AnimationPak:
Packing Elements with Scripted Animations

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ABSTRACT

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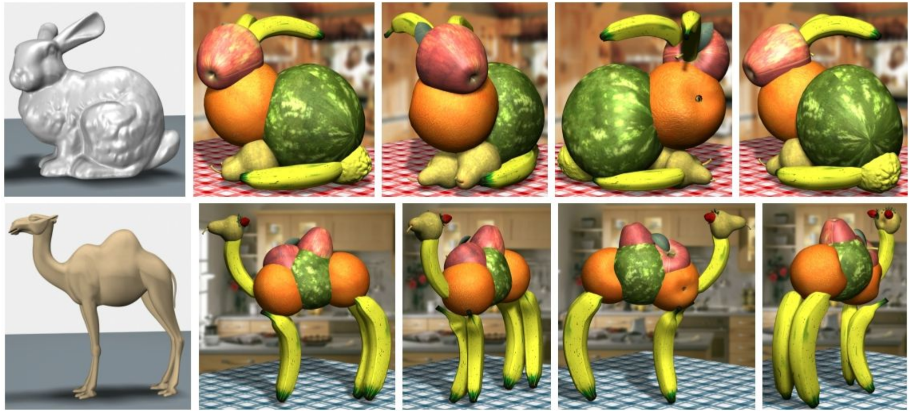
Ecological Civilization-Building a Shared Future for All Life on Earth
KUNMING · CHINA

RELATED WORK



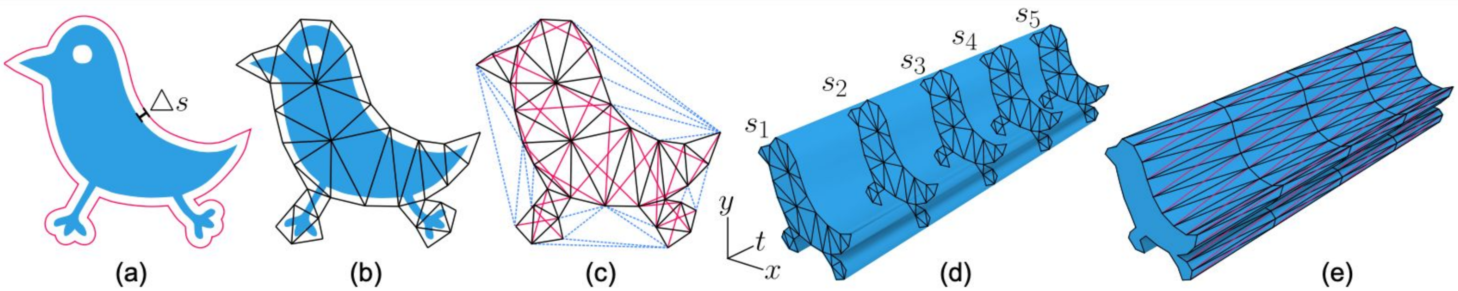
ANIMATED ELEMENTS

- The input to AnimationPak is a library of animated elements and a fixed container shape.
- AnimationPak currently supports two kinds of animation: the user can animate the shape of each individual element and can also give elements trajectories that animate their position within the container.

