Three-dimensional Proxies for Hand-drawn Characters

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Hand-drawn animation

3D CG animation

Hand-drawn animation

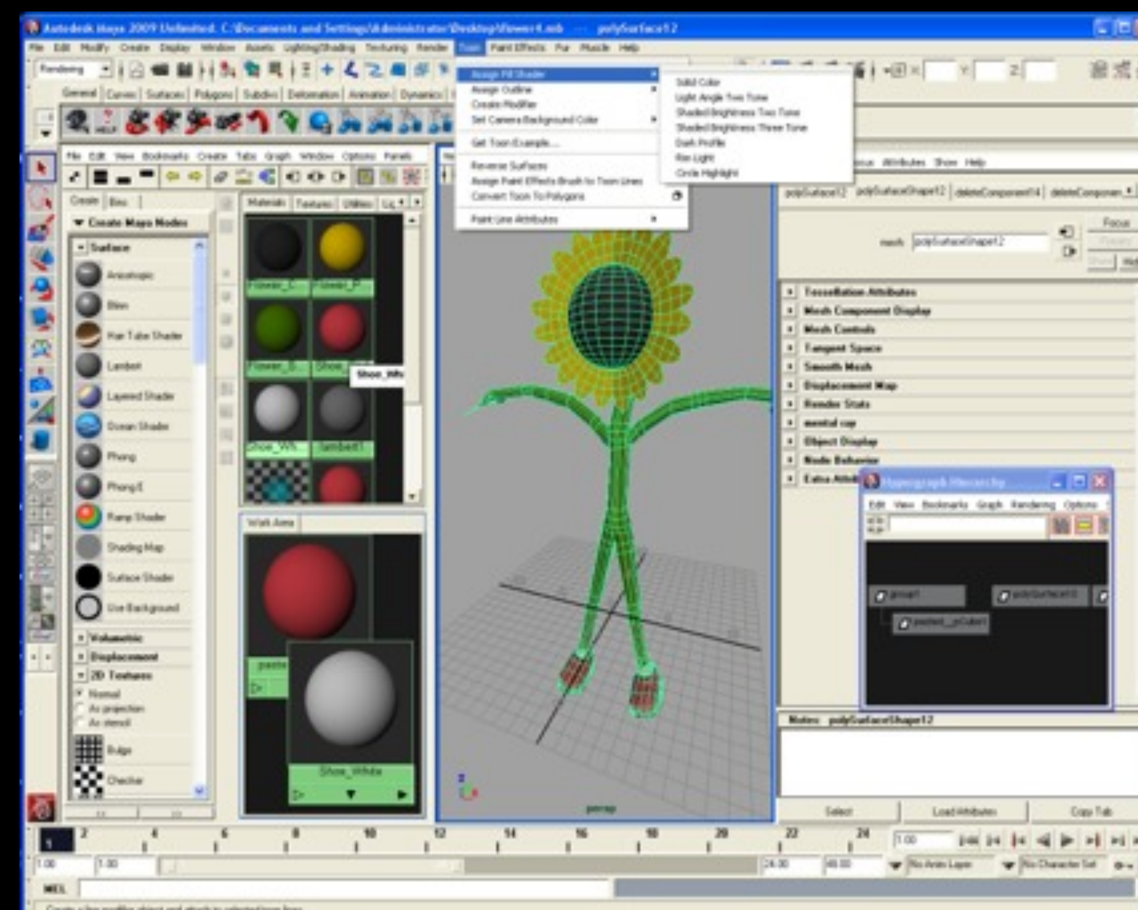
3D CG animation

Differences between hand animation and computer animation

Hand animator’s workdesk

Differences between hand animation and computer animation

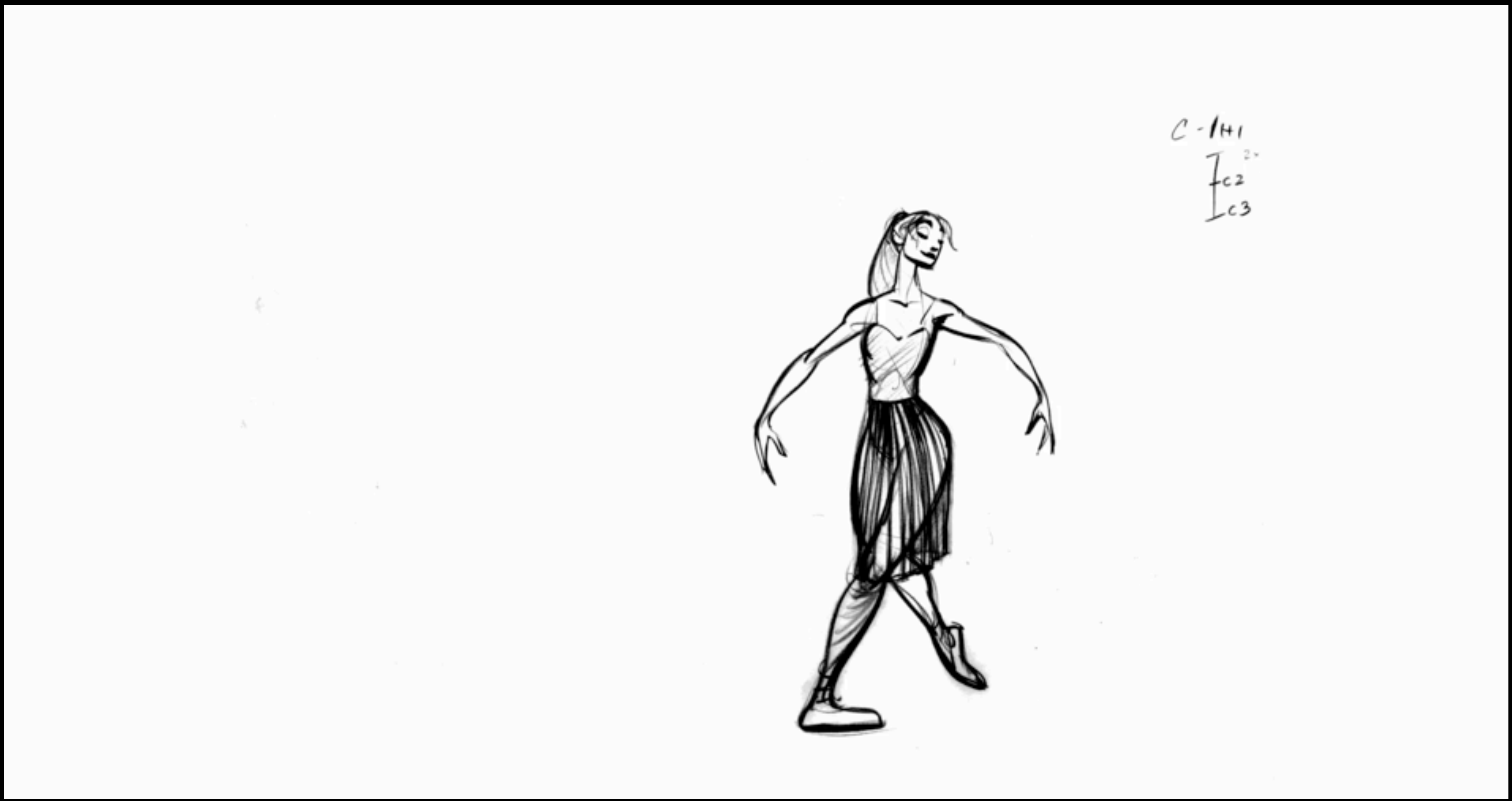
Hand animator's workdesk

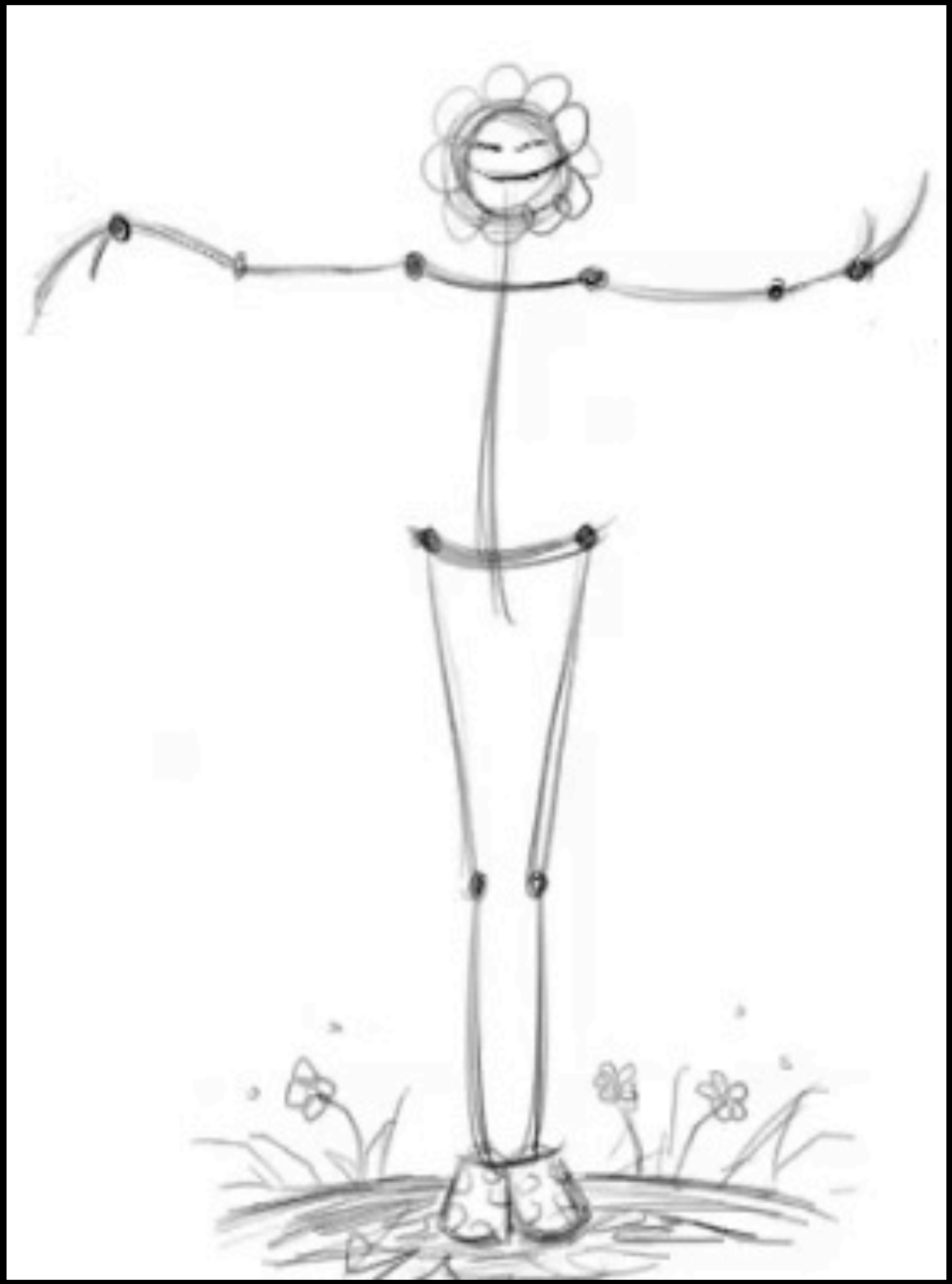


3D animation software

