about y axis by ϕ



$$\sin\phi = \frac{a}{l}, \qquad \cos\phi = \frac{d}{l}$$

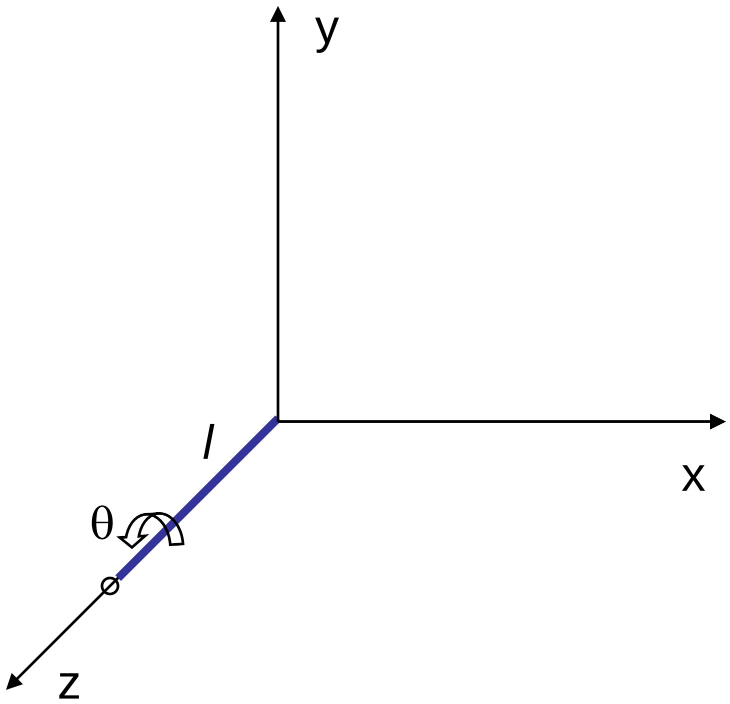
$$l^2 = a^2 + b^2 + c^2 = a^2 + d^2$$

$$d = \sqrt{b^2 + c^2}$$

$$[T_R]_y^{\phi} = \begin{bmatrix} \cos\phi & 0 & \sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} d/l & 0 & a/l & 0 \\ 0 & 1 & 0 & 0 \\ -a/l & 0 & d/l & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Arbitrary Axis Rotation

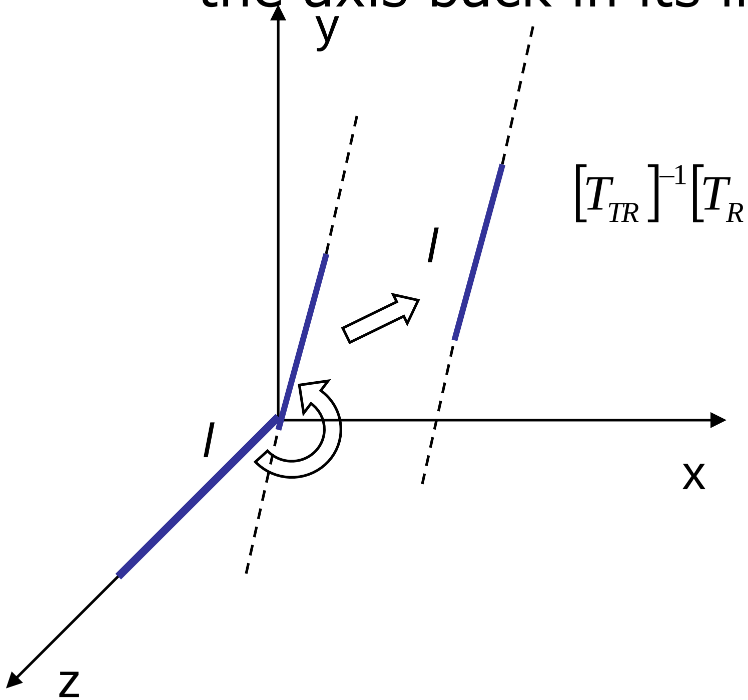
- Step 4. Rotate about *z* axis by the desired angle θ



$$[T_R]_z^{\theta} = \begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Arbitrary Axis Rotation

- Step 5. Apply the reverse transformation to place the axis back in its initial position

