SIGGRAPH2004

Cords: Keyframe Control of Curves with Physical Properties

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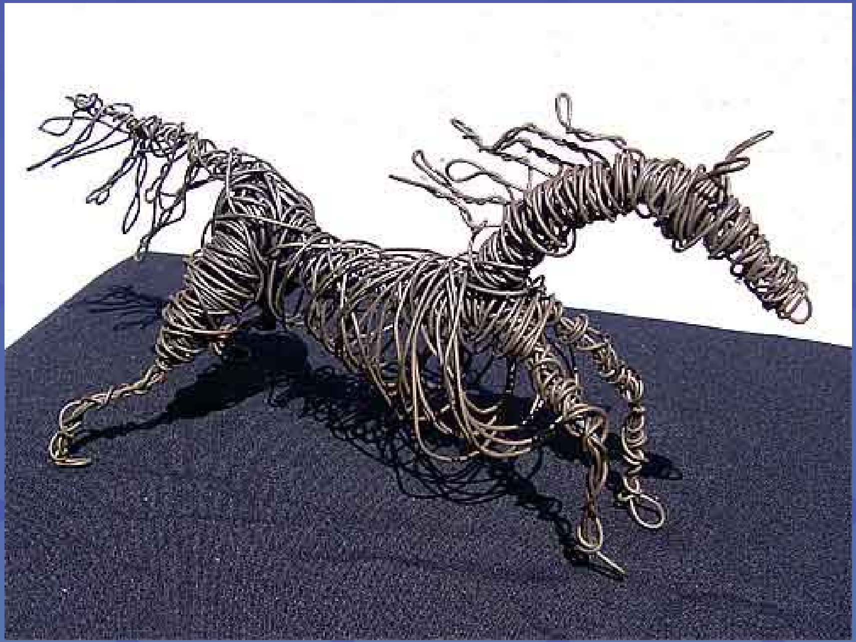
Dynamic Graphics Project, University of Toronto
August 11, 2004