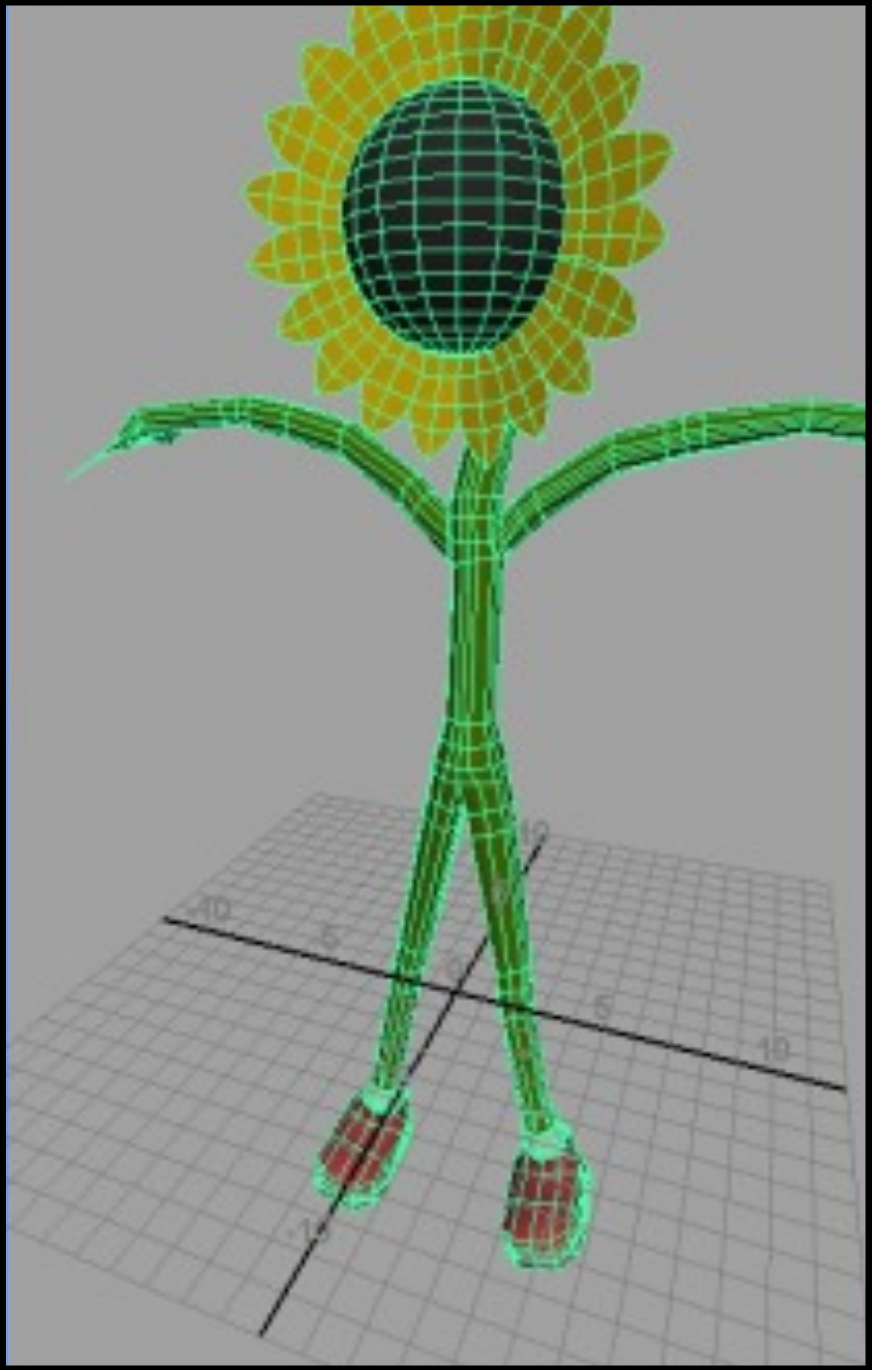
Input

Input





Hand-drawn character

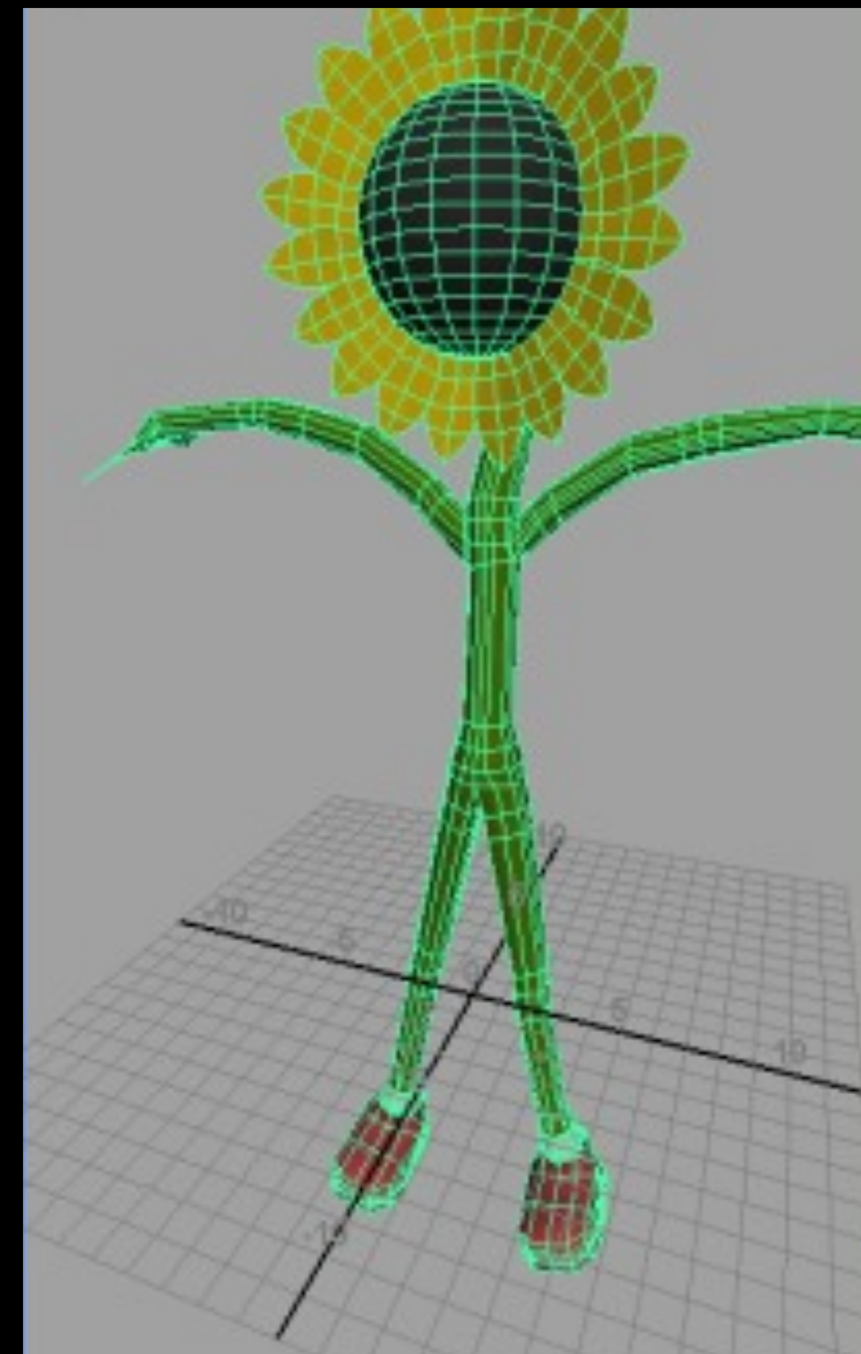


3D proxy

Hand-drawn character

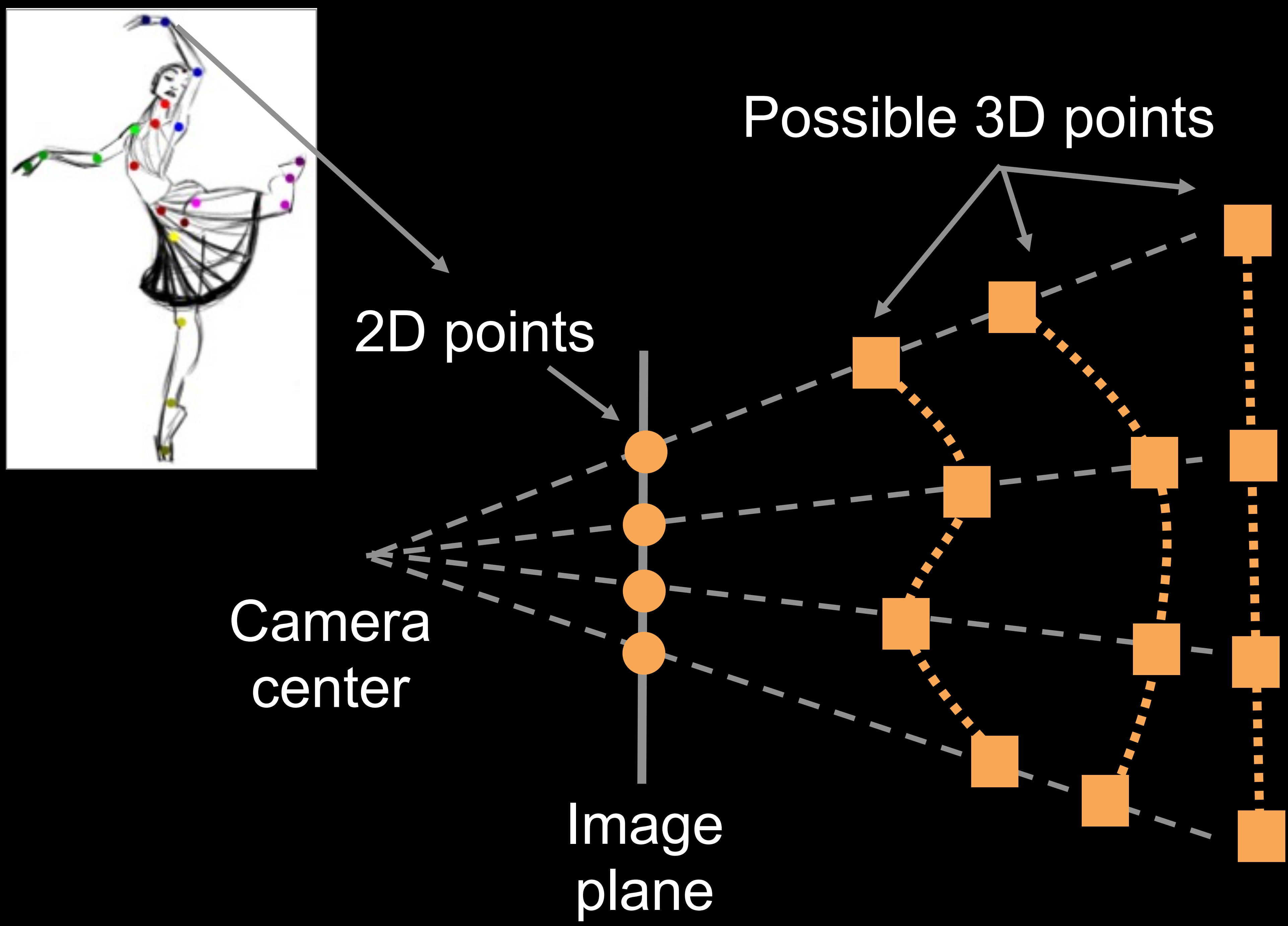
Geometry

Motion

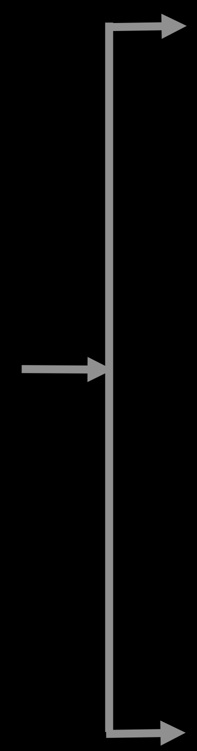


3D proxy

Challenge: Inferring third dimension



Challenge: Composite motion ambiguity



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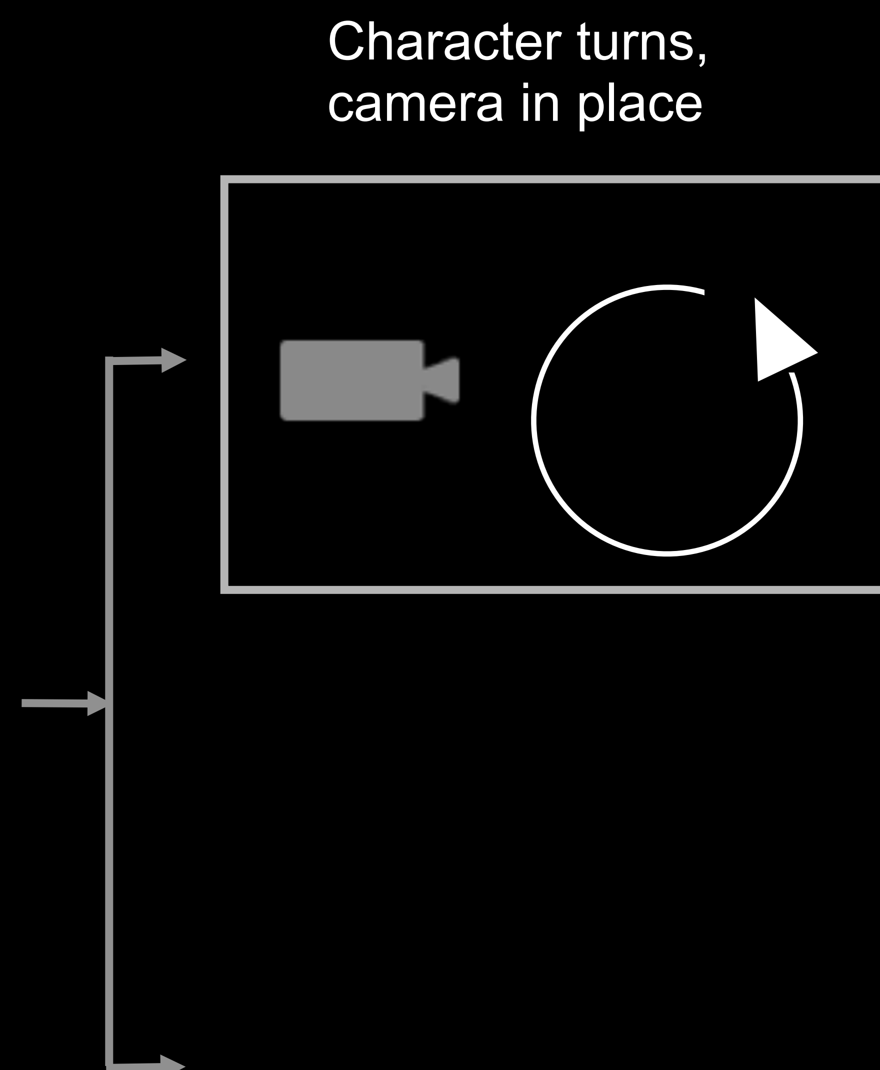
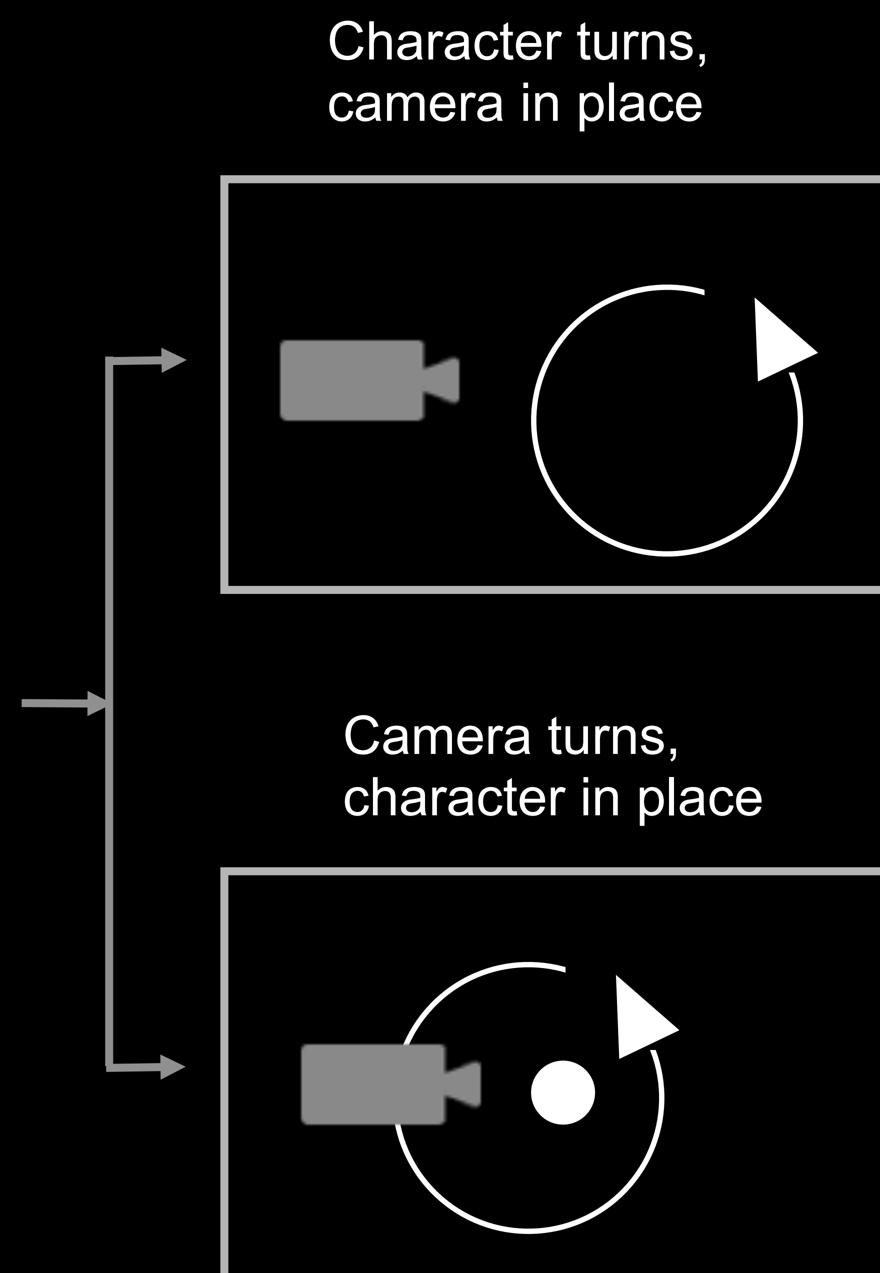
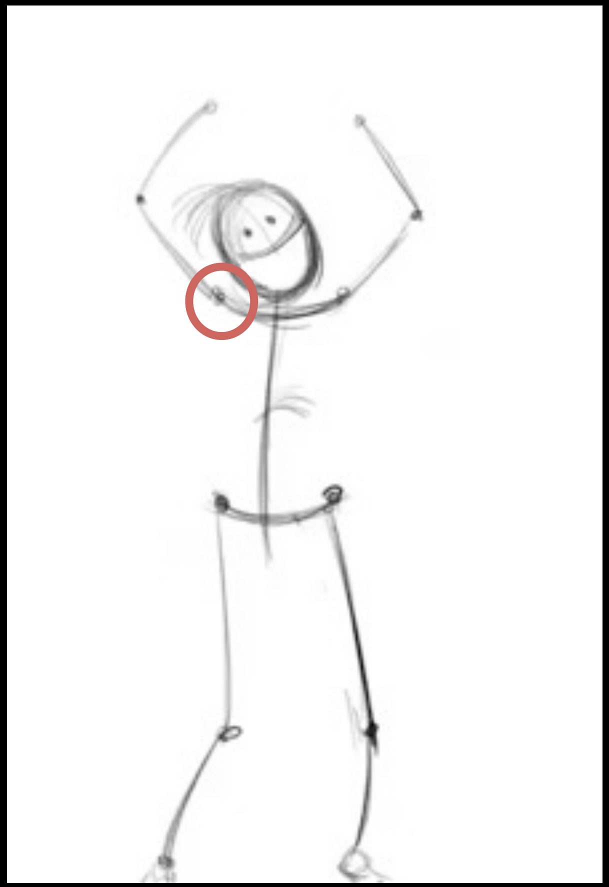