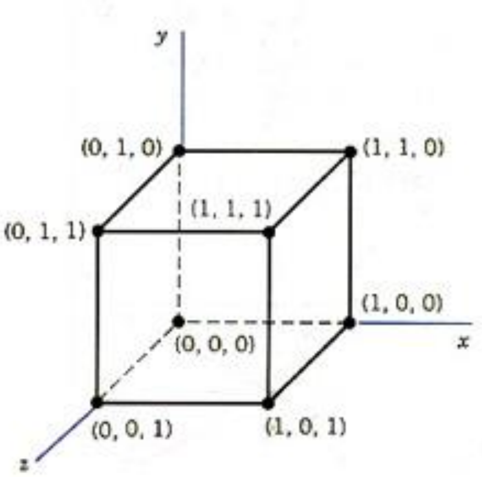


$$[T_{TR}]^{-1}[T_R]_x^{-\alpha}[T_R]_y^{-\phi} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ x_1 & y_1 & z_1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha & 0 \\ 0 & -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\phi & 0 & -\sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ \sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$[T_R]_{ARB} = [T_{TR}]^{-1}[T_R]_x^{-\alpha}[T_R]_y^{-\phi}[T_R]_z^{\theta}[T_R]_y^{\phi}[T_R]_x^{\alpha}[T_{TR}]$$

Example

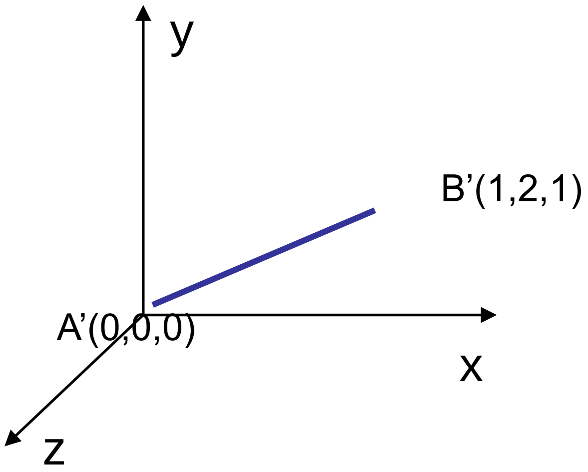
Ex) Find the new coordinates of a unit cube 90º-rotated about an axis defined by its endpoints A(2,1,0) and B(3,3,1).



A Unit Cube

Example

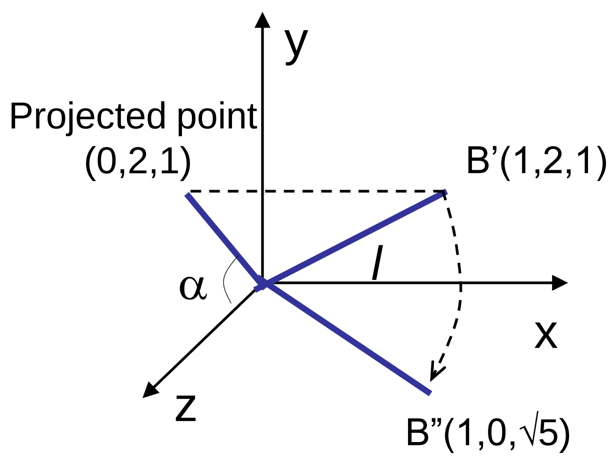
- Step1. Translate point A to the origin



$$[T_{TR}] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -2 & -1 & 0 & 1 \end{bmatrix}$$

Example

- Step 2. Rotate axis *A′B′* about the x axis by and angle α, until it lies on the *xz* plane.



$$\sin\alpha = \frac{2}{\sqrt{2^2+1^2}} = \frac{2}{\sqrt{5}} = \frac{2\sqrt{5}}{5}$$

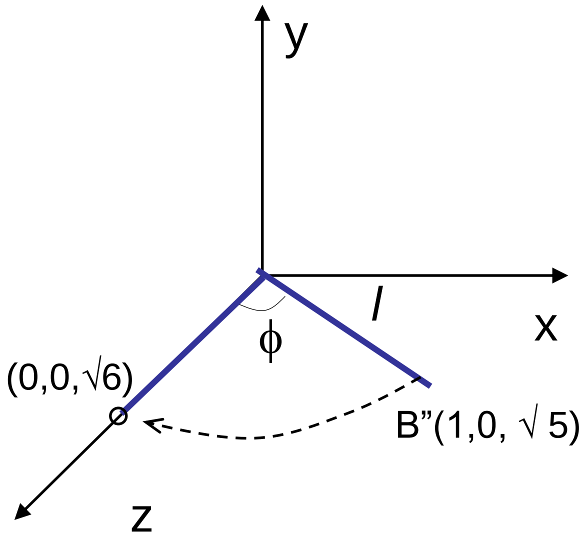
$$\cos\alpha = \frac{1}{\sqrt{5}} = \frac{\sqrt{5}}{5}$$

$$l = \sqrt{1^2+2^2+1^2} = \sqrt{6}$$

$$[T_R]_x^\alpha = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{\sqrt{5}}{5} & -\frac{2\sqrt{5}}{5} & 0 \\ 0 & \frac{2\sqrt{5}}{5} & \frac{\sqrt{5}}{5} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Example