https://www.youtube.com/watch?v=Y60xcp-EZOw

ANIMATED ELEMENTS

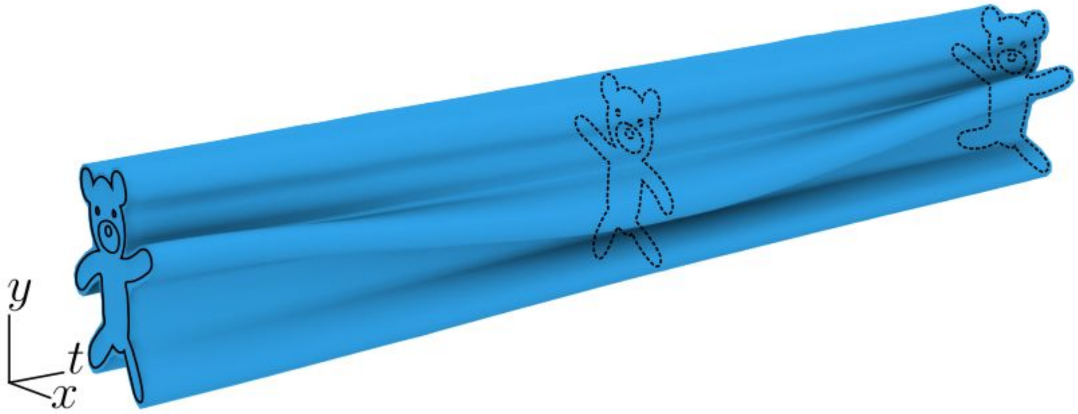
- Spacetime Extrusion



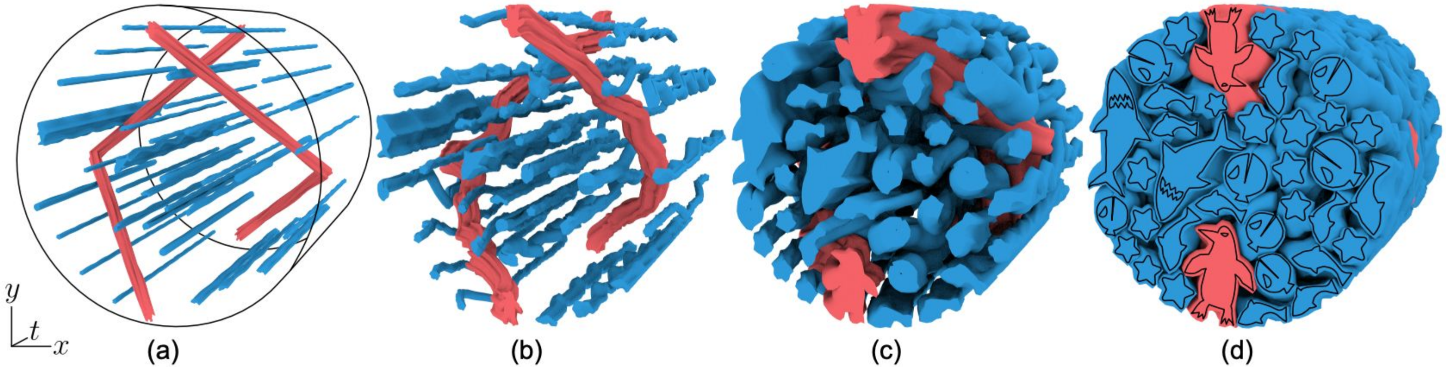
- we first offset the shape's paths by a distance Δs, leaving the shape surrounded by a channel of negative space.
- Delaunay triangulation
- adding extra edges to prevent folding or self-overlaps during simulation
- To extend the element into the time dimension, we now position evenly-spaced copies of the slice along the time axis.
- To complete the construction of a spacetime element without animation, we stitch the slices together into a single 3D object

ANIMATED ELEMENTS

- Animation
  - The results in this paper all use fewer than ten input elements



INITIAL CONFIGURATION



SIMULATION

- Repulsion Forces

boundary as:

$$\boldsymbol{F}_{\text{rpl}} = k_{\text{rpl}} \sum_{i=1}^{n} \frac{\boldsymbol{u}}{\|\boldsymbol{u}\|} \frac{1}{\epsilon + \|\boldsymbol{u}\|^2} \qquad (1)$$

where

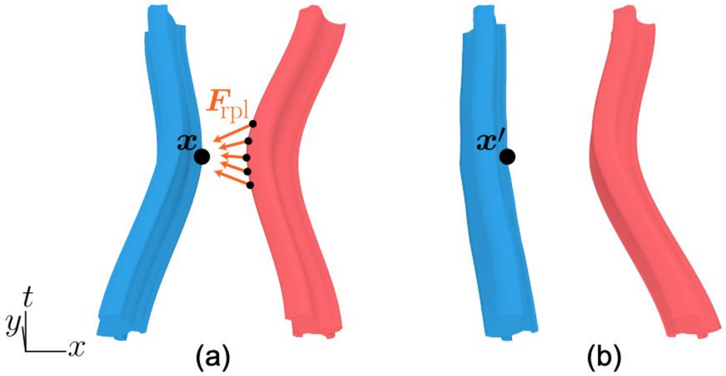
k_{rpl} is the relative strength of $\boldsymbol{F}_{\text{rpl}}$. We set $k_{\text{rpl}} = 10$;

n is the number of nearest points to $\boldsymbol{x}$;

$\boldsymbol{x}_i$ is the i-th closest point on the neighboring element surfaces;

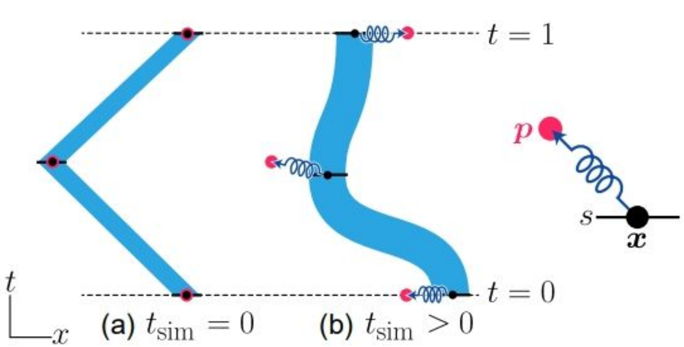
$\boldsymbol{u} = \boldsymbol{x} - \boldsymbol{x}_i$; and

ϵ is a *soft parameter* to avoid instability when $\|\boldsymbol{u}\|$ is small. We set $\epsilon = 1$.