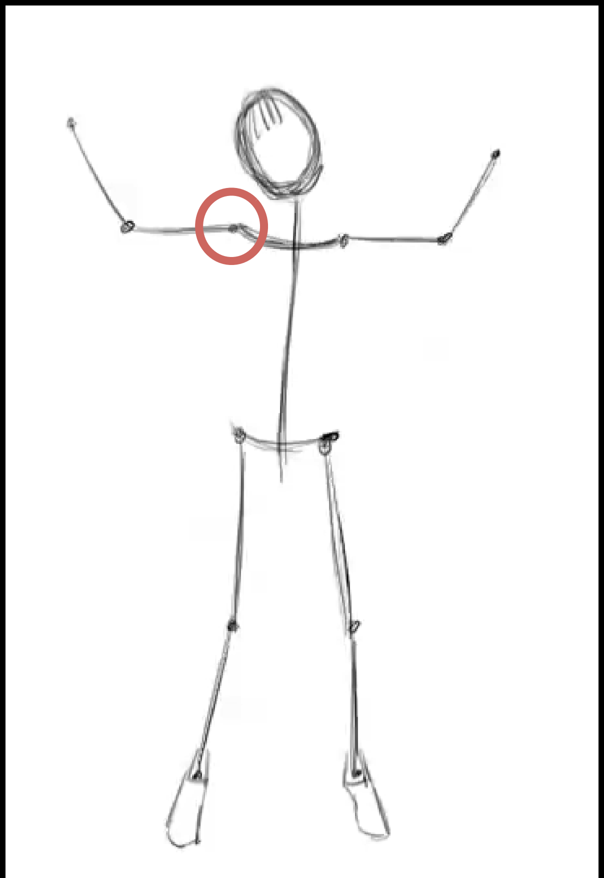
Challenge: Composite motion ambiguity



Challenge: Artistic license

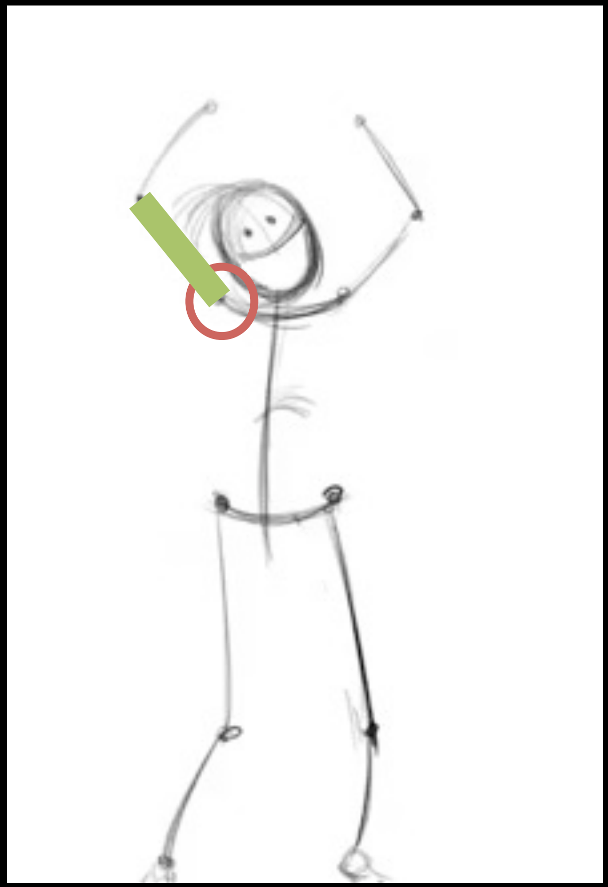


Frame #1

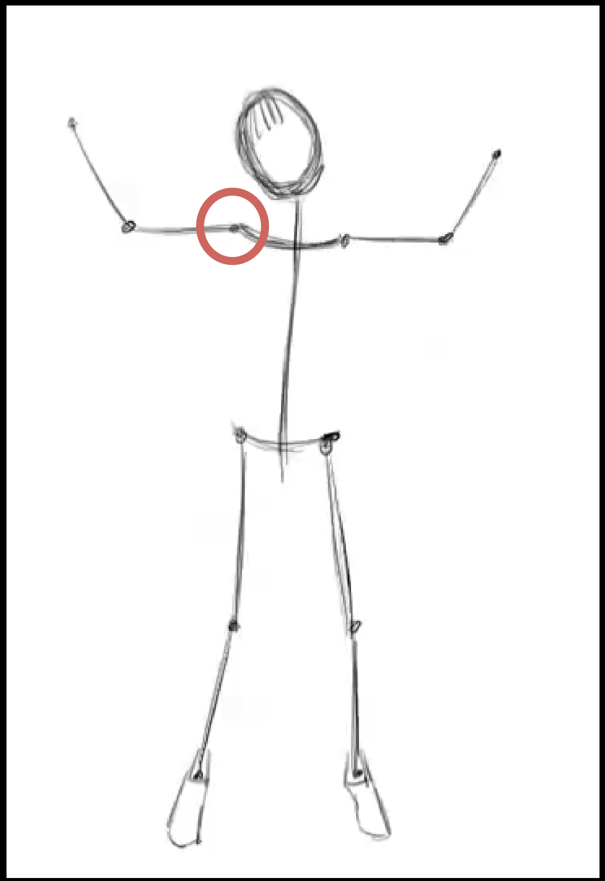


Frame #40

Challenge: Artistic license

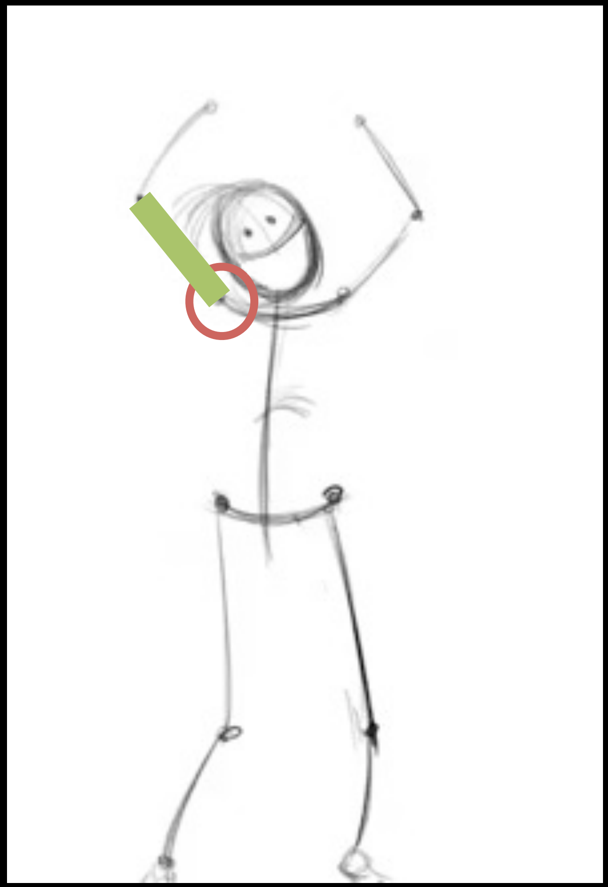


Frame #1

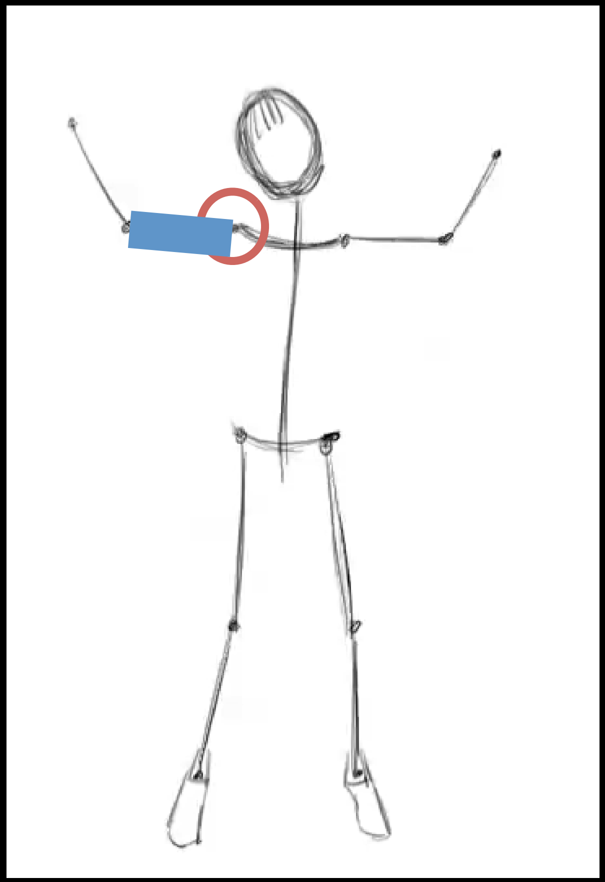


Frame #40

Challenge: Artistic license

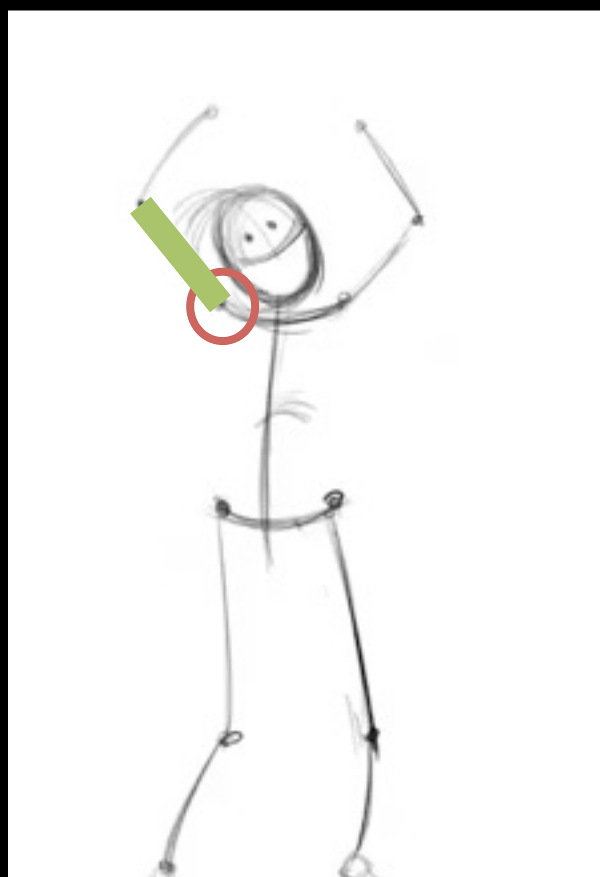


Frame #1

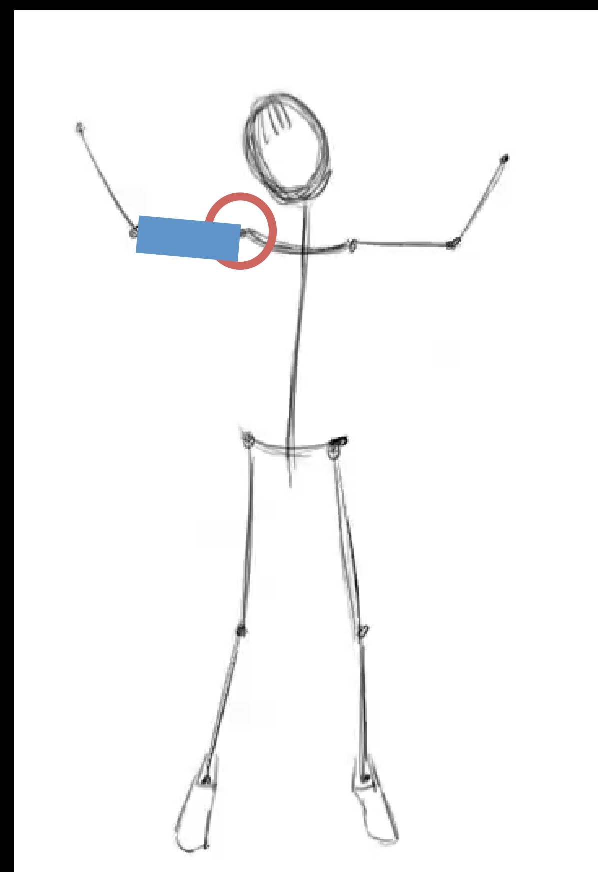


Frame #40

Challenge: Artistic license



Frame #1



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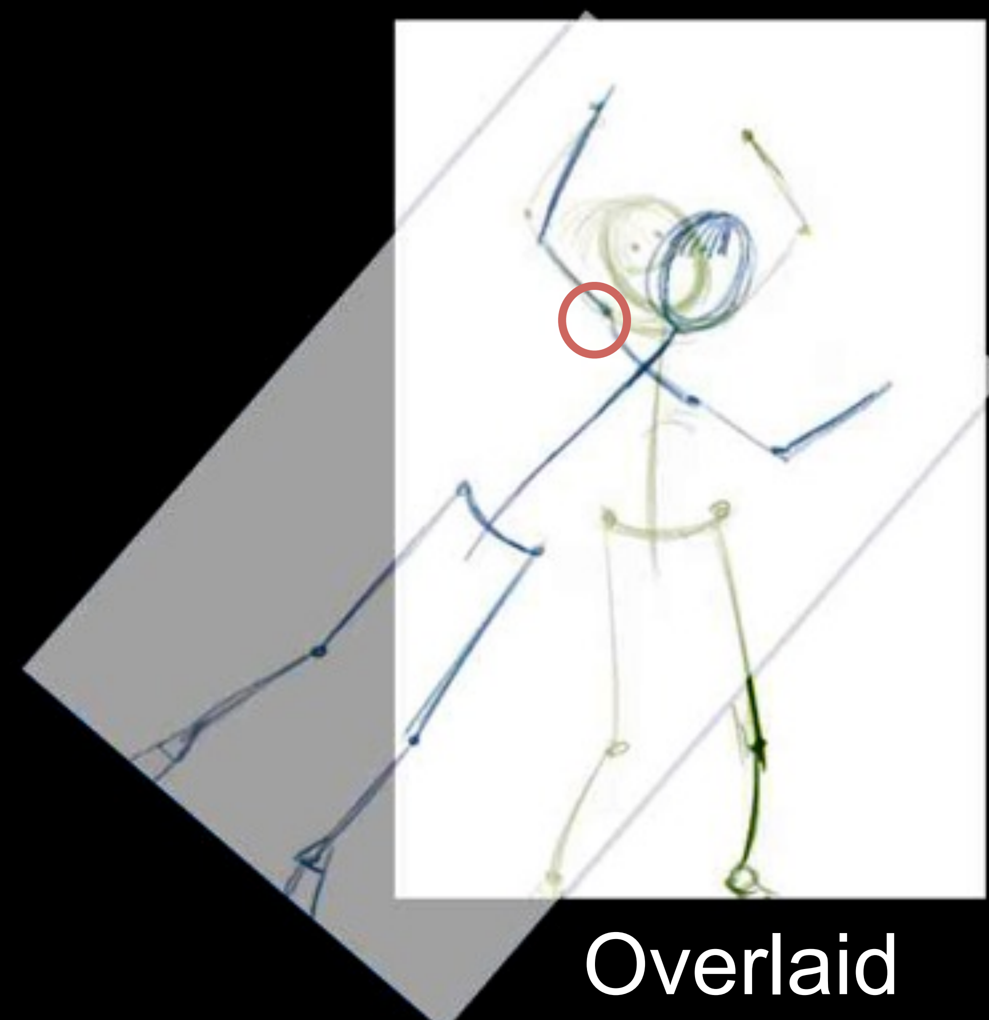
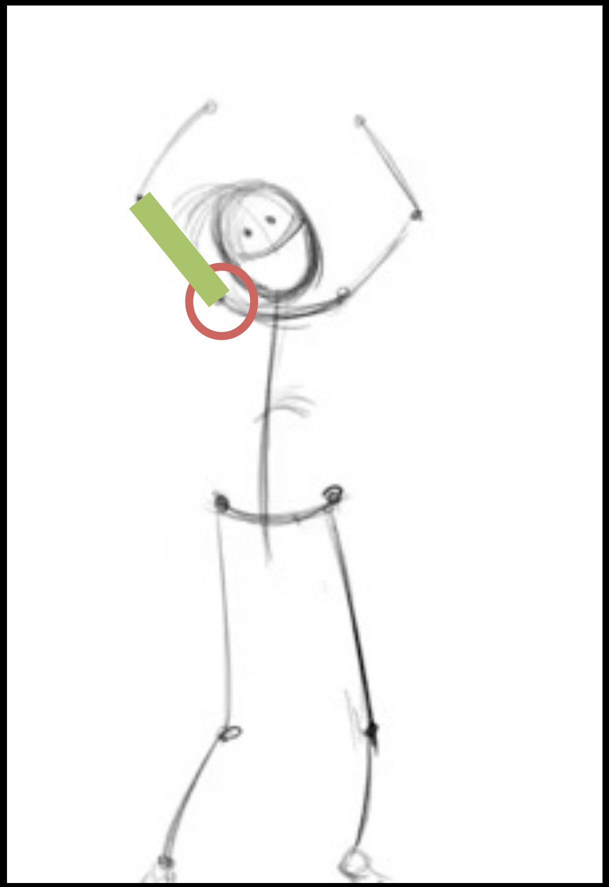
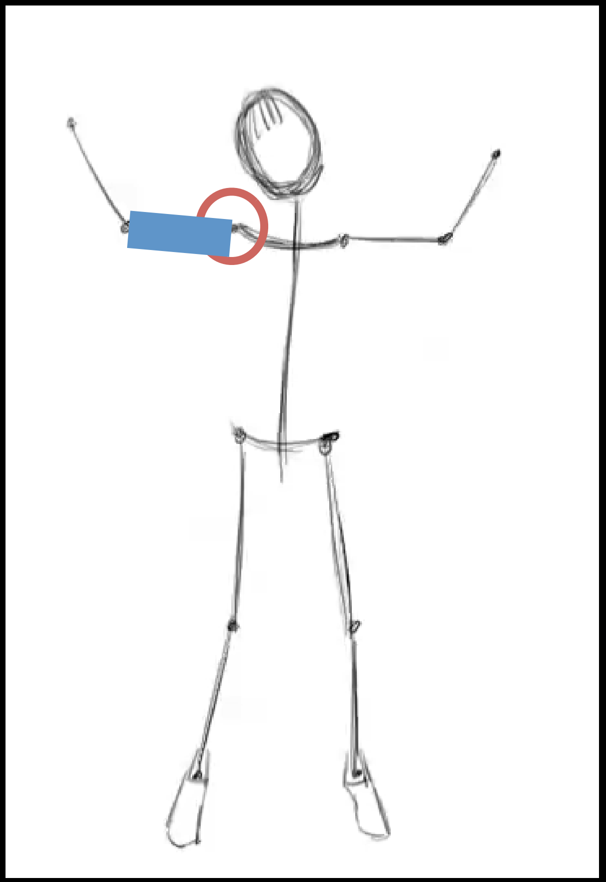