- Step 3. Rotate axis *A′B″* about the y axis by and angle ϕ, until it coincides with the z axis.



$$\sin\phi = \frac{1}{\sqrt{6}} = \frac{\sqrt{6}}{6}$$

$$\cos\phi = \frac{\sqrt{5}}{\sqrt{6}} = \frac{\sqrt{30}}{6}$$

$$[T_R]_y^{\phi} = \begin{bmatrix} \frac{\sqrt{30}}{6} & 0 & -\frac{\sqrt{6}}{6} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{\sqrt{6}}{6} & 0 & \frac{\sqrt{30}}{6} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Example

- Step 4. Rotate the cube 90° about the z axis

$$[T_R]_z^{90^\circ} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Finally, the concatenated rotation matrix about the arbitrary axis AB becomes,

$$[T_R]_{ARB} = [T_{TR}]^{-1}[T_R]_x^{-\alpha}[T_R]_y^{-\phi}[T_R]_z^{90^\circ}[T_R]_y^{\phi}[T_R]_x^{\alpha}[T_{TR}]$$

$$[T_R]_{ARB} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -2 & -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{\sqrt{5}}{5} & -\frac{2\sqrt{5}}{5} & 0 \\ 0 & \frac{2\sqrt{5}}{5} & \frac{\sqrt{5}}{5} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{\sqrt{30}}{6} & 0 & -\frac{\sqrt{6}}{6} & 0 \\ 0 & 1 & 0 & 0 \\ \frac{\sqrt{6}}{6} & 0 & \frac{\sqrt{30}}{6} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \frac{\sqrt{30}}{6} & 0 & \frac{\sqrt{6}}{6} & 0 \\ 0 & 1 & 0 & 0 \\ -\frac{\sqrt{6}}{6} & 0 & \frac{\sqrt{30}}{6} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{\sqrt{5}}{5} & \frac{2\sqrt{5}}{5} & 0 \\ 0 & -\frac{2\sqrt{5}}{5} & \frac{\sqrt{5}}{5} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 2 & 1 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.166 & -0.075 & 0.983 & 1.742 \\ 0.742 & 0.667 & 0.075 & -1.151 \\ -0.650 & 0.741 & 0.167 & 0.560 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Example

- Multiplying $[T_R]_{AB}$ by the point matrix of the original cube

$$\left[P^*\right]=\left[T_R\right]_{ARB}\cdot\left[P\right]$$

$$\left[P^*\right]=\begin{bmatrix} 0.166 & -0.075 & 0.983 & 1.742 \\ 0.742 & 0.667 & 0.075 & -1.151 \\ -0.650 & 0.741 & 0.167 & 0.560 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

$$=\begin{bmatrix} 2.650 & 1.667 & 1.834 & 2.816 & 2.725 & 1.742 & 1.909 & 2.891 \\ -0.558 & -0.484 & 0.258 & 0.184 & -1.225 & -1.151 & -0.409 & -0.483 \\ 1.467 & 1.301 & 0.650 & 0.817 & 0.726 & 0.560 & -0.091 & 0.076 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

REFLEKSI 3D

- Refleksi pada bidang utama xy, yz dan xz
- MTU Refleksi pada bidang xy
- MTU Refleksi pada bidang yz
- MTU Refleksi pada bidang xz

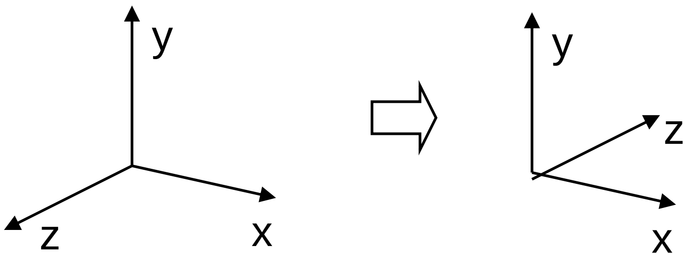
$$\left[T_{xy}\right] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\left[T_{yz}\right] = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\left[T_{xz}\right] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Refleksi