SIMULATION

- Edge Forces



$$\boldsymbol{F}_{\text{edg}} = k_{\text{edg}} \frac{\boldsymbol{u}}{\|\boldsymbol{u}\|} s \left(\|\boldsymbol{u}\| - \ell\right)^2 \qquad (2)$$

where

k_{edg} is is the relative strength of $\boldsymbol{F}_{\text{edg}}$. Different classes of spring will have different k_{edg} values;

$\boldsymbol{u} = \boldsymbol{x_b} - \boldsymbol{x_a}$;

ℓ is the rest length of the spring; and

s is +1 or -1, according to whether $(\|\boldsymbol{u}\| - \ell)$ is positive or negative.

SIMULATION

- Overlap forces

$$\boldsymbol{F}_{\text{ovr}} = k_{\text{ovr}} \sum_{i=1}^{n} (\boldsymbol{p_i} - \boldsymbol{x}) \quad (3)$$

where

k_{ovr} is the relative strength of $\boldsymbol{F}_{\text{ovr}}$. We set $k_{\text{ovr}} = 5$;
n is the number of slice triangles that have $\boldsymbol{x}$ as a vertex; and
$\boldsymbol{p_i}$ is the centroid of the i-th slice triangle incident on $\boldsymbol{x}$.

SIMULATION

- Boundary forces

$$\boldsymbol{F}_{\mathrm{bdr}} = k_{\mathrm{bdr}}(\boldsymbol{p_b} - \boldsymbol{x}) \tag{4}$$

where
k_{bdr} is the relative strength of $\boldsymbol{F}_{\mathrm{bdr}}$. We set $k_{\mathrm{bdr}} = 5$; and
$\boldsymbol{p_b}$ is the closest point on the target container to $\boldsymbol{x}$.

SIMULATION

- Torsional forces

$$\boldsymbol{F}_{\text{tor}} = \begin{cases} k_{\text{tor}}\boldsymbol{u}^{\perp}, & \text{if}\theta > 0 \\ -k_{\text{tor}}\boldsymbol{u}^{\perp}, & \text{if}\theta < 0 \end{cases} \qquad (5)$$

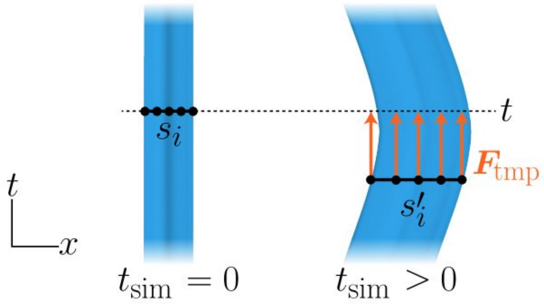
where
k_{tor} is the relative strength of $\boldsymbol{F}_{\text{tor}}$. We set $k_{\text{tor}} = 0.1$;
θ is the signed angle between $\boldsymbol{u}_r$ and $\boldsymbol{u}$; and
$\boldsymbol{u}^{\perp}$ is a unit vector rotated 90° counterclockwise relative to $\boldsymbol{u}$.

SIMULATION

- Temporal forces

$$\boldsymbol{F}_{\text{tmp}} = k_{\text{tmp}} \boldsymbol{u}^t (t - t') \quad (6)$$