Overlaid

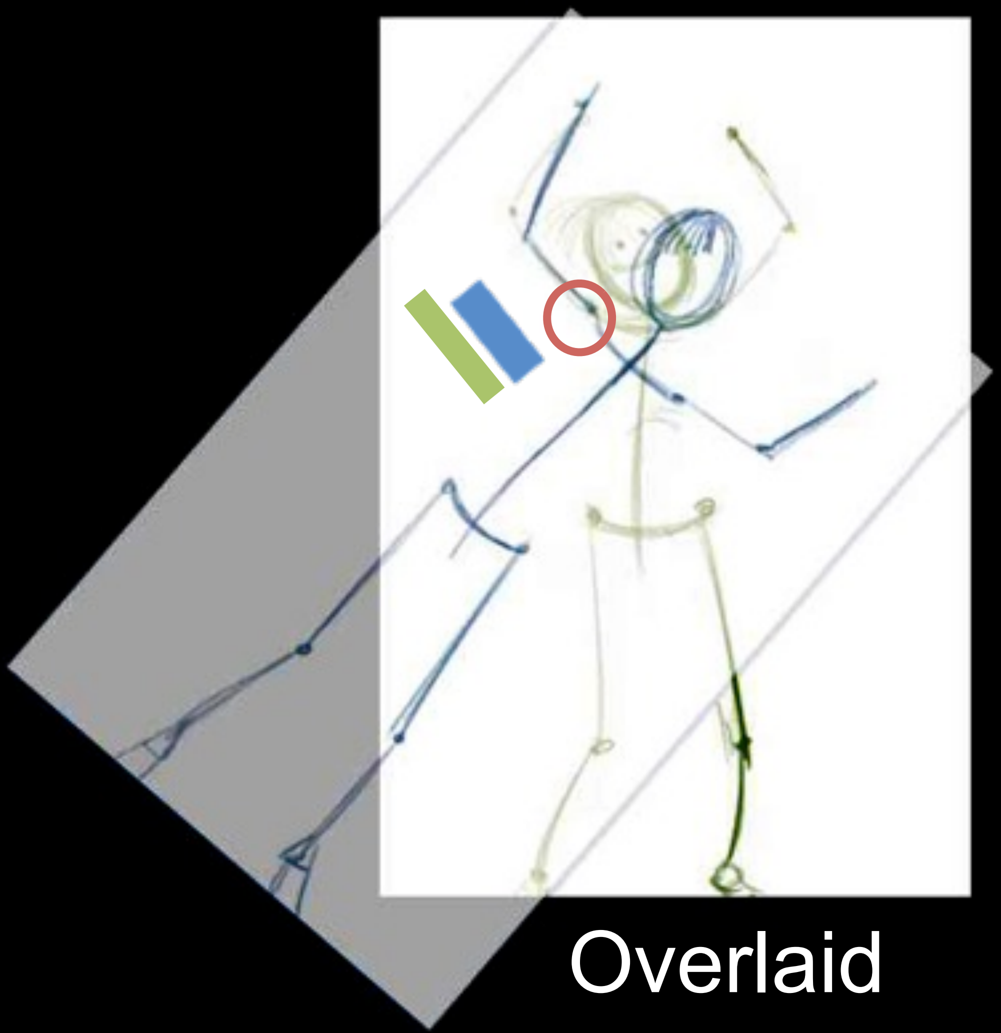
Challenge: Artistic license



Frame #1

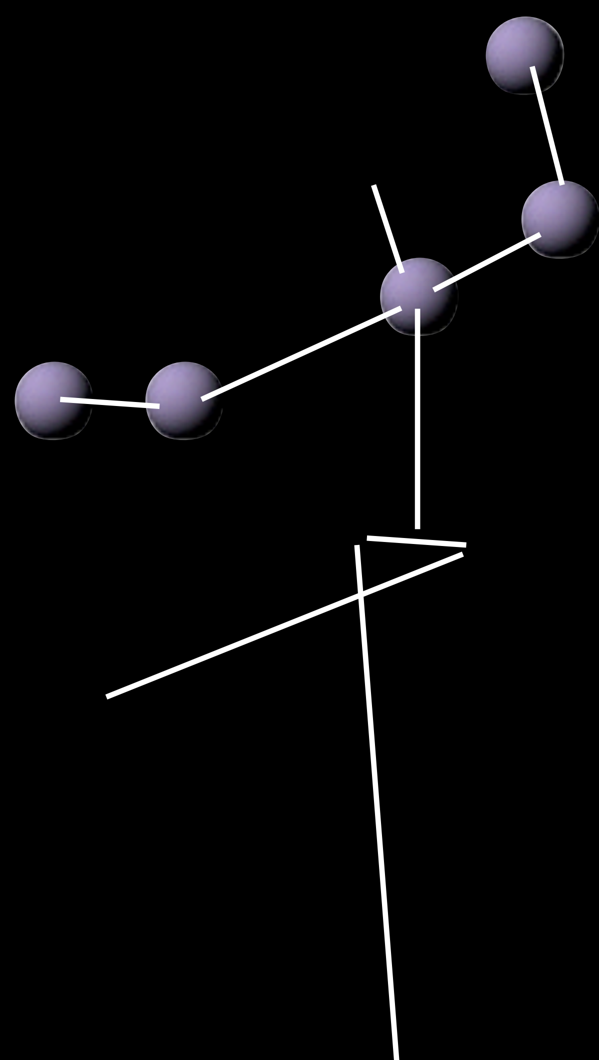


Frame #40

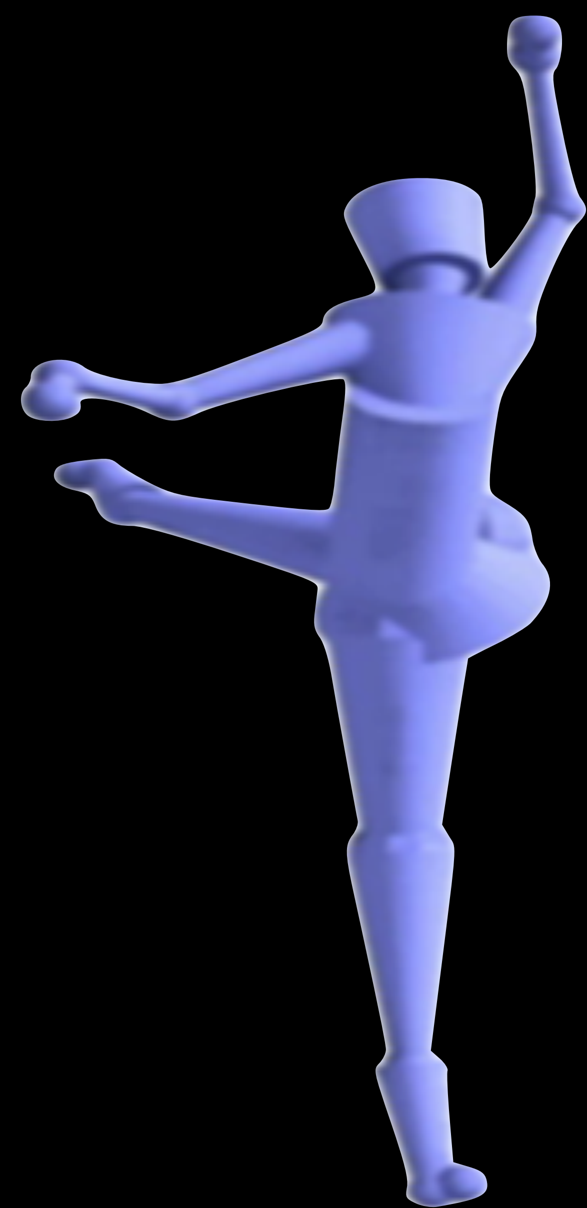


Overlaid

Three-dimensional proxies with different levels of detail



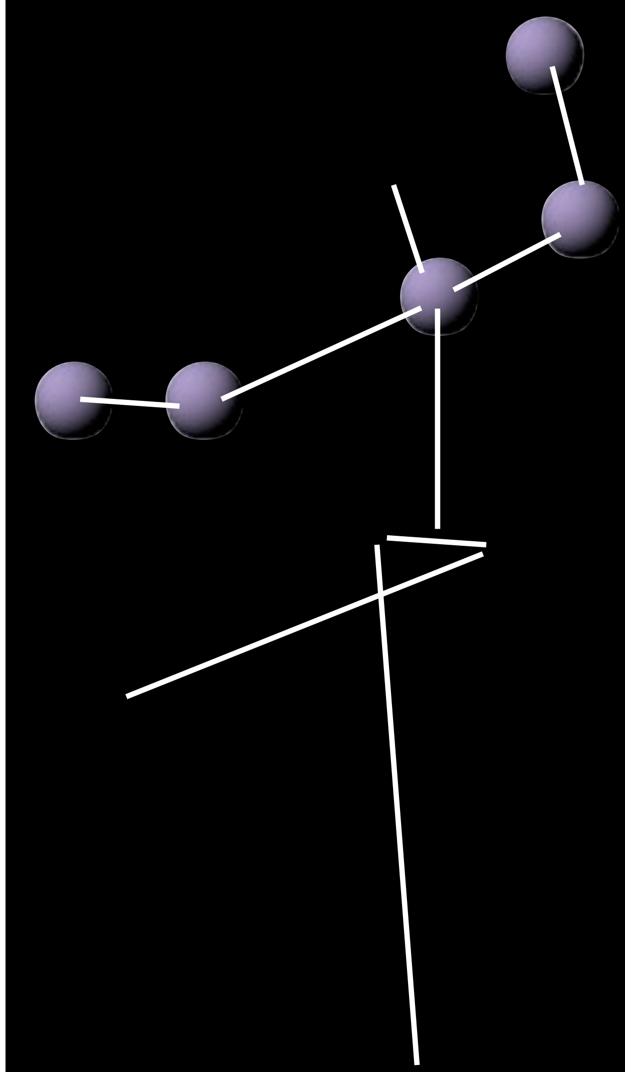
Single points
(3D markers)



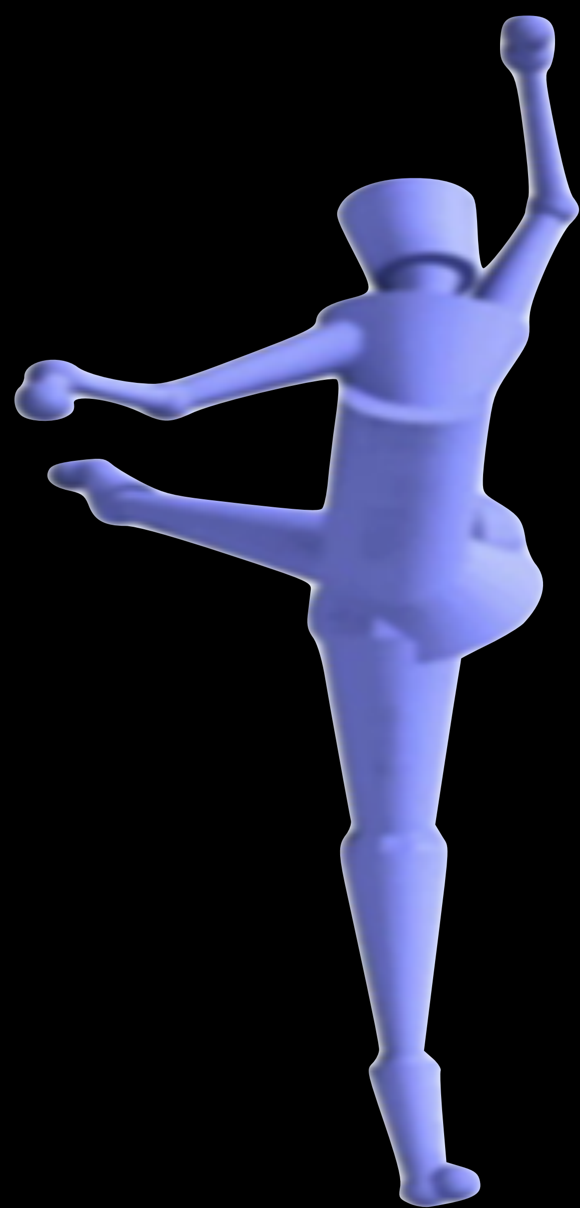
3D Polygonal shapes

Joint hierarchy
based skeleton

Three-dimensional proxies with different levels of detail



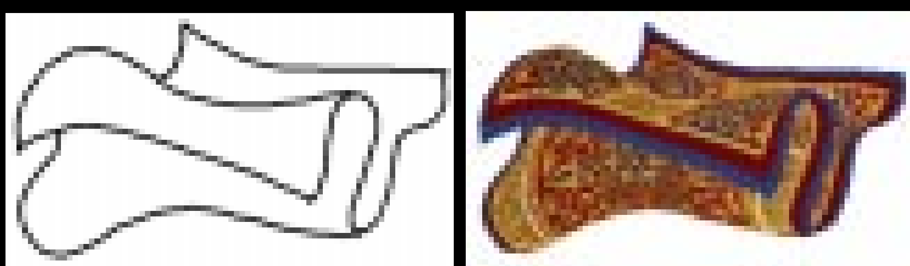
Single points
(3D markers)



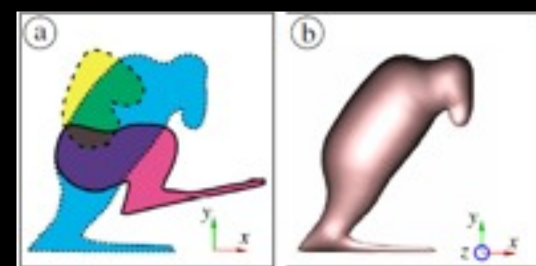
3D Polygonal shapes

Joint hierarchy
based skeleton

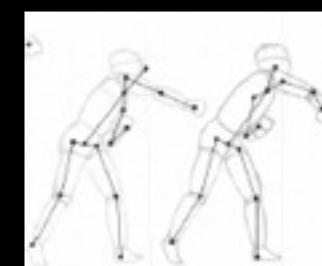
Past work



Correa et al.
(1998)

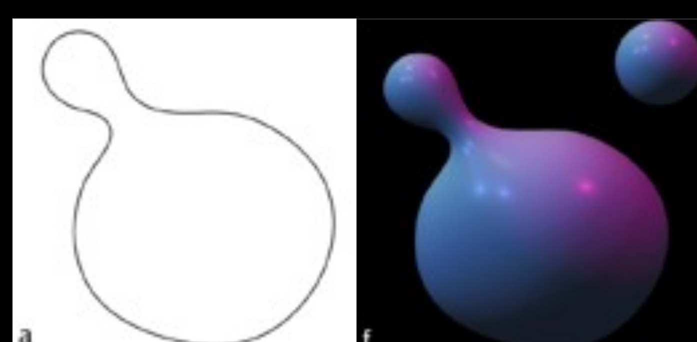


Petrovic et al.
(2000)

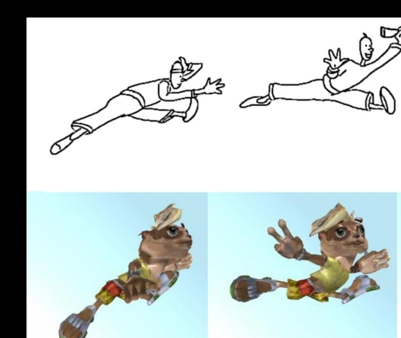


Davis et al.
(2003)

Li et al.
(2003)



Johnston
(2002)



Bregler et al.
(2002)

User Input


Virtual markers


Limb bounding boxes


Color coded body parts

User Input

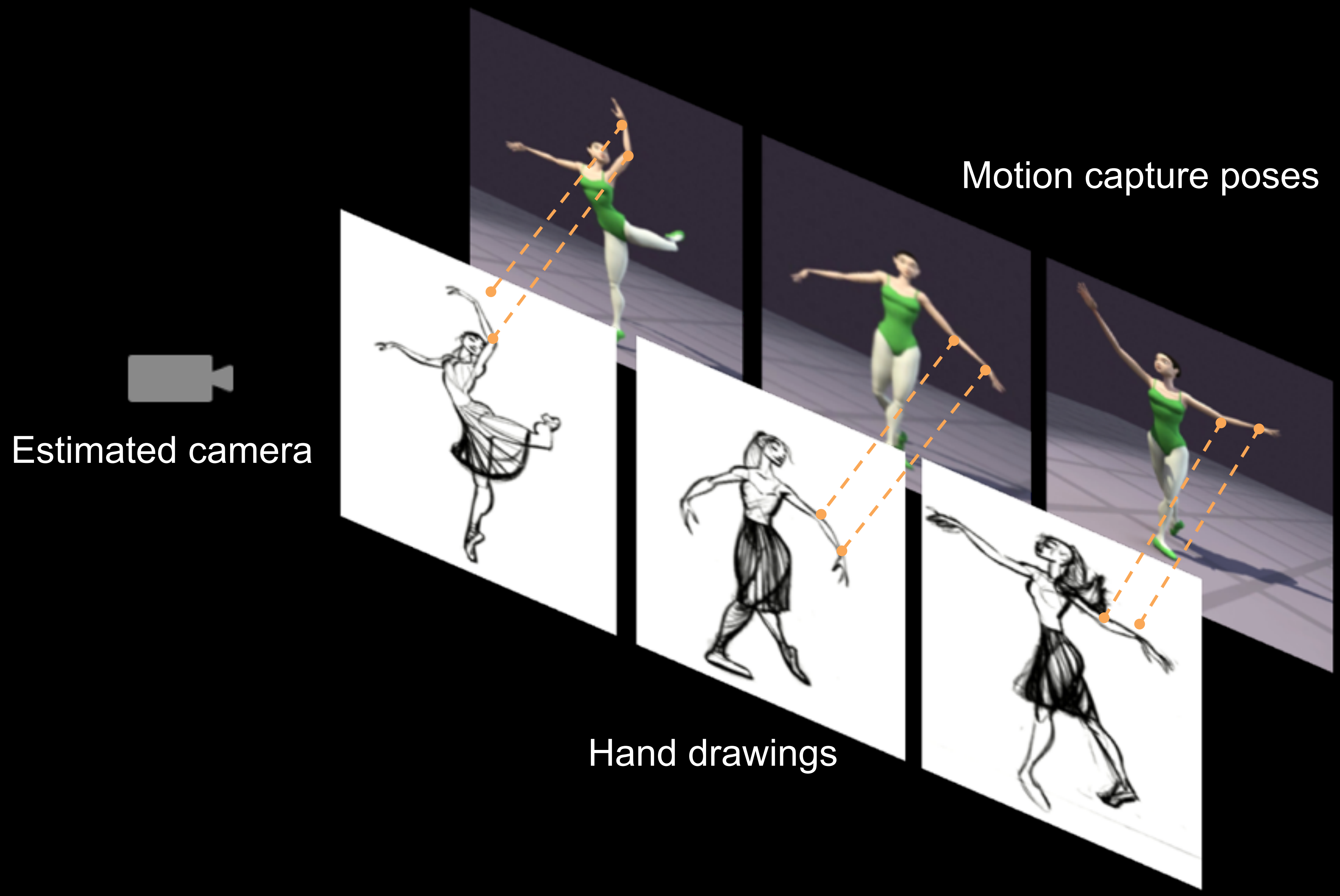
Virtual markers

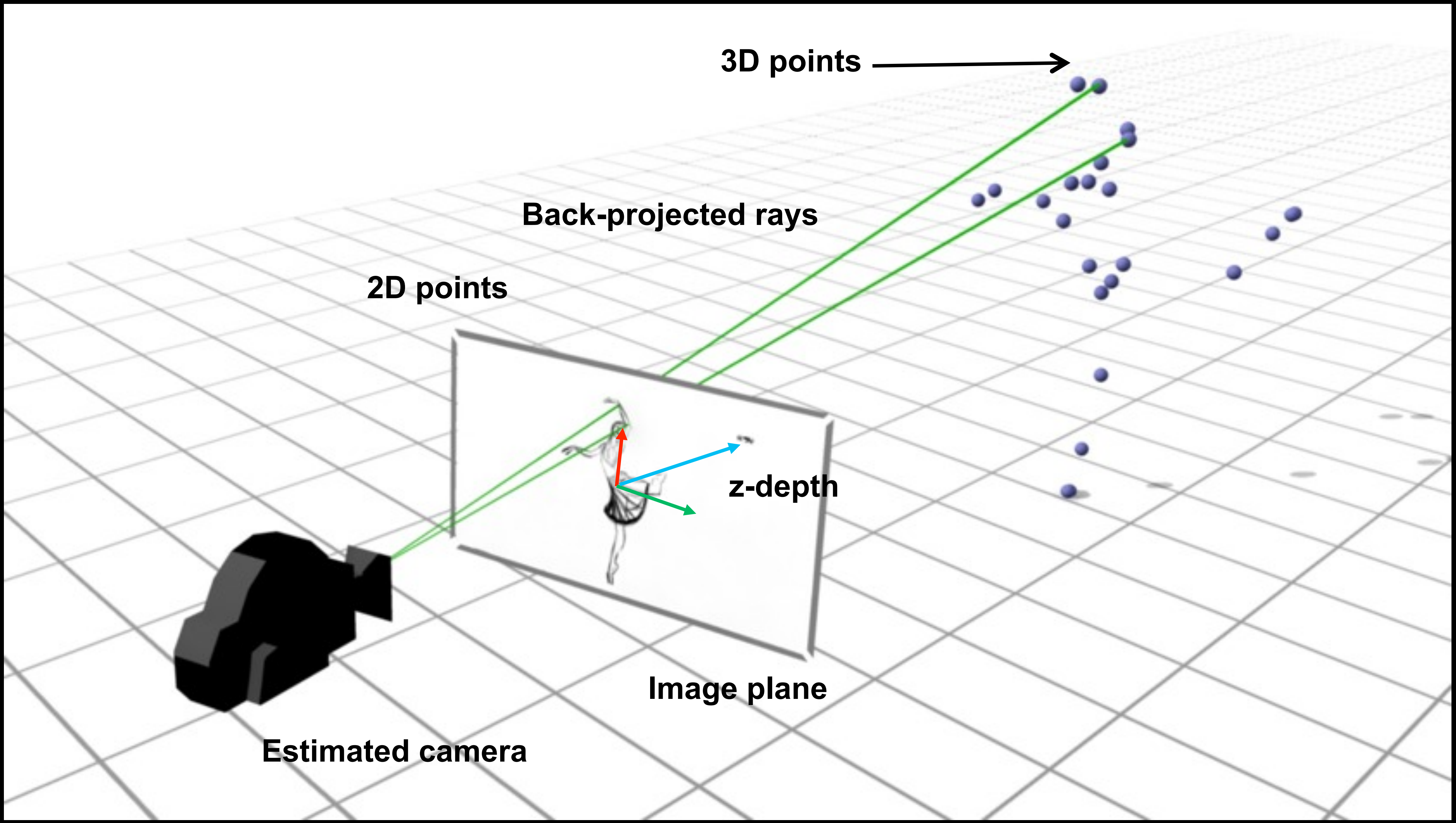
Limb bounding boxes

Color coded body parts

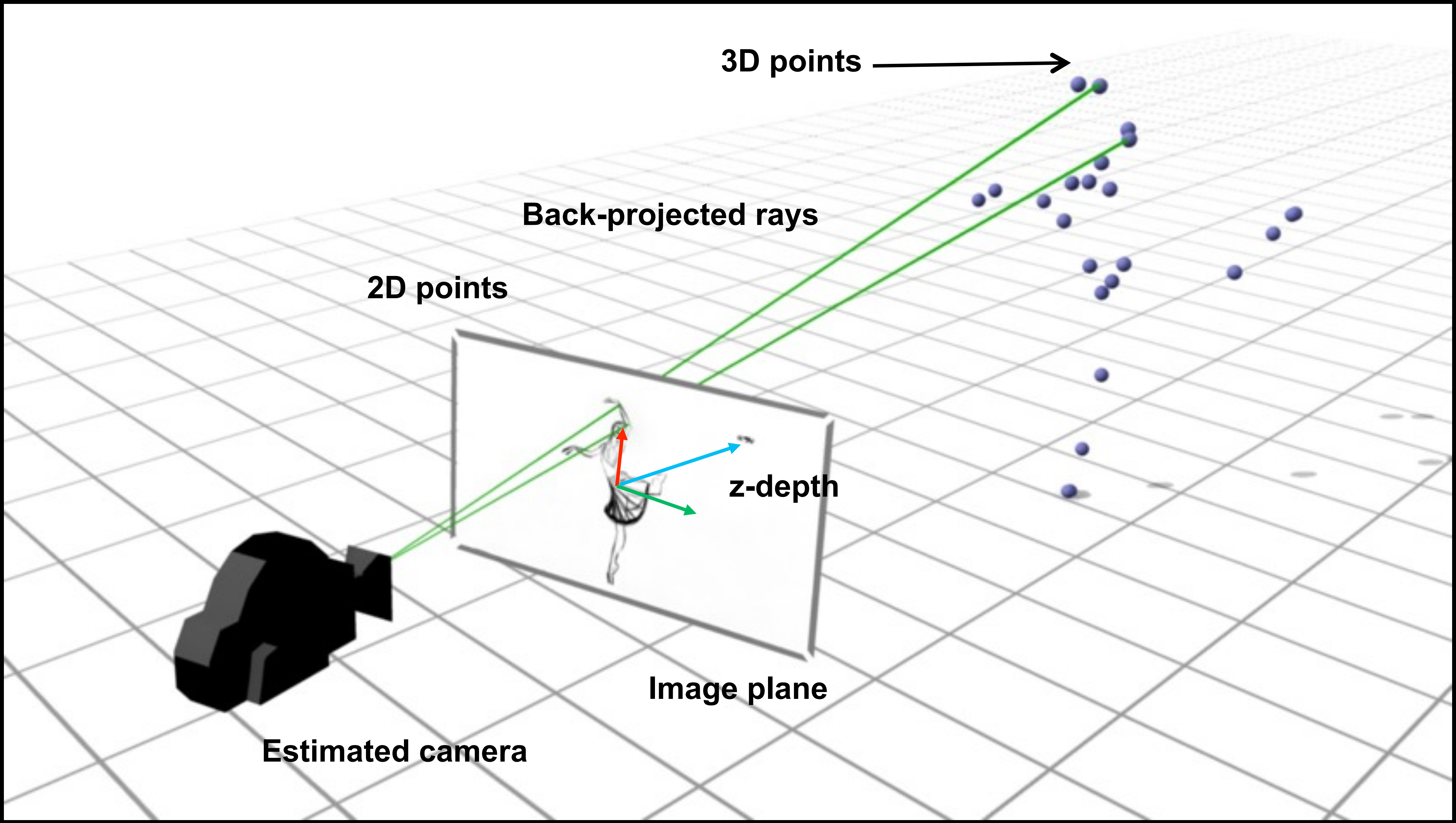
Motion capture segment with similar depth information, time-warped via Dynamic Time Warping