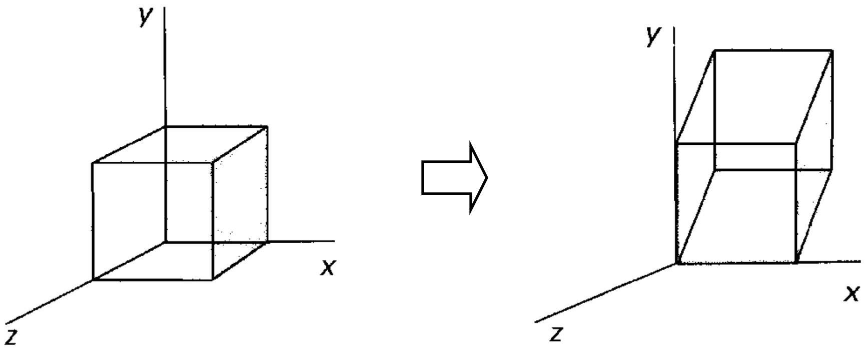
- Refleksi pada bidang xy



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \boxed{-1} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

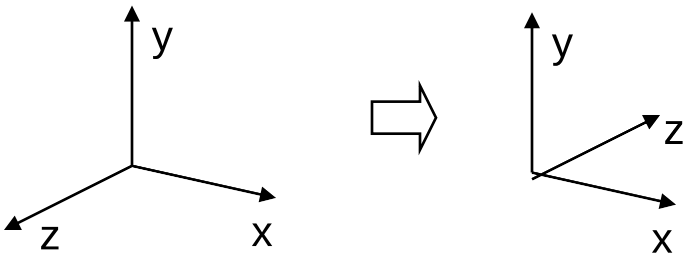
- Z-axis Shear

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & \boxed{a} & 0 \\ 0 & 1 & \boxed{b} & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$



Refleksi pada bidang utama

- Reflection the xy Plane



$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \boxed{-1} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- Reflection the yz Plane

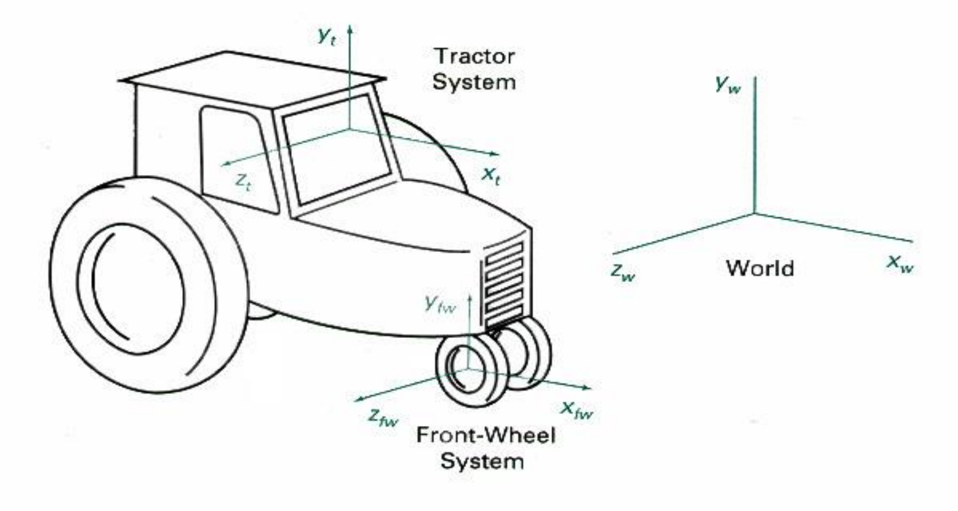
$$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- Reflection the xz Plane

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformasi Multi Koordinat

- Multiple Coordinate System
  - Hierarchical Modeling



World Coordinate System

↓

Tractor Coordinate System

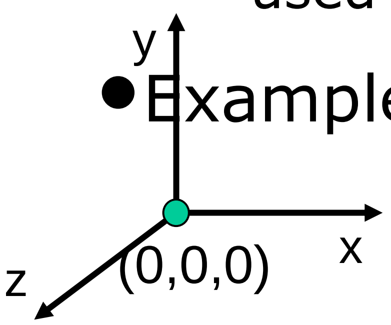
↓

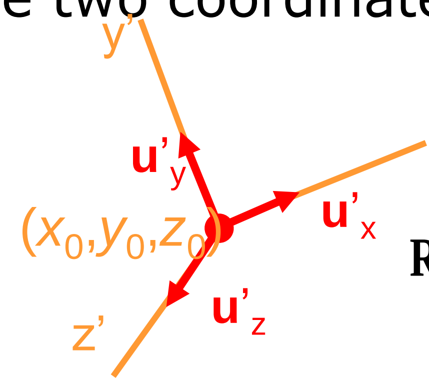
Front-Wheel Coordinate System

- As tractor moves, **tractor coordinate system** and **front-wheel coordinate system** move in world coordinate system
- **front wheels** rotate in wheel coordinate system
- When tractor turns, **wheel coordinate system** rotates in tractor system