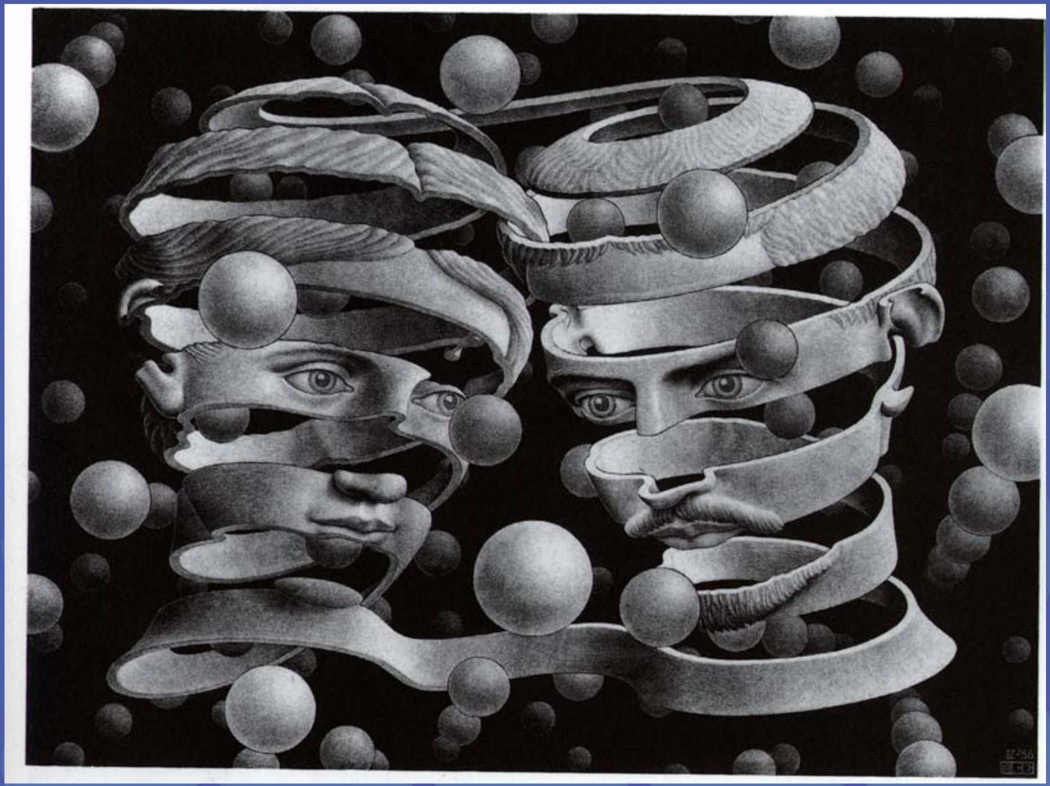
Motivation

- Precise interactive control of curves with physical appearance properties
- String, wire, rubber bands, etc.



Motivation

- Artistic control of primitives that interact with geometry



Motivation

- *Ryan*

Design Requirements

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- Intuitive parameter space
- Interactive and precise control
- Continuous shape for keyframe animation
- No dependence on simulation data

Related Work

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- Physical simulation
  - Terzopoulos et al. 87, Pai 02
- Empirical simulation
  - Brown 04
- Faking dynamics
  - Barzel 97

Traditional Curve Modeling

- Animators and modelers understand the control point editing paradigm
- Interaction with scene geometry can require arbitrarily complex shapes
  - Too many control points
  - Shape and detail change with animation

Simulation

- Animators control initial state, environment, and simulation parameters
  - Excellent for reactive motion
  - Adheres to a given physical model
- Control
  - Hard to achieve desired response
  - Can’t specify shape at arbitrary time

Contributions

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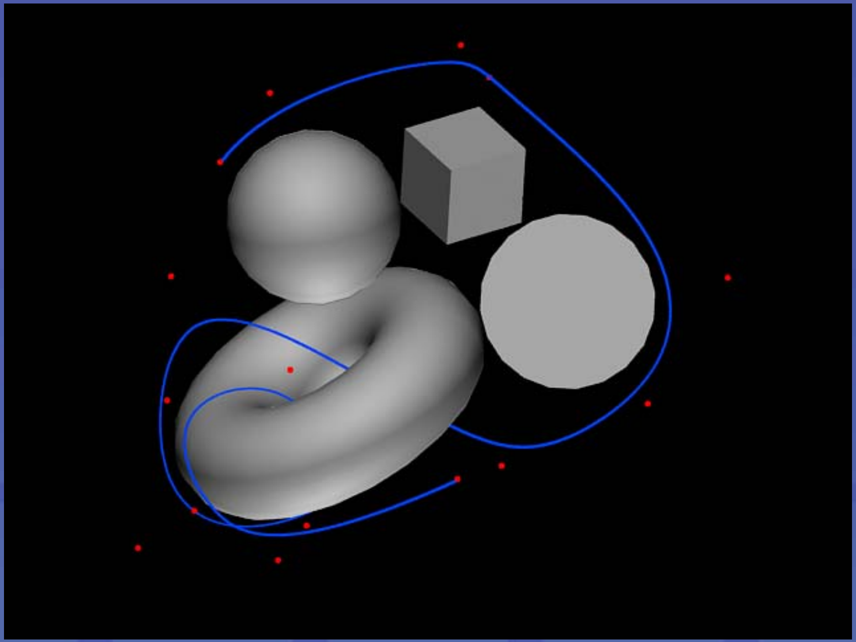
- Precise control for keyframe animation
- Automatic bending and wrapping
- Intuitive parameter space for predictable response
- Easy to code algorithms