Camera Estimation



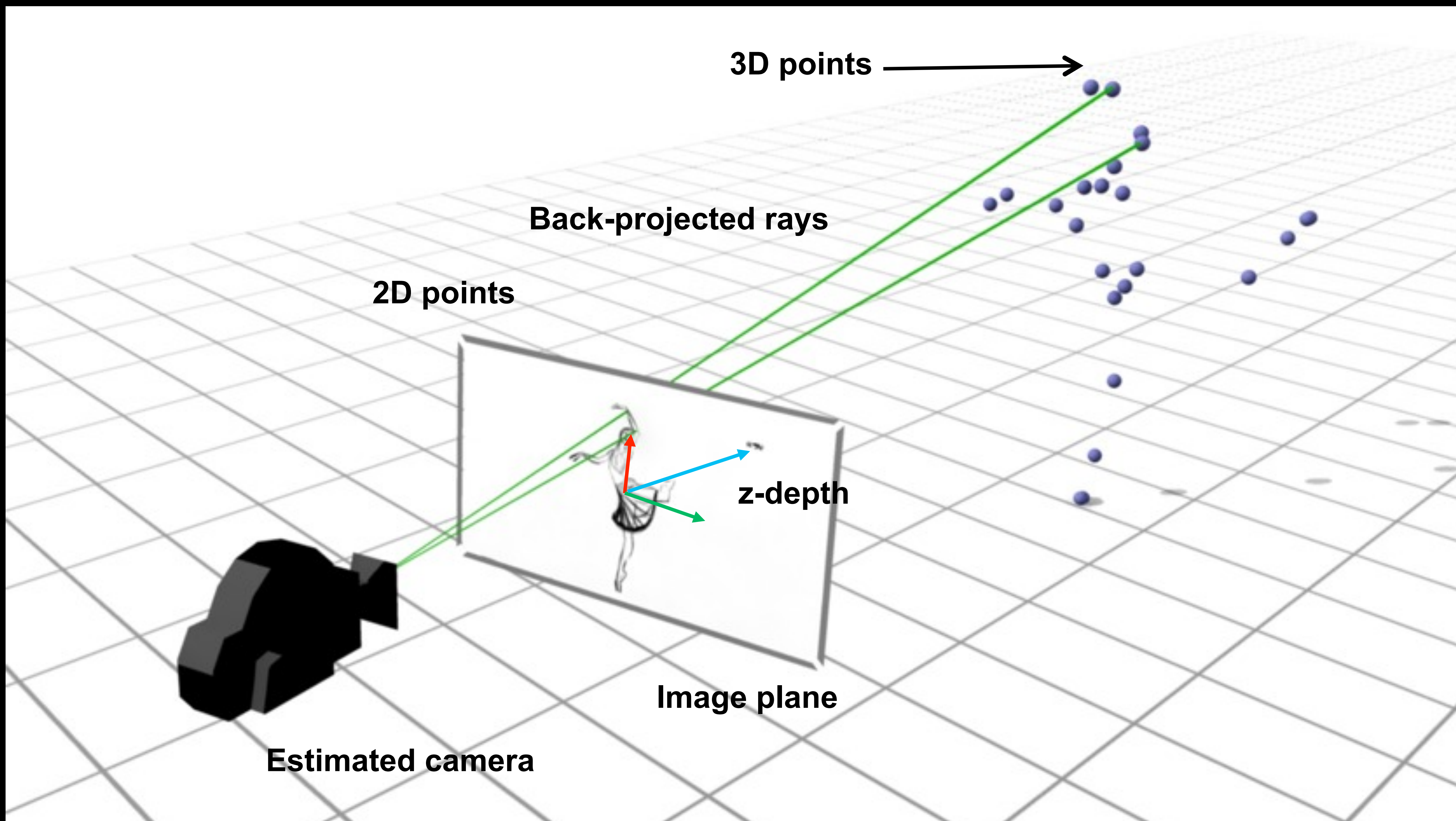

3D points
Back-projected rays
2D points
z-depth
Image plane
Estimated camera

$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$



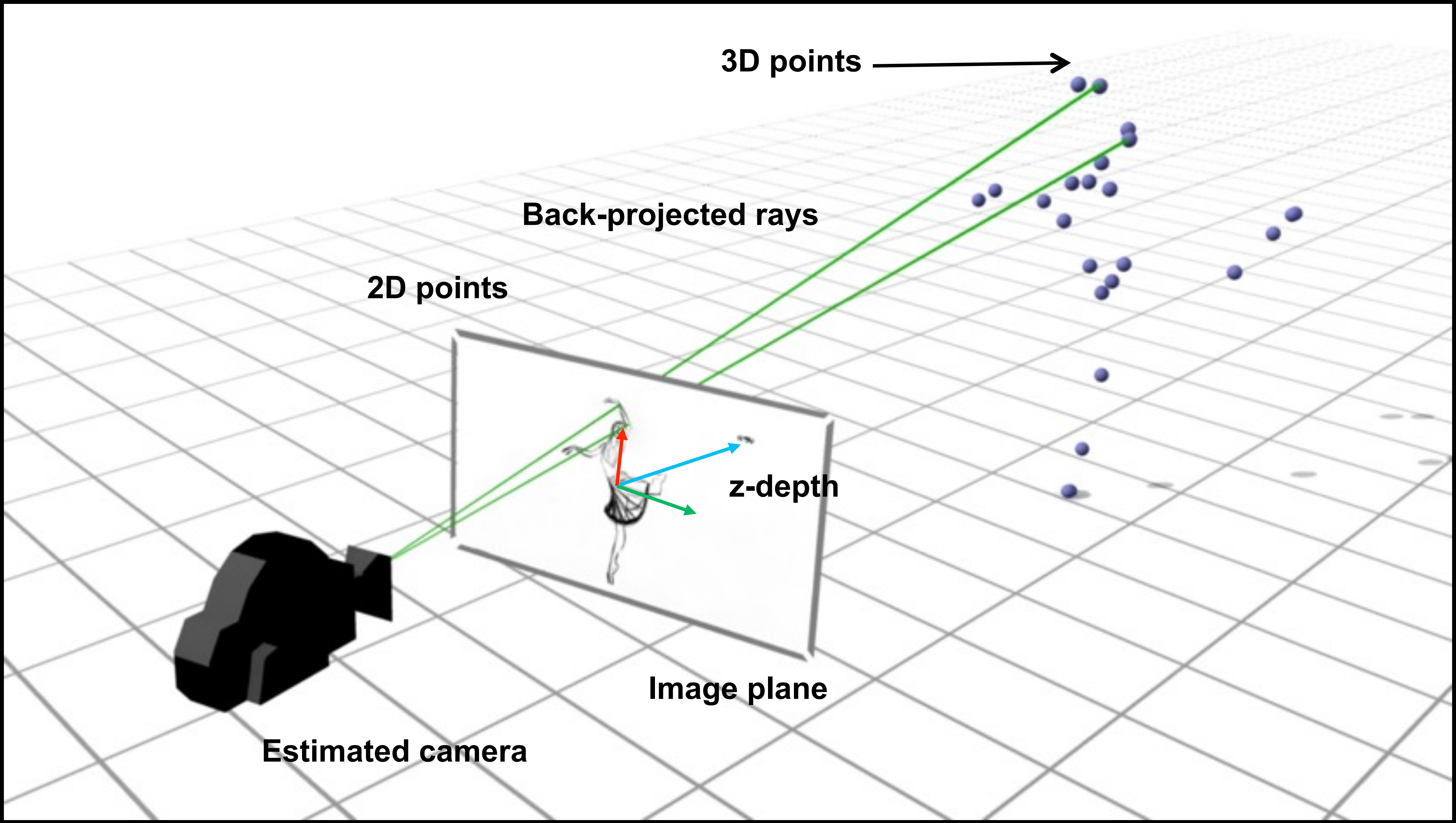
$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching



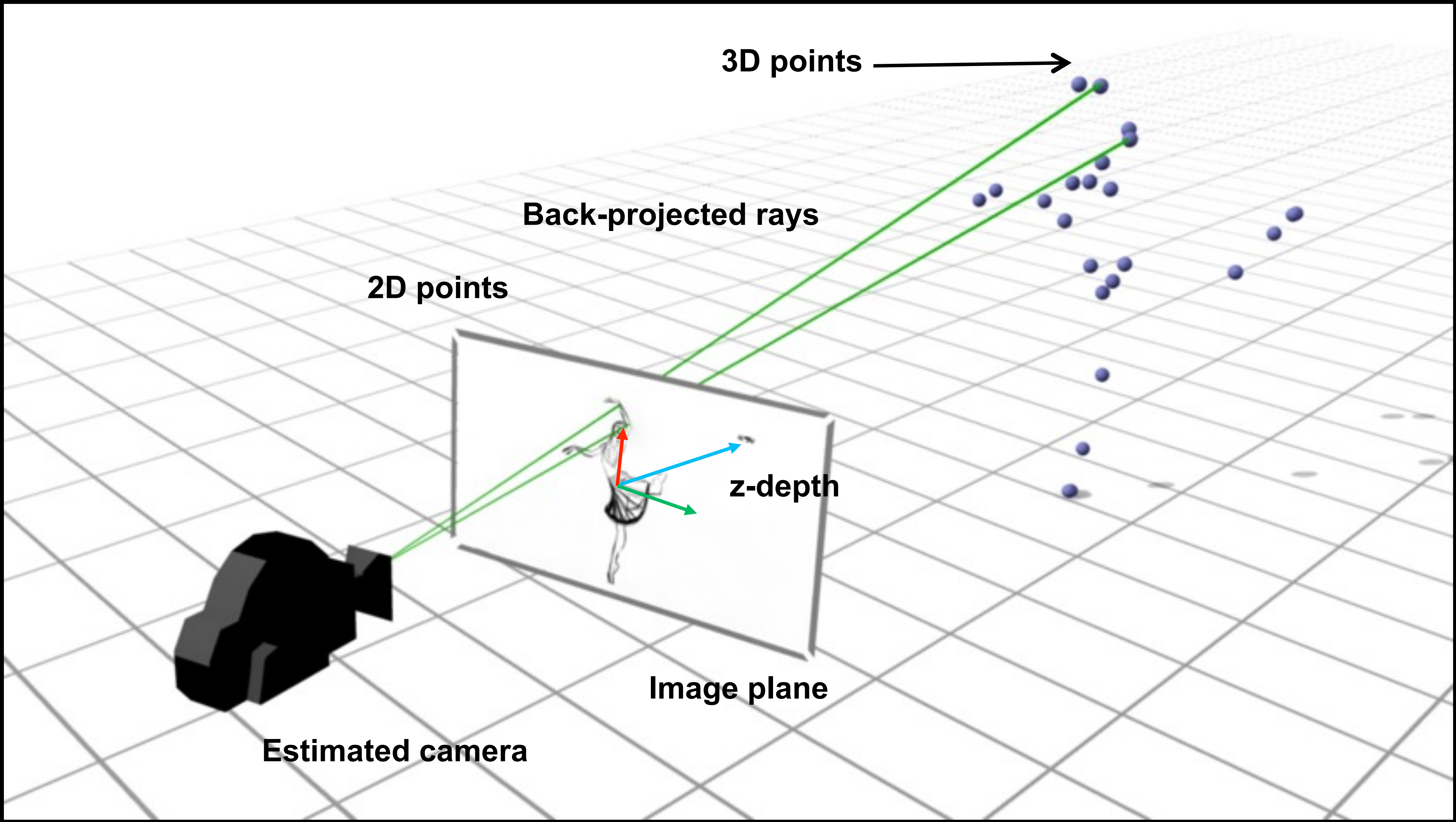
$$\arg\min_x (e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

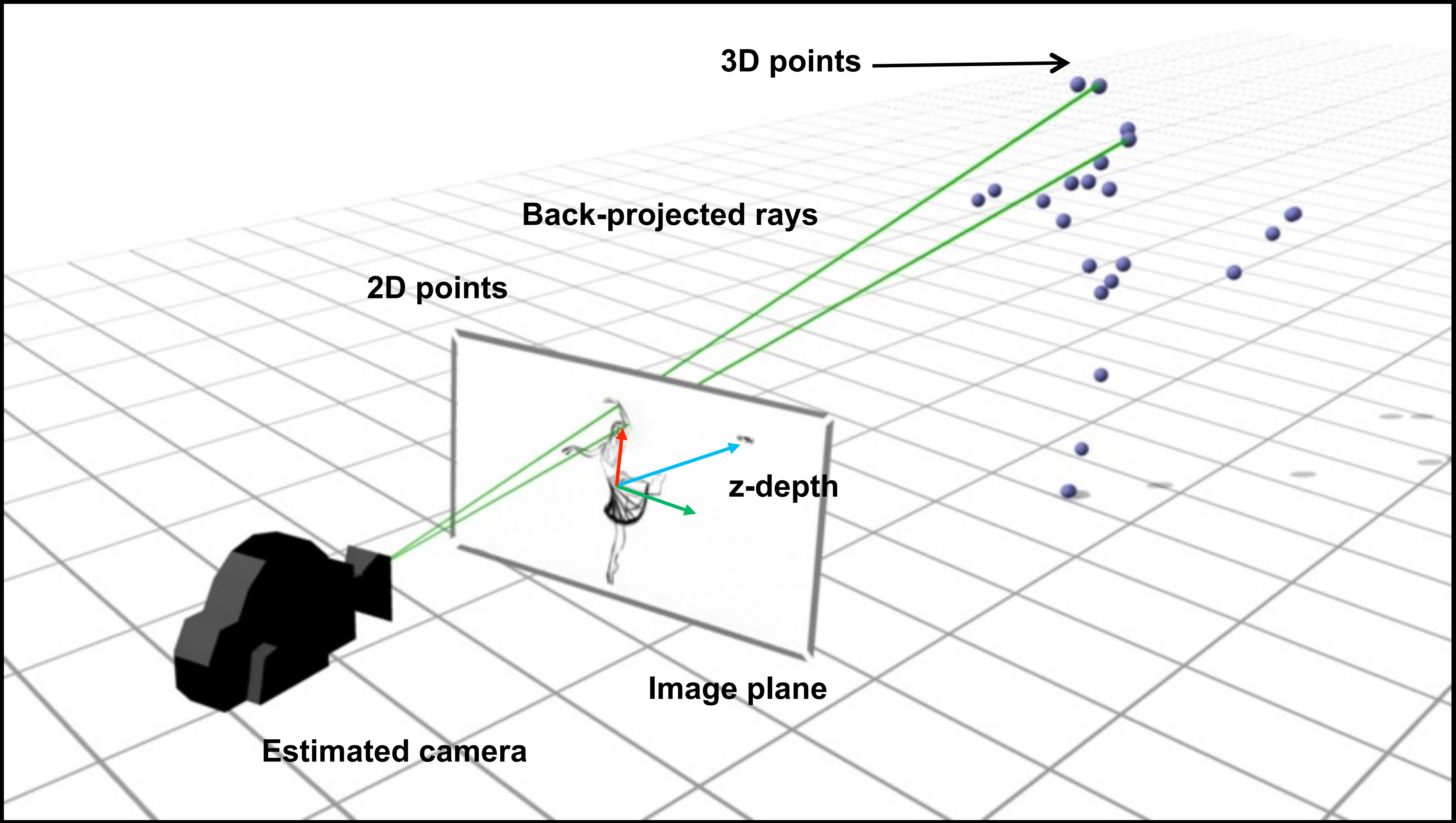
input-matching depth prior smoothing term