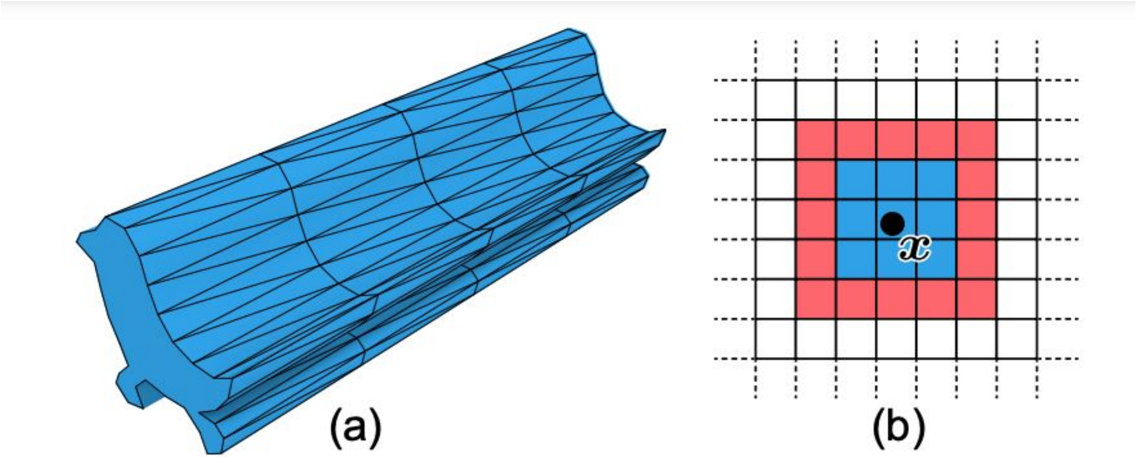
where
k_{tmp} is the relative strength of $\boldsymbol{F}_{\text{tmp}}$. We set $k_{\text{tmp}} = 1$;
t is the initial time of the slice to which the vertex belongs;
t' is the current time value of the vertex; and
$\boldsymbol{u}^t = (0, 0, 1)$.



$$\boldsymbol{F}_{\text{total}} = \boldsymbol{F}_{\text{rpl}} + \boldsymbol{F}_{\text{edg}} + \boldsymbol{F}_{\text{bdr}} + \boldsymbol{F}_{\text{ovr}} + \boldsymbol{F}_{\text{tor}} + \boldsymbol{F}_{\text{tmp}} \quad (7)$$

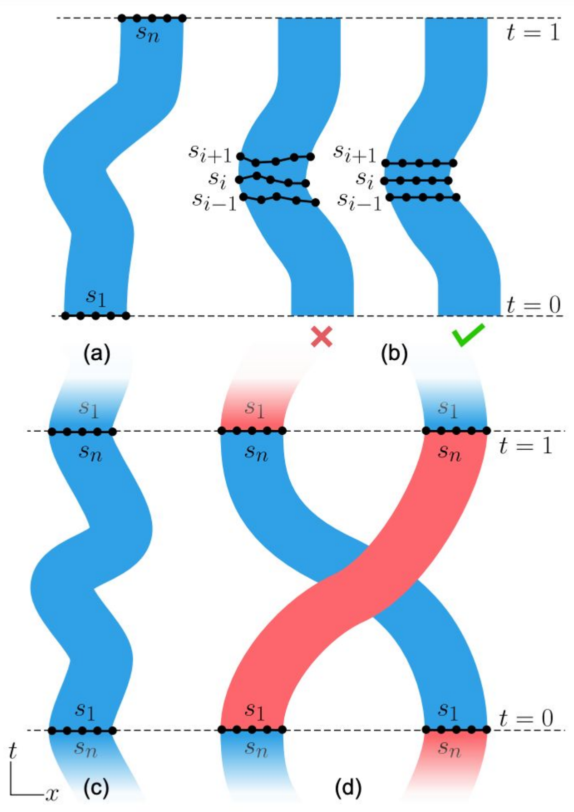
SIMULATION

- Spatial Queries



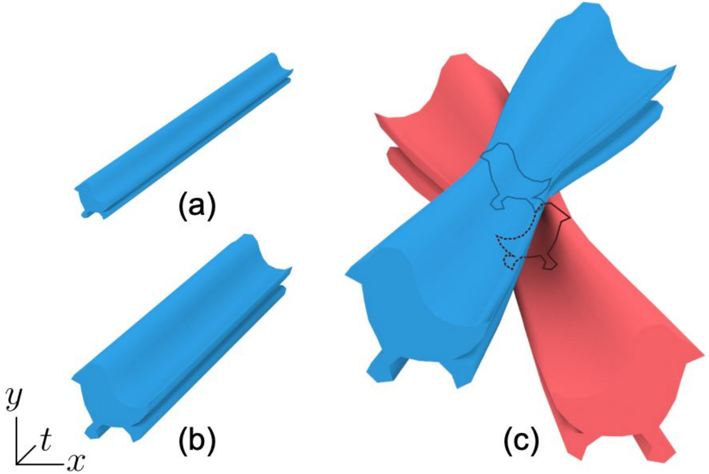
SIMULATION

- Slice Constraints
  - End-to-end constraint: A spacetime element must be present for the full length of the animation from t = 0 to t = 1.(Fig. a).
  - Simultaneity constraint: we compute the average t value of all vertices belonging to each slice other than the first and last slices, and snap all the slice's vertices to that t value (Fig. b).
  - Loop constraint: (c)(d)