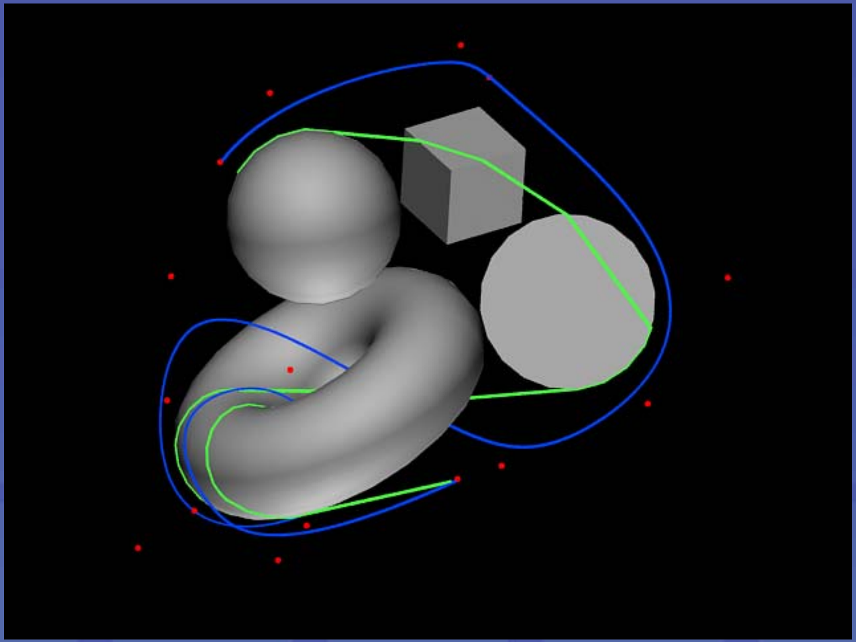
Cords Approach

- User controls general path with a *guide curve*
  - Arbitrary parametric curve in space f(t)



Cords Approach

- Procedural generation of cord
  - Analytic, continuous shape that follows guide curve
  - Material-like properties of length, stiffness, elasticity



Cords Approach

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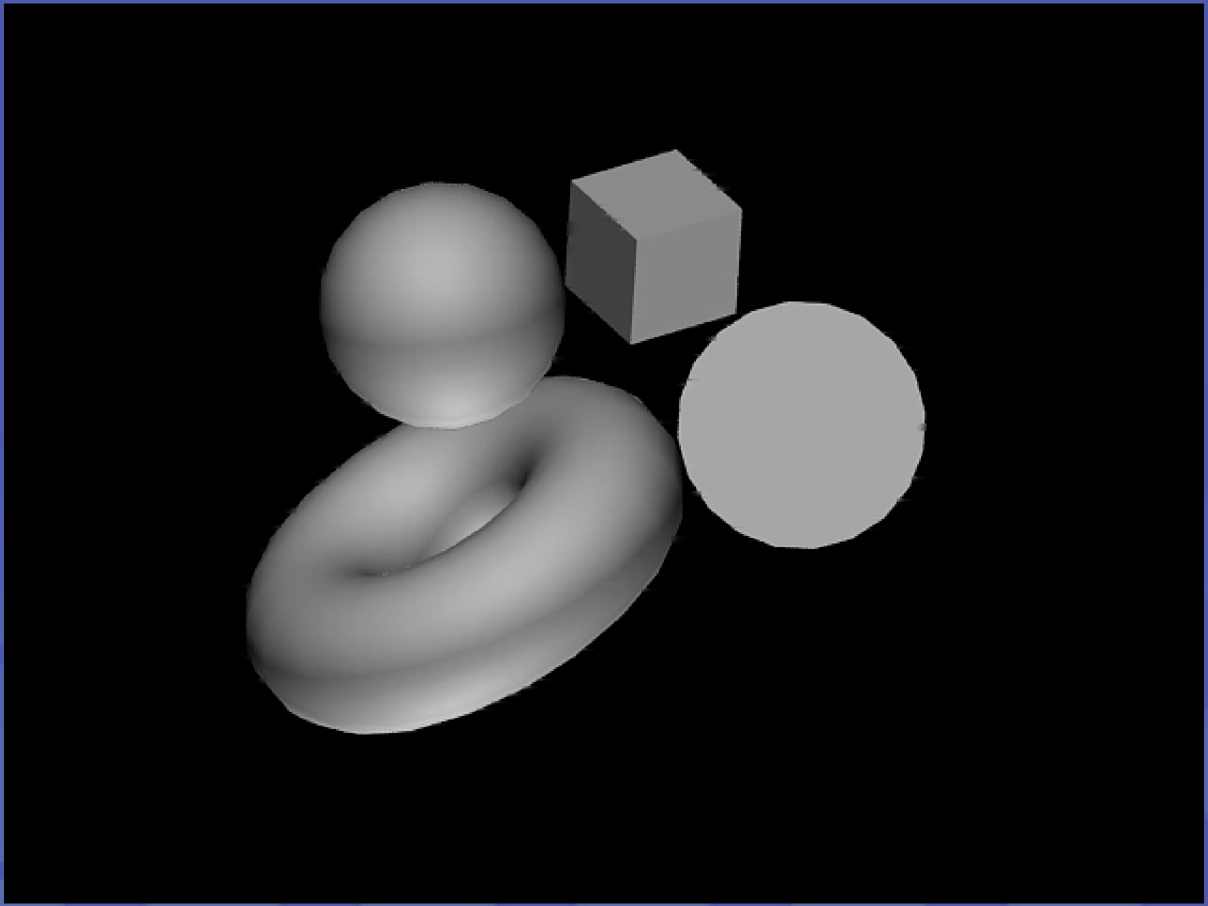