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior smoothing term

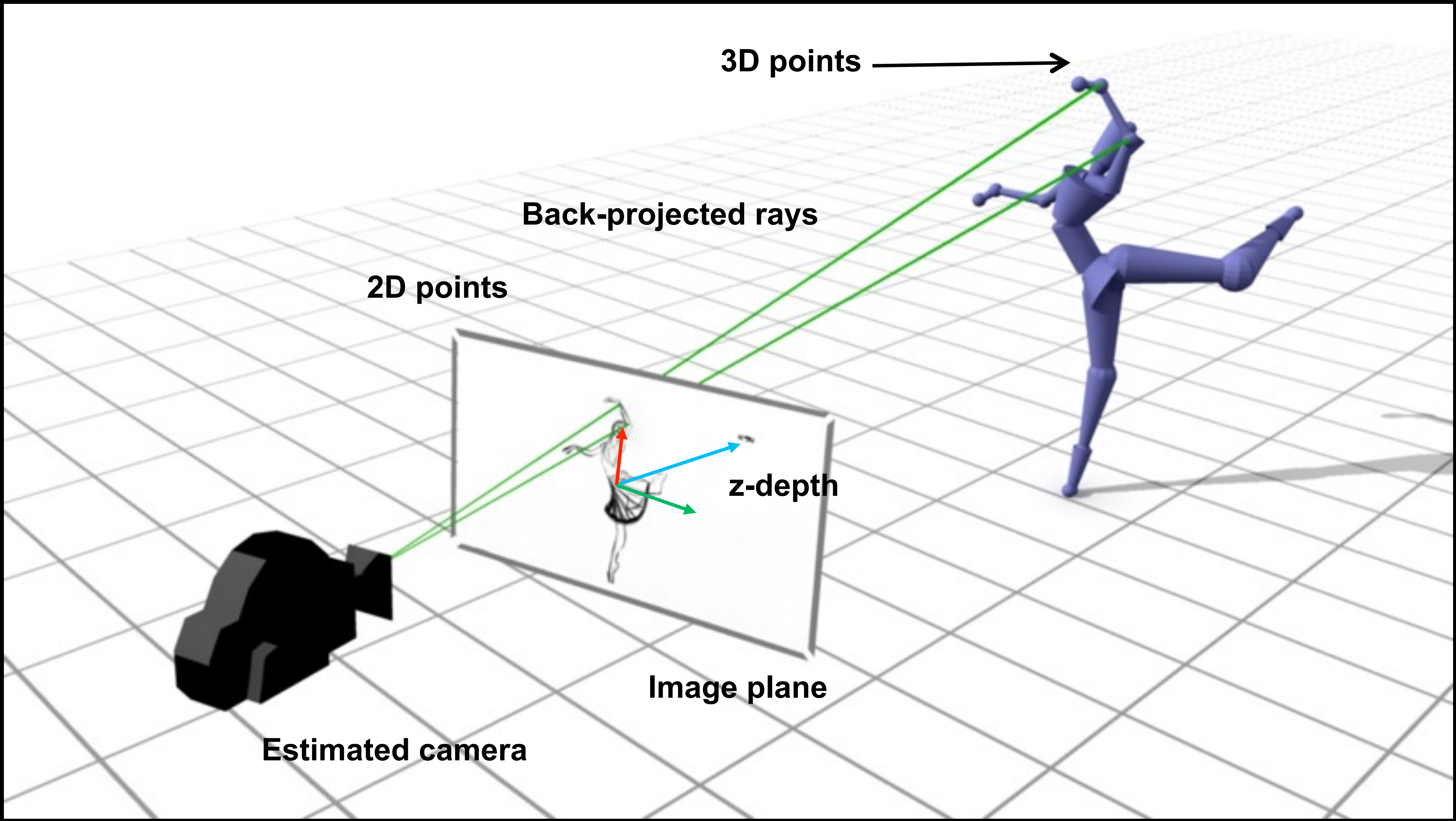
Linear system: least squares solution



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching — depth prior — smoothing term

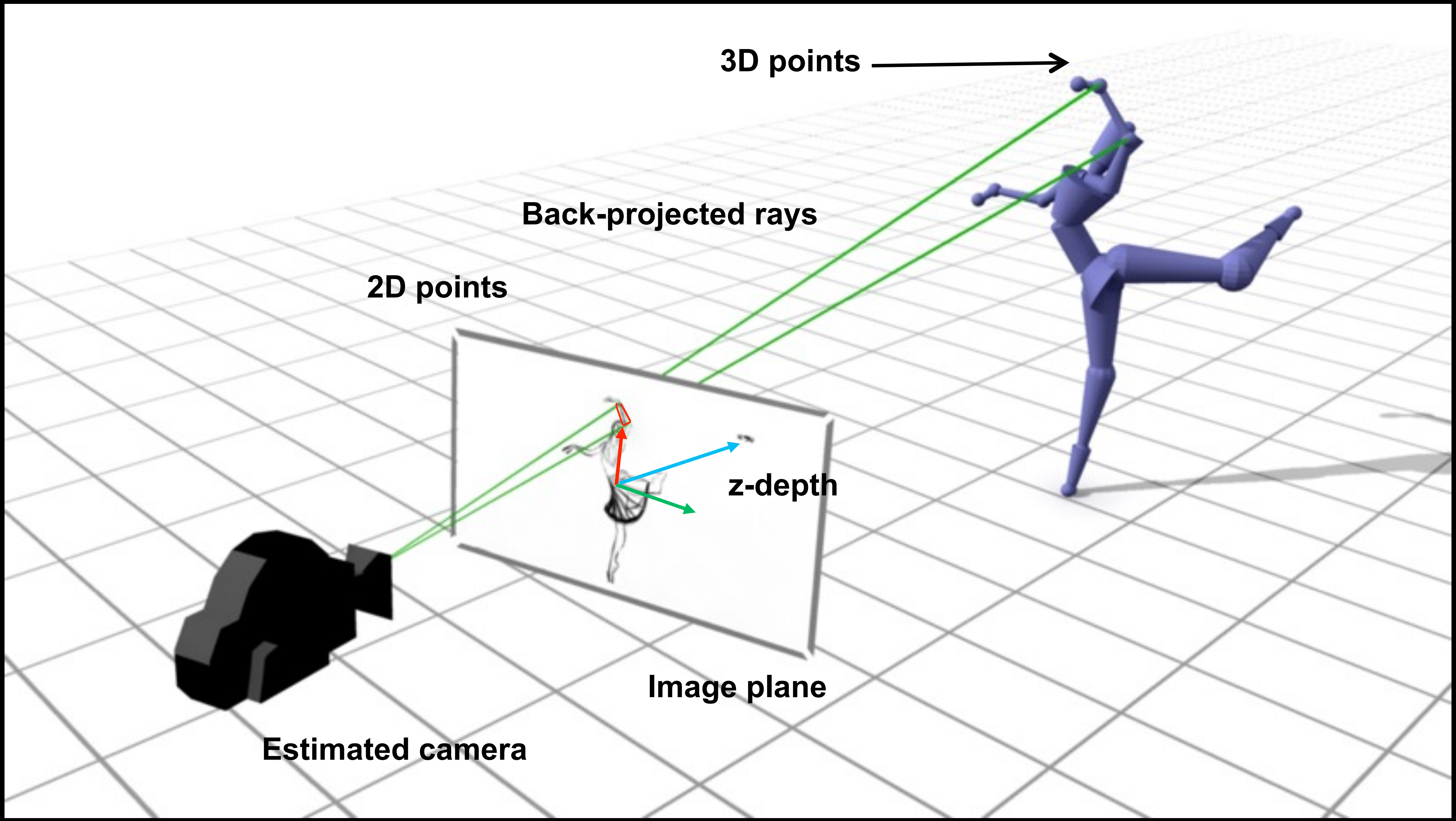
Linear system: least squares solution



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior smoothing term

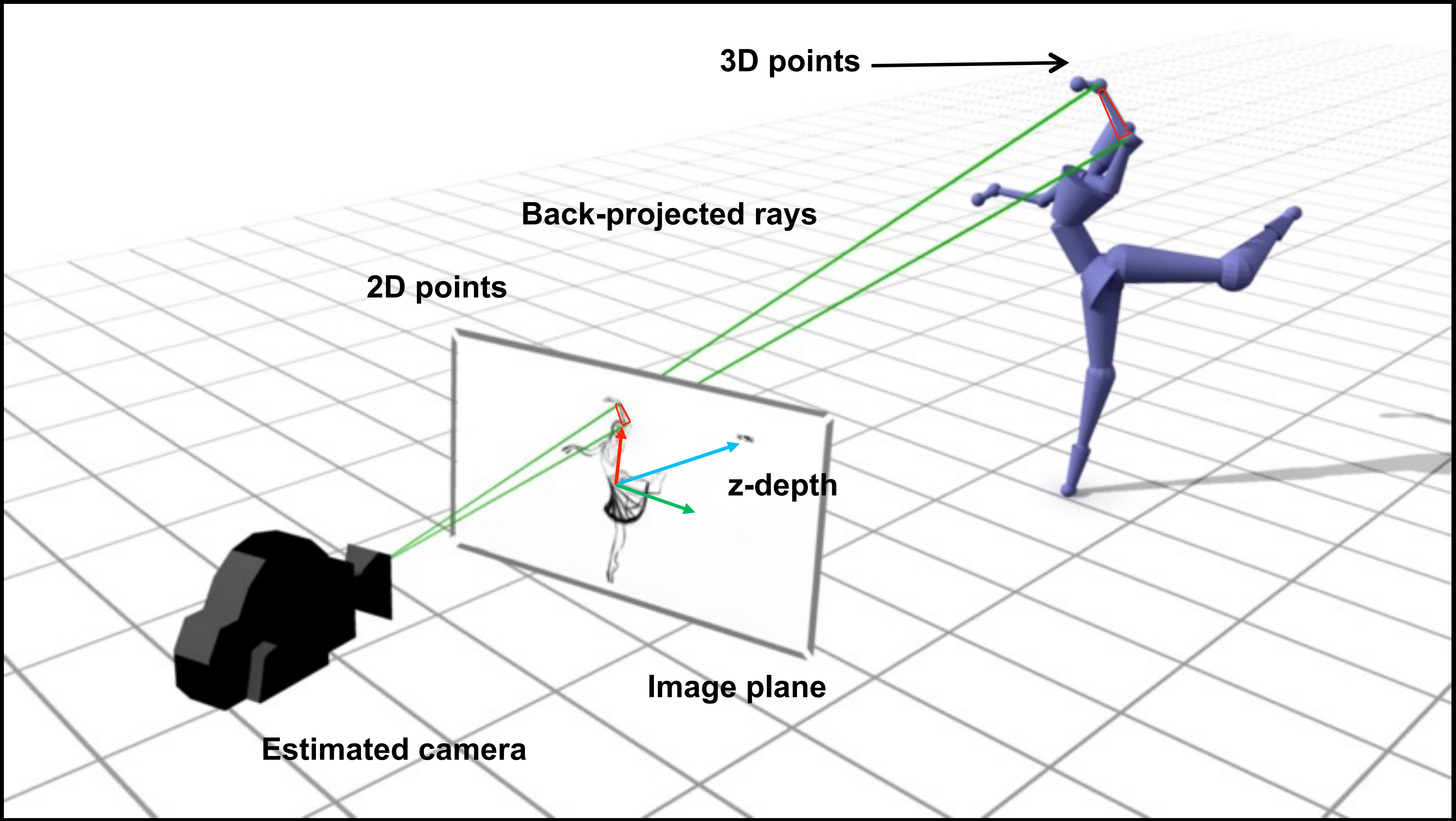
Linear system: least squares solution



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior smoothing term

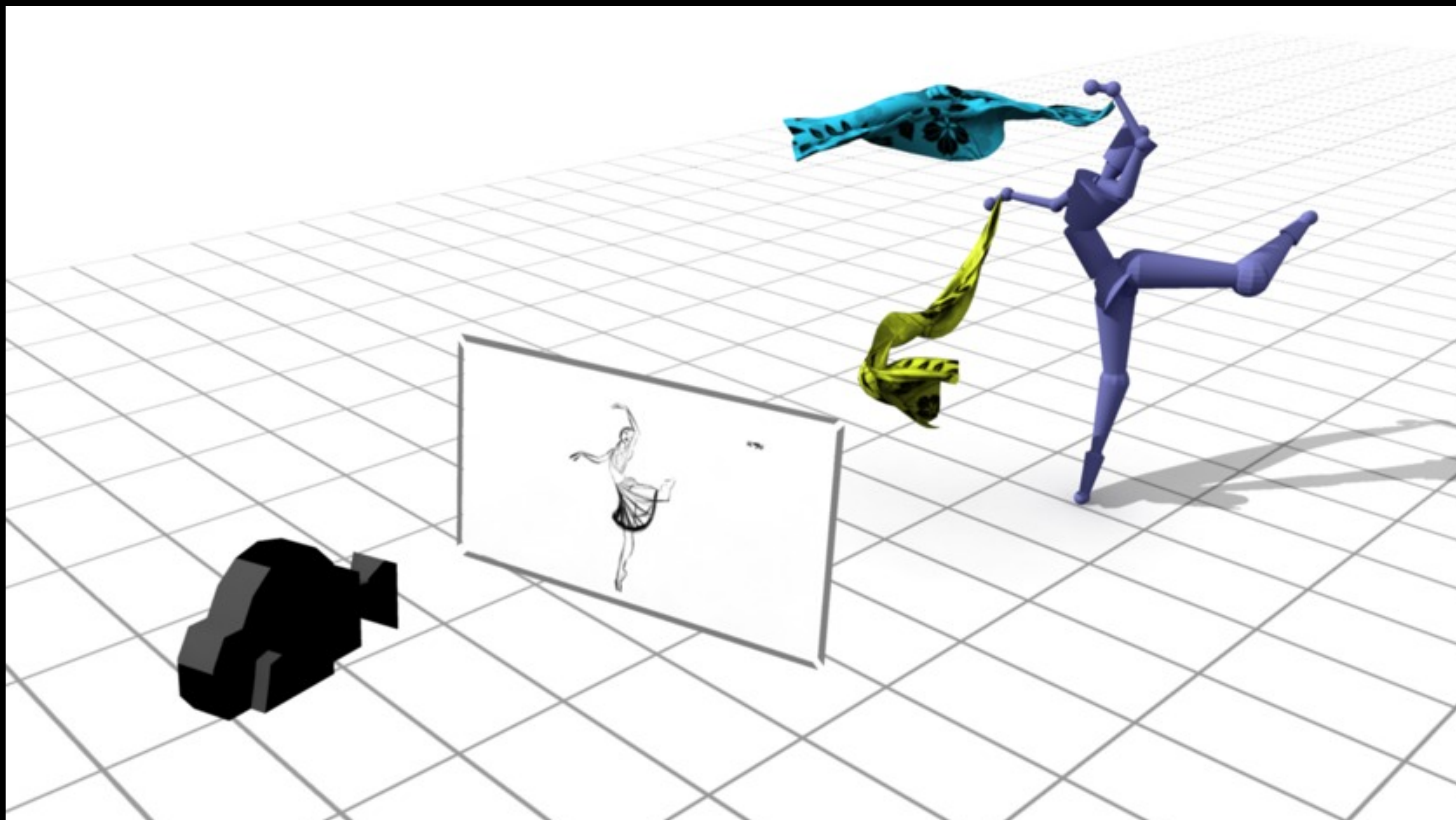
Linear system: least squares solution



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching   depth prior   smoothing term

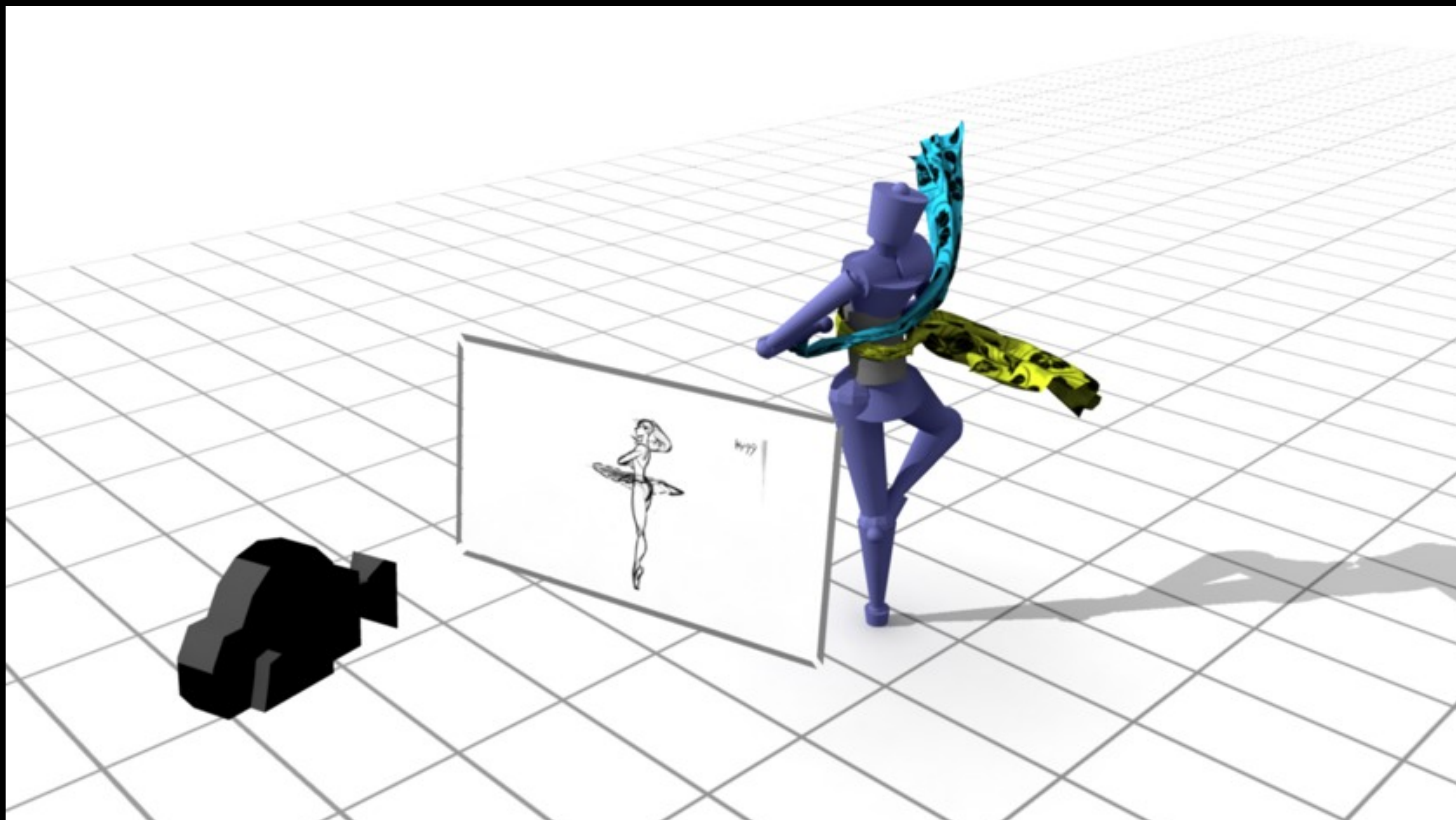
Linear system: least squares solution



$$\arg\min_x (e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior smoothing term