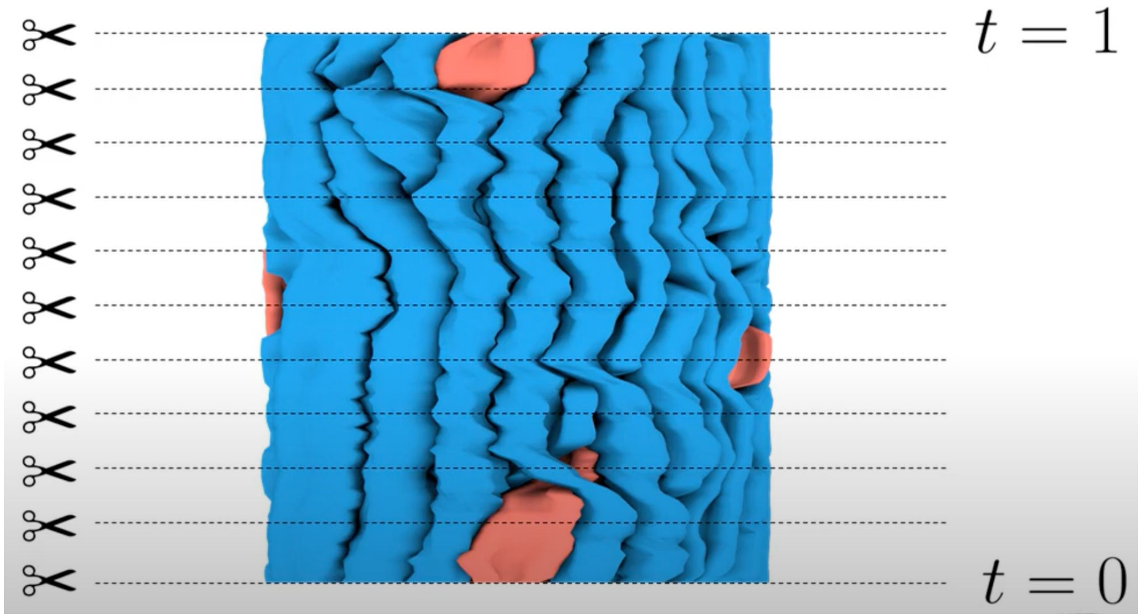
SIMULATION

- Element Growth and Stopping Criteria

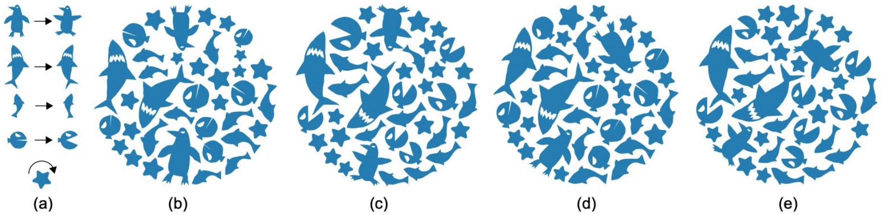


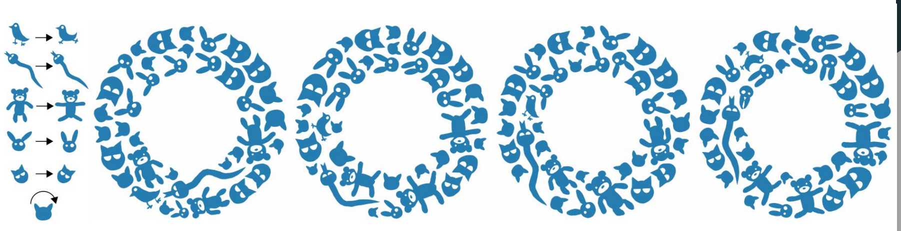
RENDERING

- For our results, we typically render 500-frame animations.



IMPLEMENTATION AND RESULTS





Packing	Elements	Vertices	Springs	Triangles	Time
Aquatic animals (Fig. 1)	37	97,800	623,634	106,000	01:06:35
Snake and birb (Fig. 11)	37	58,700	370,571	58,700	01:01:32
Penguin to giraffe (Fig. 12)	33	124,300	824,164	143,000	01:19:50
Heart stars (Fig. 13c)	26	85,200	598,218	858,00	00:23:08
Animals (Fig. 15b)	34	69,600	444,337	69,800	01:00:19
Lion (Fig. 14b)	16	39,400	236,086	41,800	00:41:56