Cords Workflow

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- Generation follows path of guide curve, wrapping around scene geometry
- User positions the guide curve and edits cord properties

Cords Workflow

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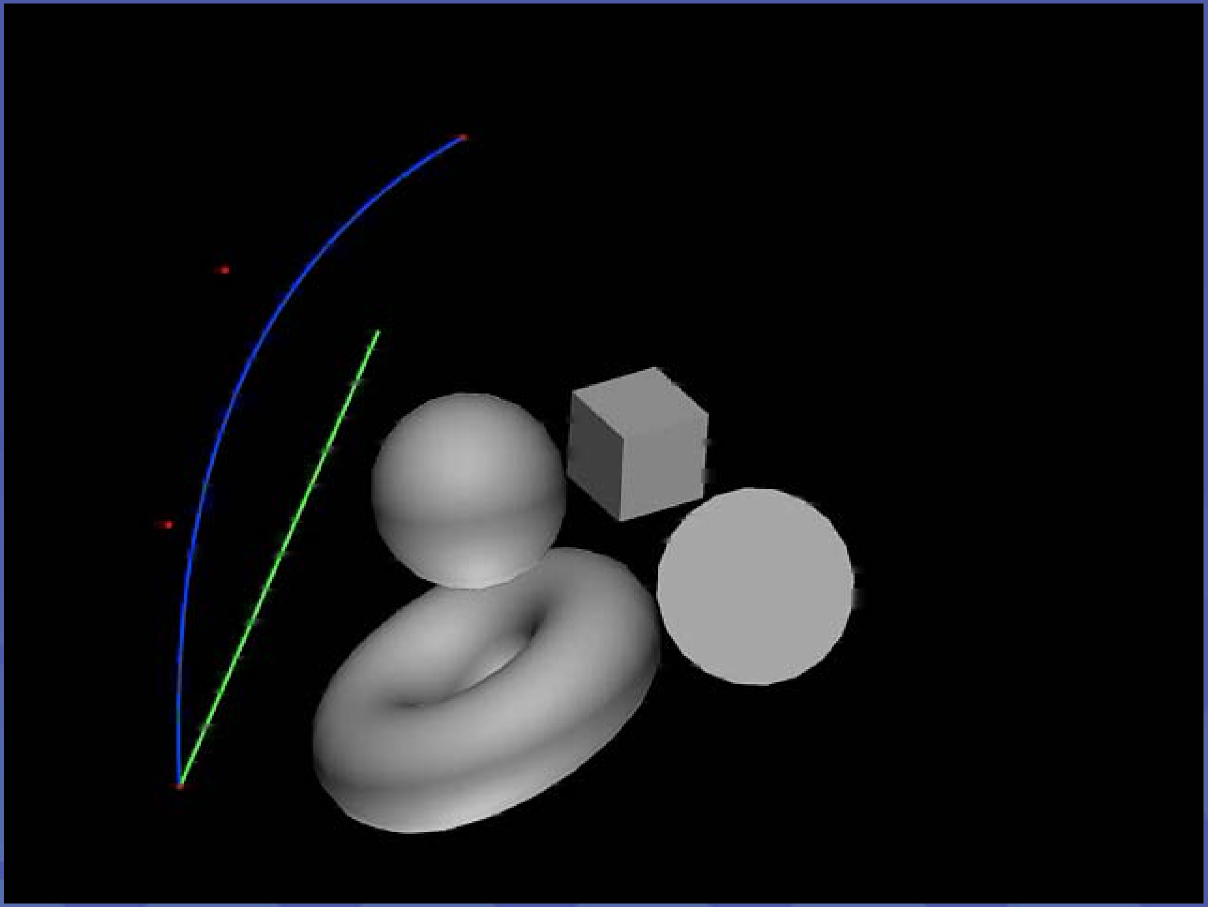