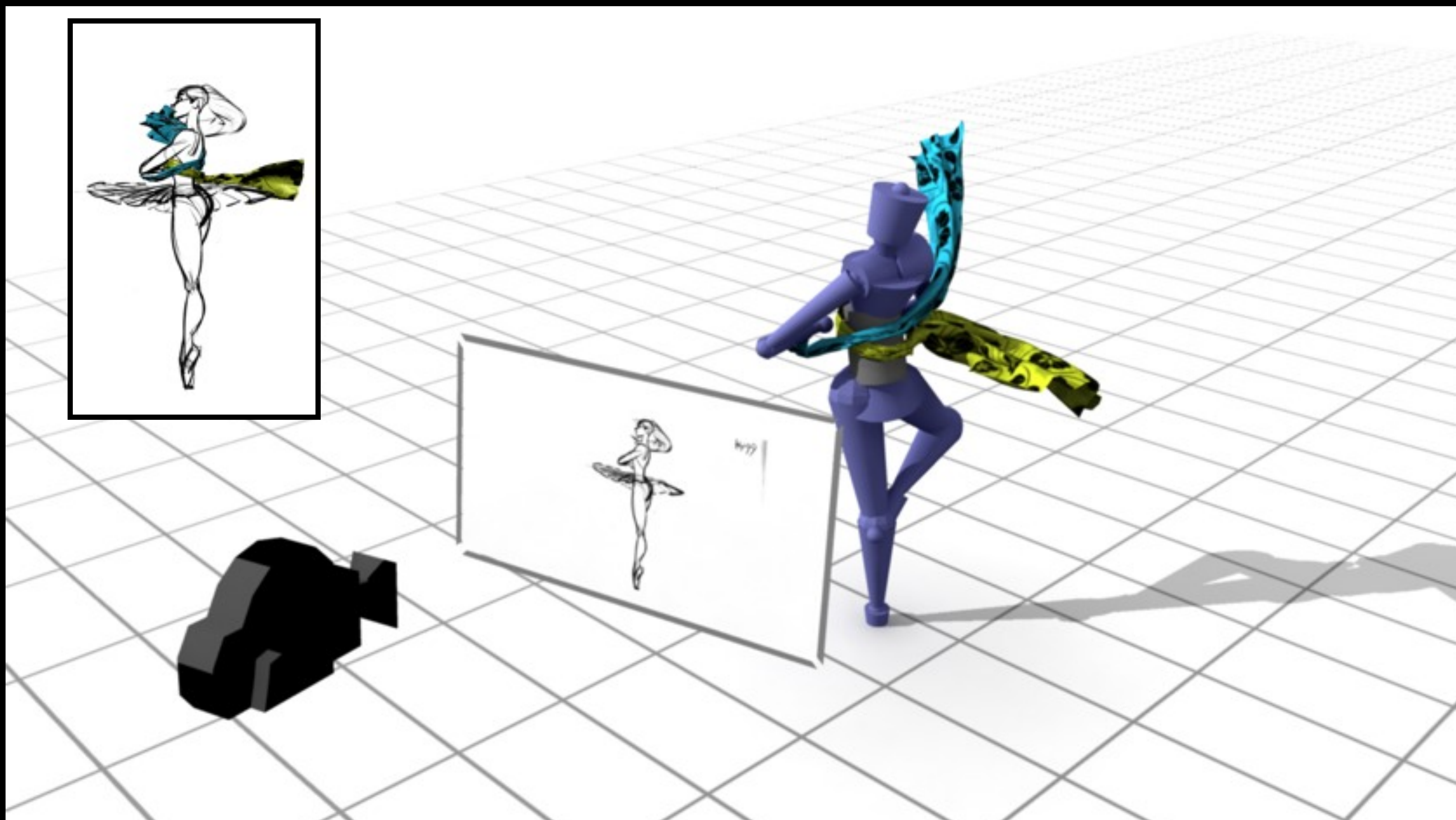
Linear system: least squares solution



$$\arg\min_{x}(e_a(x) + e_m(x) + e_s(x))$$

input-matching depth prior smoothing term

Linear system: least squares solution



Depth compositing

Rendered image

Depth compositing

Rendered image

Depth map for rendered image

Depth compositing

Rendered image

Depth map for
rendered image

Depth map for
hand drawing

Depth compositing

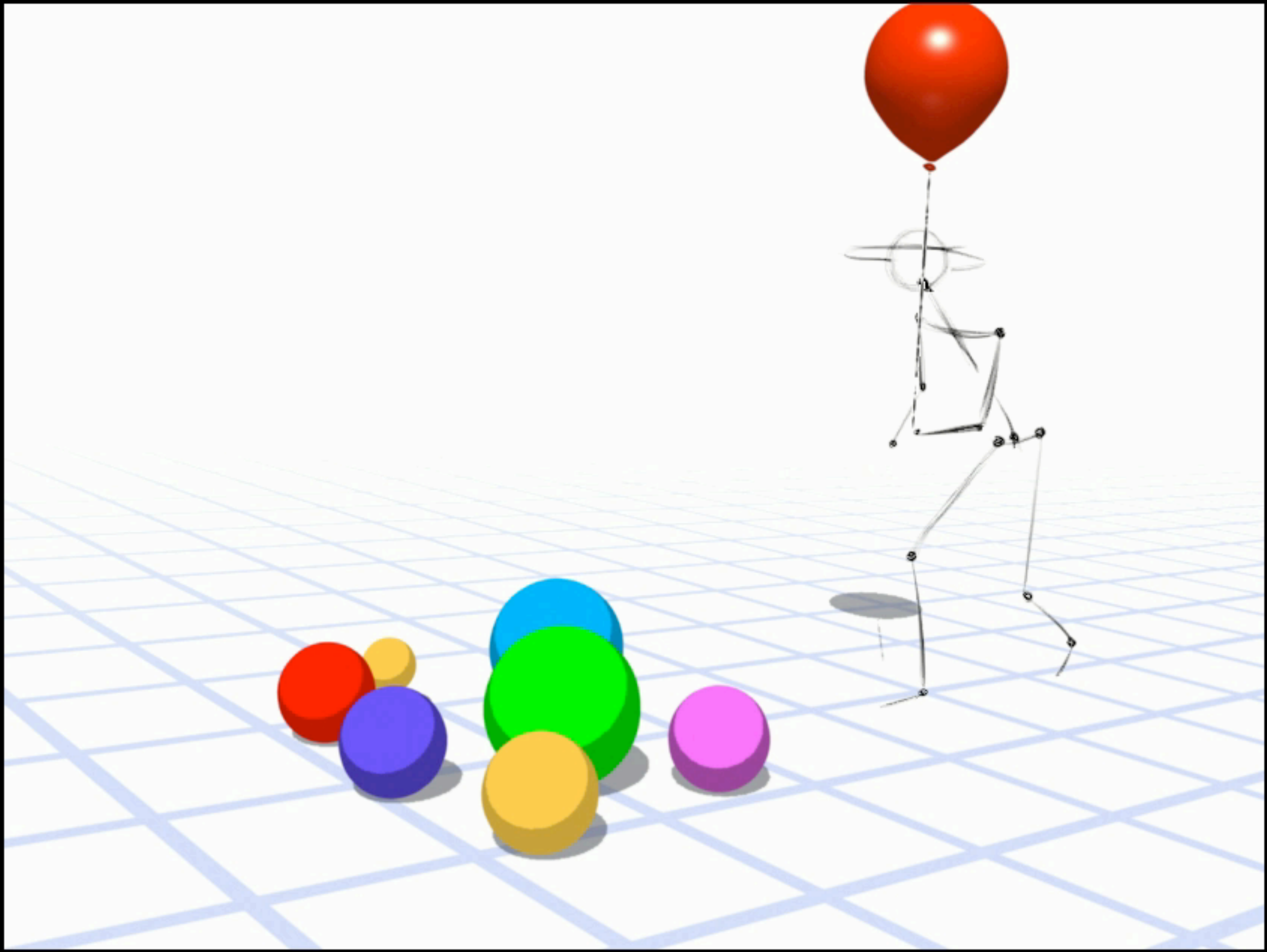

Rendered image

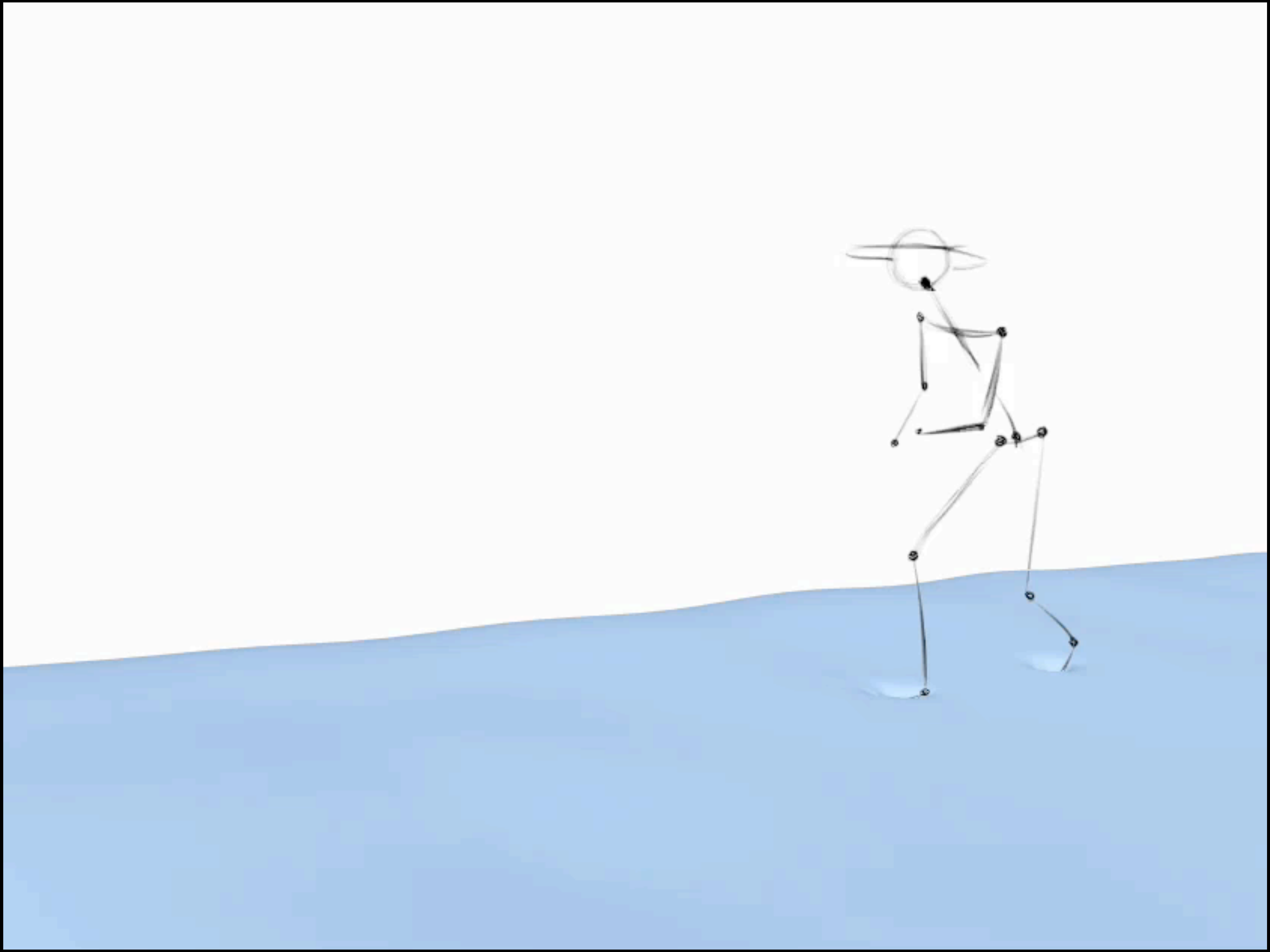

Depth map for rendered image


Depth map for hand drawing

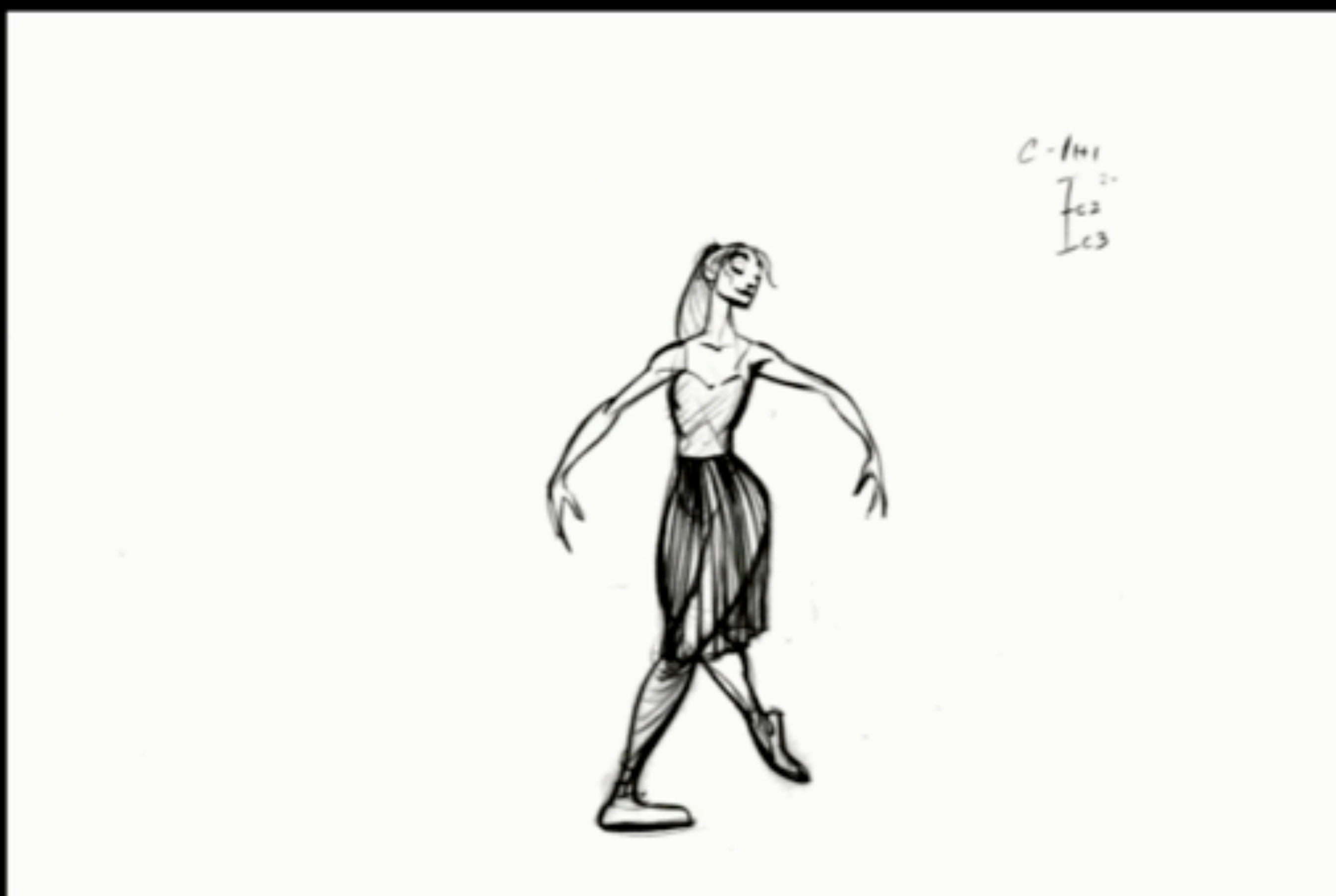

Composited frame


C-1H1
C2
C3

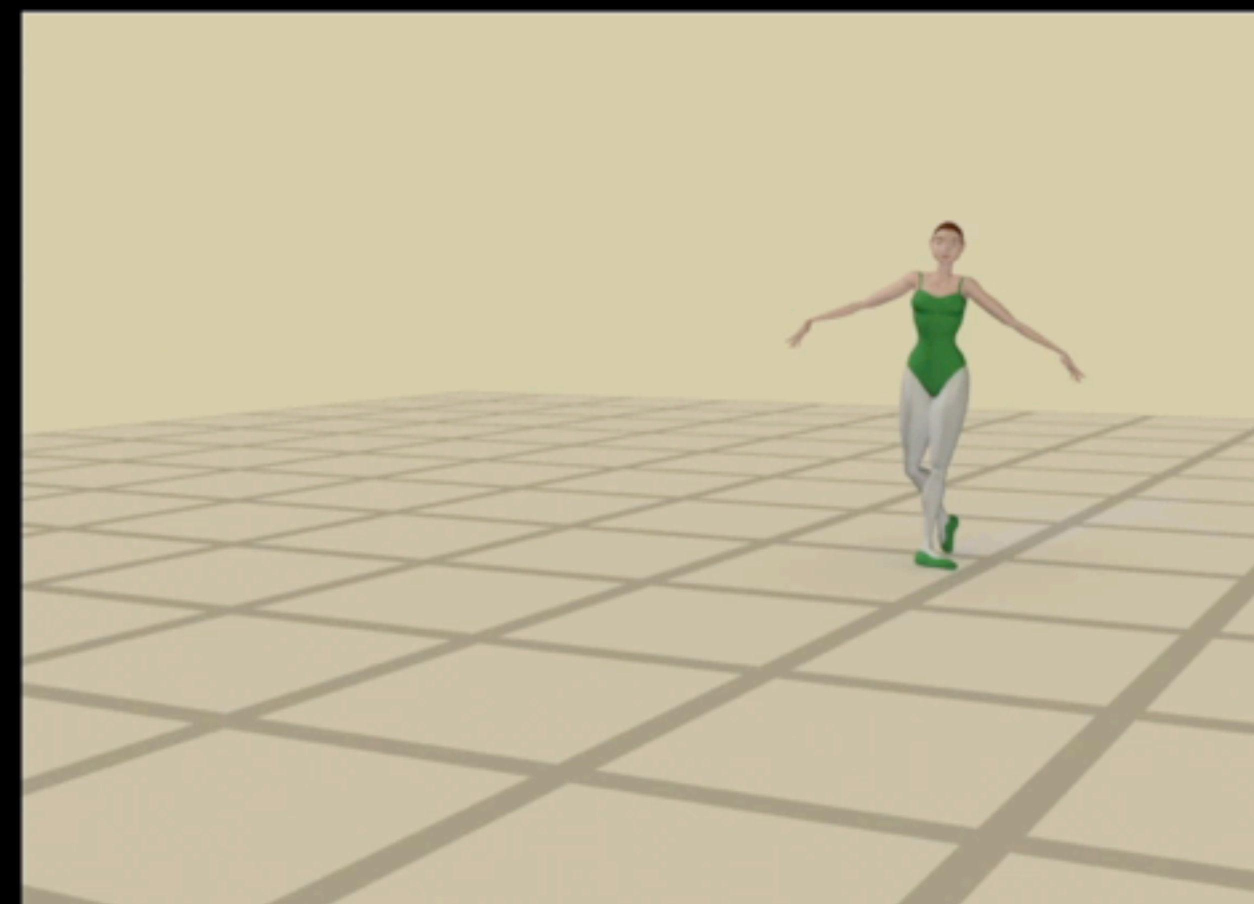


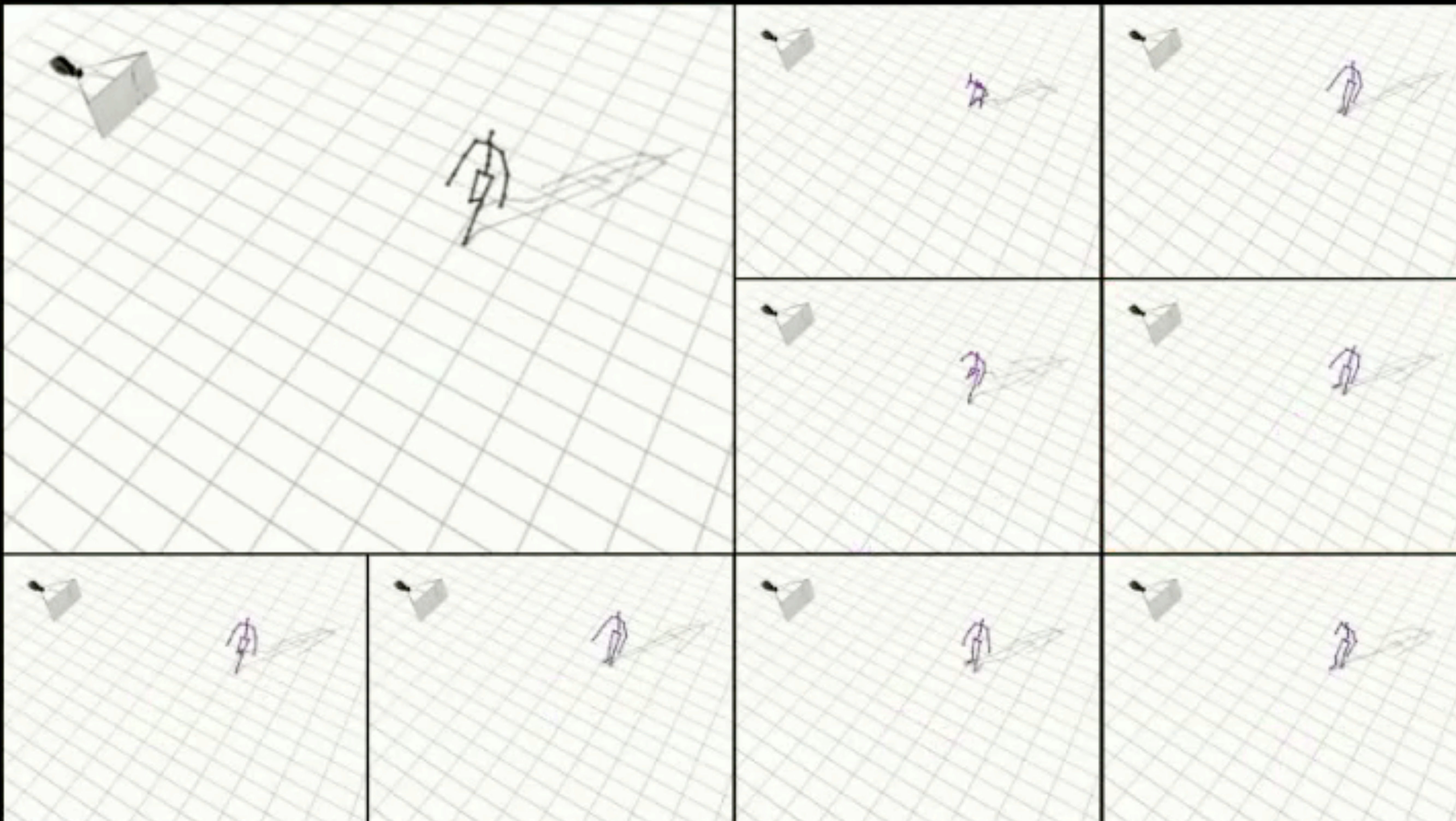


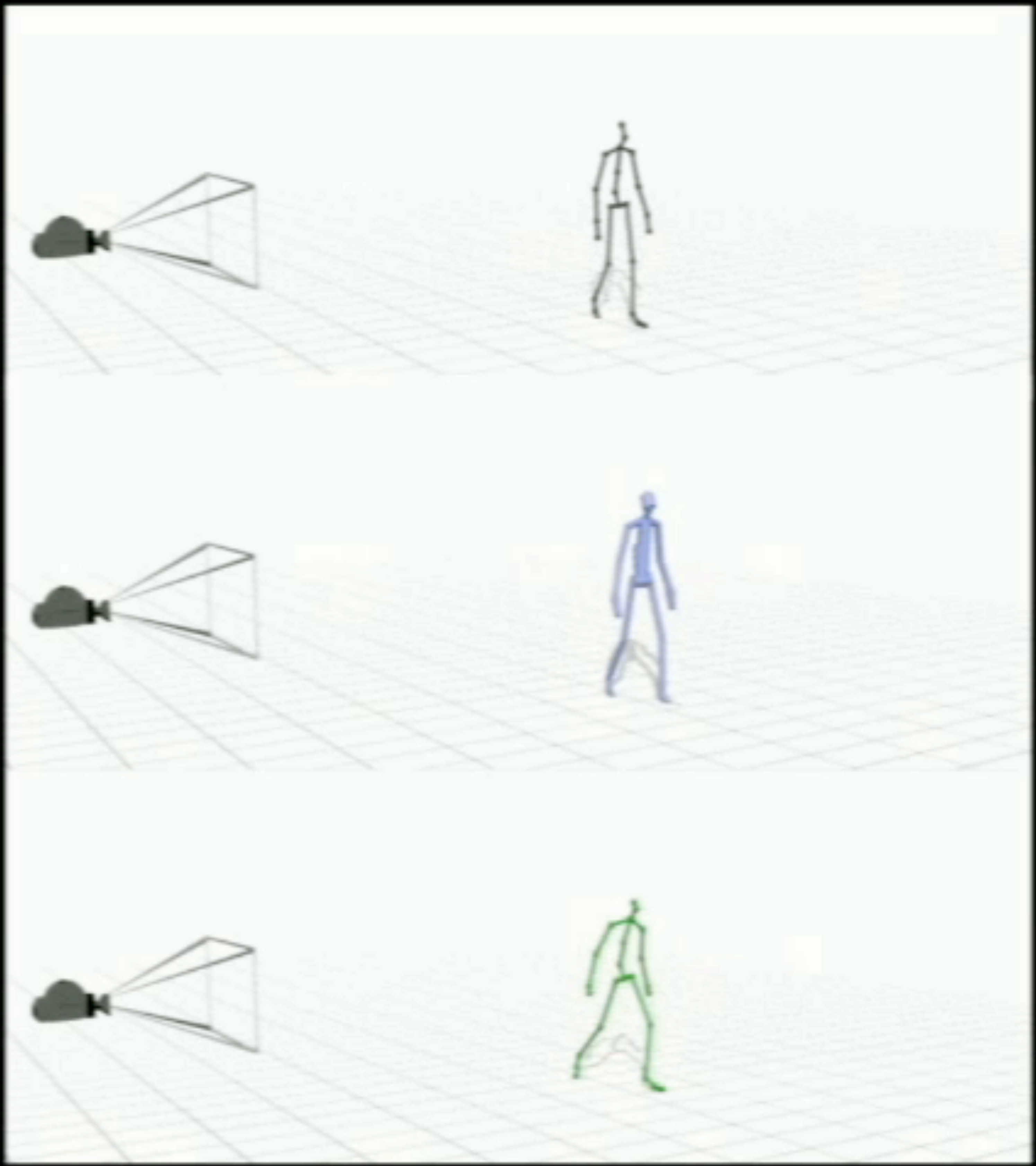
Hand-drawn



Motion capture







Ground truth

Output

Motion capture:
happy walk

Summary

3D Polygonal shapes

Summary

3D Polygonal shapes

Summary

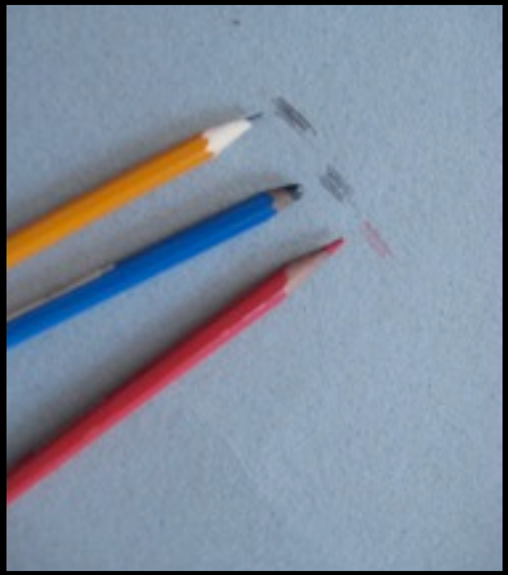
3D Polygonal shapes

3D Joint hierarchy skeleton

Summary

3D Polygonal shapes

3D Joint hierarchy skeleton

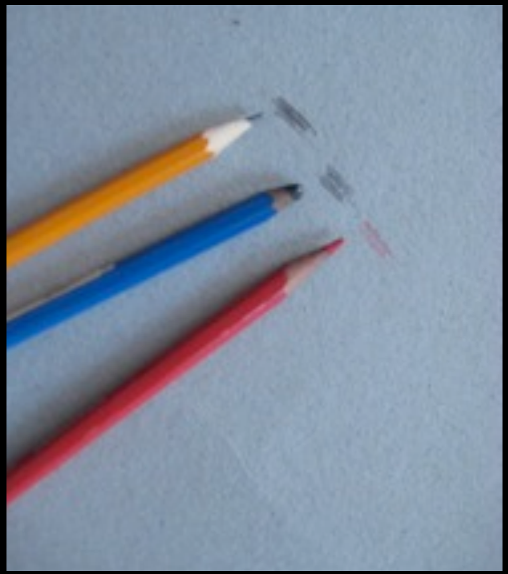


Hand animator modifies
physical simulation?

Summary

3D Polygonal shapes

3D Joint hierarchy skeleton



Hand animator modifies physical simulation?

Learn cartoon physics?

Extra Slides

Camera Estimation

Camera rotation and translation

$$\rho(i) = (\theta_x(i), \theta_y(i), \theta_z(i), t_x(i), t_y(i), t_z(i))^T$$

$$\rho^*(i) = \arg\min_{\rho}(w_1 e_g + w_2 e_l + w_3 e_o + w_4 e_s)$$

Camera Estimation

Camera rotation and translation

$$\rho(i) = (\theta_x(i), \theta_y(i), \theta_z(i), t_x(i), t_y(i), t_z(i))^T$$

$$\rho^*(i) = \arg\min_{\rho}(w_1 e_g + w_2 e_l + w_3 e_o + w_4 e_s)$$

Geometric projection error

Hand drawings

$$e_g = \sum_{t=-K/2}^{K/2} ||\tilde{\mathbf{x}}_{i+t} - \mathbf{x}_{i+t}^{proj}||$$

where $\mathbf{x}_{i+t}^{proj} \cong \mathbf{M}_i \tilde{\mathbf{X}}_{i+t}$

Motion capture poses

$$\arg\min_x(\lambda_a e_a(x) + \lambda_m e_m(x) + \lambda_s e_s(x))$$

input-matching | motion prior | smoothing term

$$\boxed{e_a = ||\tilde{\mathbf{x}}_{ij} - \mathbf{x}_{ij}^{proj}||}$$

$$\mathbf{x}_{ij}^{proj} \cong \mathbf{M}_i \mathbf{X}_{ij}^w$$

$$\tilde{\mathbf{x}}_{ij} \times \mathbf{M}_i \mathbf{X}_{ij}^w = 0$$

$$\mathbf{C}\mathbf{M}_i \begin{bmatrix} X_{ij}^w \\ Y_{ij}^w \\ Z_{ij}^w \\ 1 \end{bmatrix} = 0$$

$$\mathbf{M} = \begin{bmatrix} \mathbf{m}_1^T \\ \mathbf{m}_2^T \\ \mathbf{m}_3^T \end{bmatrix}$$

$$\arg\min_{x}(\lambda_a e_a(x) + \lambda_m e_m(x) + \lambda_s e_s(x))$$

input-matching motion prior smoothing term