Coordinate Transformations

- Transformation of an Object Description from One Coordinate System to Another
  - Set up a **translation** that brings the new coordinate origin to the position of the other coordinate origin
  - **Rotations** that corresponding coordinate axes
  - **Scaling** transformation, if different scales are used in the two coordinates systems
- Example





$$\mathbf{R}\cdot\mathbf{T}=\begin{bmatrix} u'_{x1} & u'_{x2} & u'_{x3} & 0 \\ u'_{y1} & u'_{y2} & u'_{y3} & 0 \\ u'_{z1} & u'_{z2} & u'_{z3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_0 & -y_0 & -z_0 0 & 1 \end{bmatrix}$$

LATIHAN SCALING

Diketahui sebuah objek P dengan koordinat sebagai berikut : {(0,0,1,1), (2,0,1,1), (2,3,1,1), (0,3,1,1), (0,0,0,1), (2,0,0,1), (2,3,0,1), (0,3,0,1)}.

1. Gambarkan objek tersebut !
2. Lakukan local scaling terhadap objek P dengan faktor skala xyz={1/2, 1/3 dan 1}.
   a. Tentukan koordinat baru
   b. Gambarkan hasilnya
3. Lakukan overal scaling terhadap objek asli dengan faktor 2.
   a. Tentukan koordinat baru
   b. Gambarkan hasilnya

LATIHAN ROTASI

Diketahui sebuah objek Q dengan koordinat sebagai berikut : {(0,0,1,1), (3,0,1,1), (3,2,1,1), (0,2,1,1), (0,0,0,1), (3,0,0,1), (3,2,0,1), (0,2,0,1)}.

1. Gambarkan objek tersebut !
2. Lakukan rotasi terhadap Q sebesar $\theta = -90°$ pada x
   a. Tentukan koordinat baru
   b. Gambarkan hasilnya
3. Lakukan rotasi terhadap objek Q sebesar $\phi = 90°$ pada sumbu y
   a. Tentukan koordinat baru
   b. Gambarkan hasilnya

LATIHAN REFLEKSI

Diketahui sebuah objek Q dengan koordinat sebagai berikut : {(1,0,-1,1), (2,0,-1,1), (2,1,-1,1), (1,1,-1,1), (1,0,-2,1), (2,0,-2,1), (2,1,-2,1), (1,1,-2,1)}.

1. Gambarkan objek tersebut !
2. Lakukan refleksi pada bidang xy
   a. Tentukan koordinat baru
   b. Gambarkan hasilnya

LATIHAN TRANSFORMASI GABUNGAN

1. Tentukan Matriks Transformasi Umum untuk transformasi berurutan berikut ini:
   a. Translasi sebesar -1, -1, -1 pada sumbu x, y, z
   b. Rotasi sebesar +30° pada sumbu x
   c. Rotasi sebesar + 45° pada sumbu y
2. Tentukan koordinat objek baru untuk vektor posisi homogen (3 2 1 1) yang ditransformasikan dengan MTU yang dihasilkan

- Diketahui sebuah objek dengan vektor posisi

$$\begin{bmatrix} 1 & 1 & 2 & 1 \\ 2 & 1 & 2 & 1 \\ 2 & 2 & 2 & 1 \\ 1 & 2 & 2 & 1 \\ 1 & 1 & 1 & 1 \\ 2 & 1 & 1 & 1 \\ 2 & 2 & 1 & 1 \\ 1 & 2 & 1 & 1 \end{bmatrix}$$

- Lakukan rotasi sebesar $\theta=+30°$ pada sumbu yang sejajar sumbu x dan melalui titik centroid dari objek tersebut. Koordinat centroid adalah [3/2 3/2 3/2 1].

Grafika Komputer Menggunakan Python

Sebuah Referensi Pembuatan Gambar Digital 2D dan 3D

Pengarang: Setiawan Hadi (Editor)

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You don't have to be amazing to start, BUT you have to start to be amazing

Daftar Isi

Tugas

- Eksplorasi CABRI 3D
- Buatlah objek 3D dengan aplikasi Cabri 3D
- Tuliskan cara-cara pembuatannya, dan hasilnya
- Kumpulkan di LIVE !