$$e_a = ||\tilde{\mathbf{x}}_{ij} - \mathbf{x}_{ij}^{proj}||$$

$$\mathbf{x}_{ij}^{proj} \cong \mathbf{M}_i \mathbf{X}_{ij}^{w}$$

$$\tilde{\mathbf{x}}_{ij} \times \mathbf{M}_i \mathbf{X}_{ij}^{w} = 0$$

$$\mathbf{C}\mathbf{M}_i \begin{bmatrix} X_{ij}^{w} \\ Y_{ij}^{w} \\ Z_{ij}^{w} \\ 1 \end{bmatrix} = 0$$

$$\mathbf{M} = \begin{bmatrix} \mathbf{m}_1^T \\ \mathbf{m}_2^T \\ \mathbf{m}_3^T \end{bmatrix}$$

$$e_m = ||\mathbf{m}_3^T \mathbf{X}_{ij}^{w} - \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}||$$

$$\mathbf{m}_3^T \mathbf{X}_{ij}^{w} = \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}$$

$$\arg\min_x(\lambda_a e_a(x) + \lambda_m e_m(x) + \lambda_s e_s(x))$$

input-matching motion prior smoothing term

$$e_a = ||\tilde{\mathbf{x}}_{ij} - \mathbf{x}_{ij}^{proj}||$$

$$\mathbf{x}_{ij}^{proj} \cong \mathbf{M}_i \mathbf{X}_{ij}^w$$

$$\tilde{\mathbf{x}}_{ij} \times \mathbf{M}_i \mathbf{X}_{ij}^w = 0$$

$$\mathbf{CM}_i \begin{bmatrix} X_{ij}^w \\ Y_{ij}^w \\ Z_{ij}^w \\ 1 \end{bmatrix} = 0$$

$$\mathbf{M} = \begin{bmatrix} \mathbf{m}_1^T \\ \mathbf{m}_2^T \\ \mathbf{m}_3^T \end{bmatrix}$$

$$e_m = ||\mathbf{m}_3^T \mathbf{X}_{ij}^w - \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}||$$

$$\mathbf{m}_3^T \mathbf{X}_{ij}^w = \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}$$

$$e_s = ||\mathbf{X}_{ij}^w - \mathbf{X}_{(i+1)j}^w||$$

$$\begin{bmatrix} \mathbf{I} & -\mathbf{I} \end{bmatrix} \begin{bmatrix} \mathbf{X}_{ij}^w \\ \mathbf{X}_{(i+1)j}^w \end{bmatrix} = \begin{bmatrix} \mathbf{0} \end{bmatrix}$$

$$\arg\min_x(\lambda_a e_a(x) + \lambda_m e_m(x) + \lambda_s e_s(x))$$

input-matching   motion prior   smoothing term

$$e_a = ||\tilde{\mathbf{x}}_{ij} - \mathbf{x}_{ij}^{proj}||$$

$$\mathbf{x}_{ij}^{proj} \cong \mathbf{M}_i \mathbf{X}_{ij}^w$$

$$\tilde{\mathbf{x}}_{ij} \times \mathbf{M}_i \mathbf{X}_{ij}^w = 0$$

$$\mathbf{C}\mathbf{M}_i \begin{bmatrix} X_{ij}^w \\ Y_{ij}^w \\ Z_{ij}^w \\ 1 \end{bmatrix} = 0$$

$$\mathbf{M} = \begin{bmatrix} \mathbf{m}_1^T \\ \mathbf{m}_2^T \\ \mathbf{m}_3^T \end{bmatrix}$$

$$e_m = ||\mathbf{m}_3^T \mathbf{X}_{ij}^w - \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}||$$

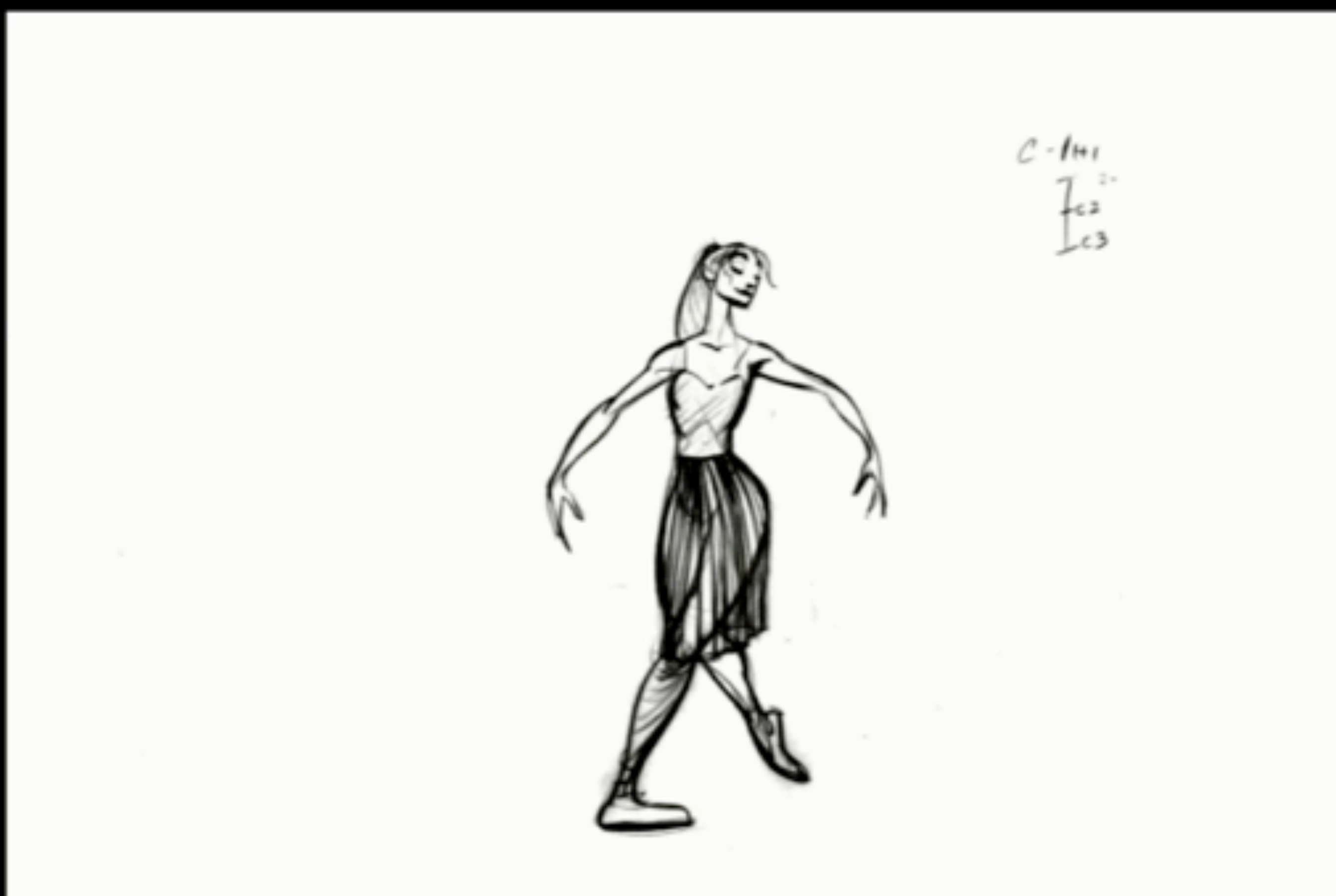
$$\mathbf{m}_3^T \mathbf{X}_{ij}^w = \mathbf{m}_3^T \tilde{\mathbf{X}}_{ij}$$

$$e_s = ||\mathbf{X}_{ij}^w - \mathbf{X}_{(i+1)j}^w||$$

$$\begin{bmatrix} \mathbf{I} & -\mathbf{I} \end{bmatrix} \begin{bmatrix} \mathbf{X}_{ij}^w \\ \mathbf{X}_{(i+1)j}^w \end{bmatrix} = \begin{bmatrix} \mathbf{0} \end{bmatrix}$$

$$\mathbf{W}\mathbf{A}_i \mathbf{X}_i^w = \mathbf{b}_i$$

Hand-drawn



Time warped motion capture