Cords Algorithm

- Initialize Cord to f(0).
- Grow the Cord by stepping along f.

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if (ray from Cord to f intersects geometry)
    grow cord to intersection
else
    grow cord by a stiffness factor s along the ray
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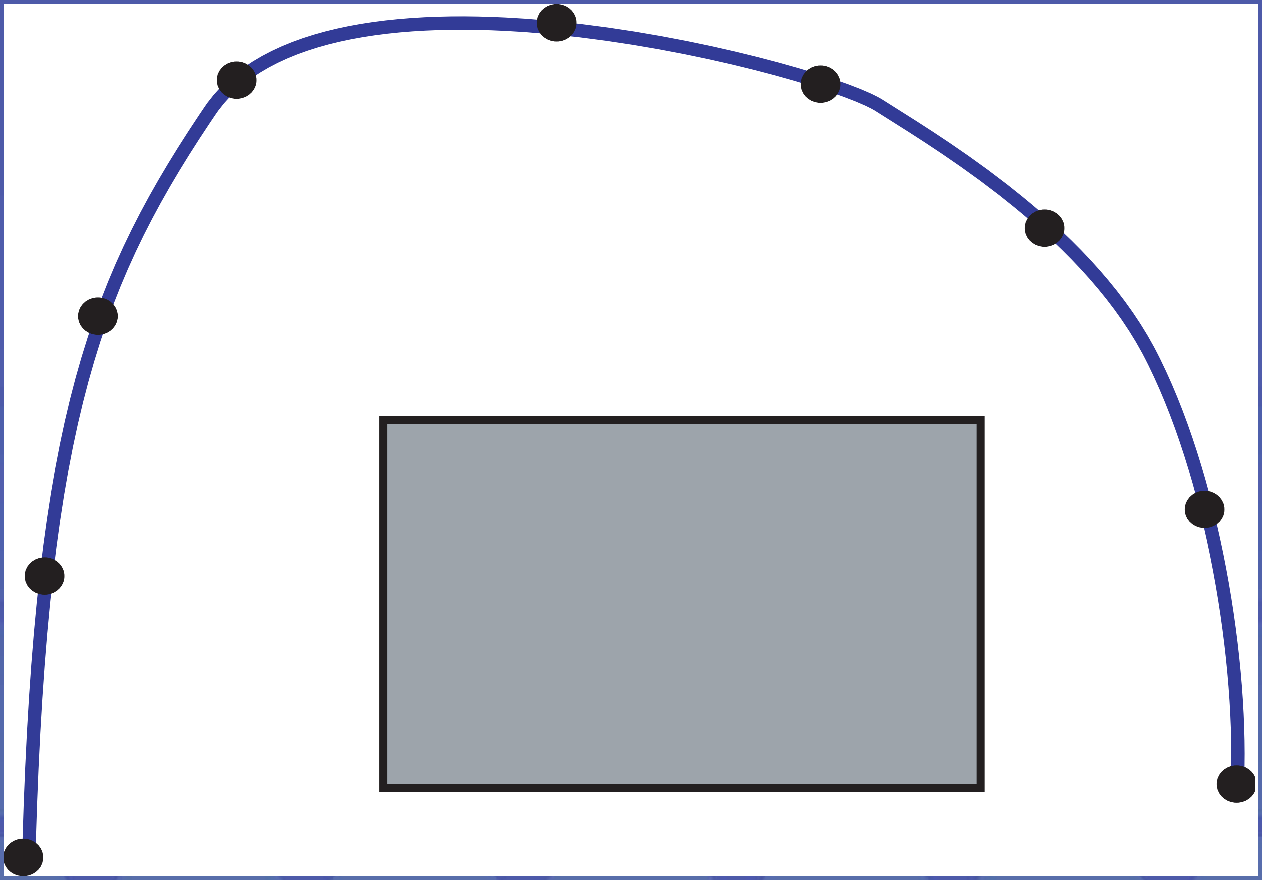
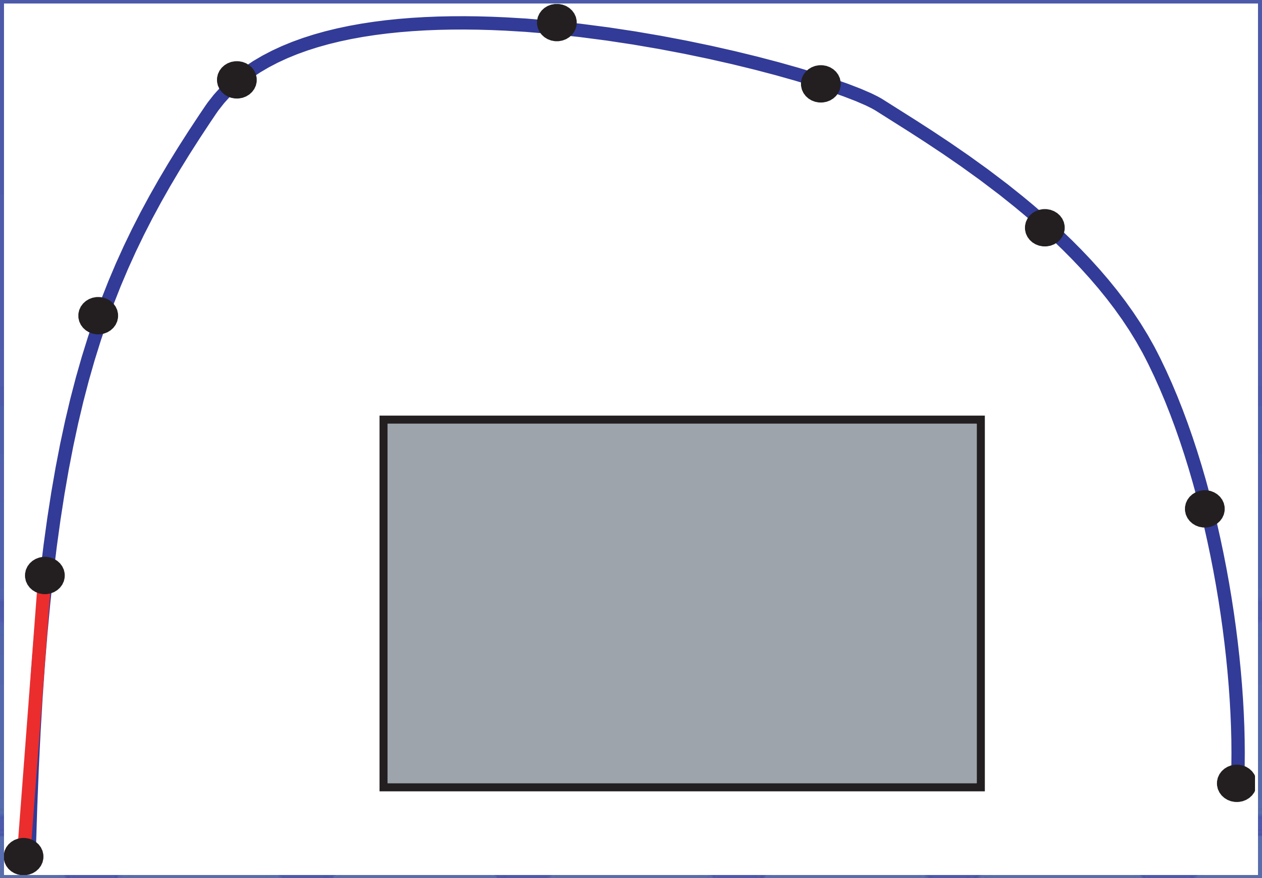
- Adjust Cord to given length, elasticity.

Cords Algorithm



Cords Algorithm



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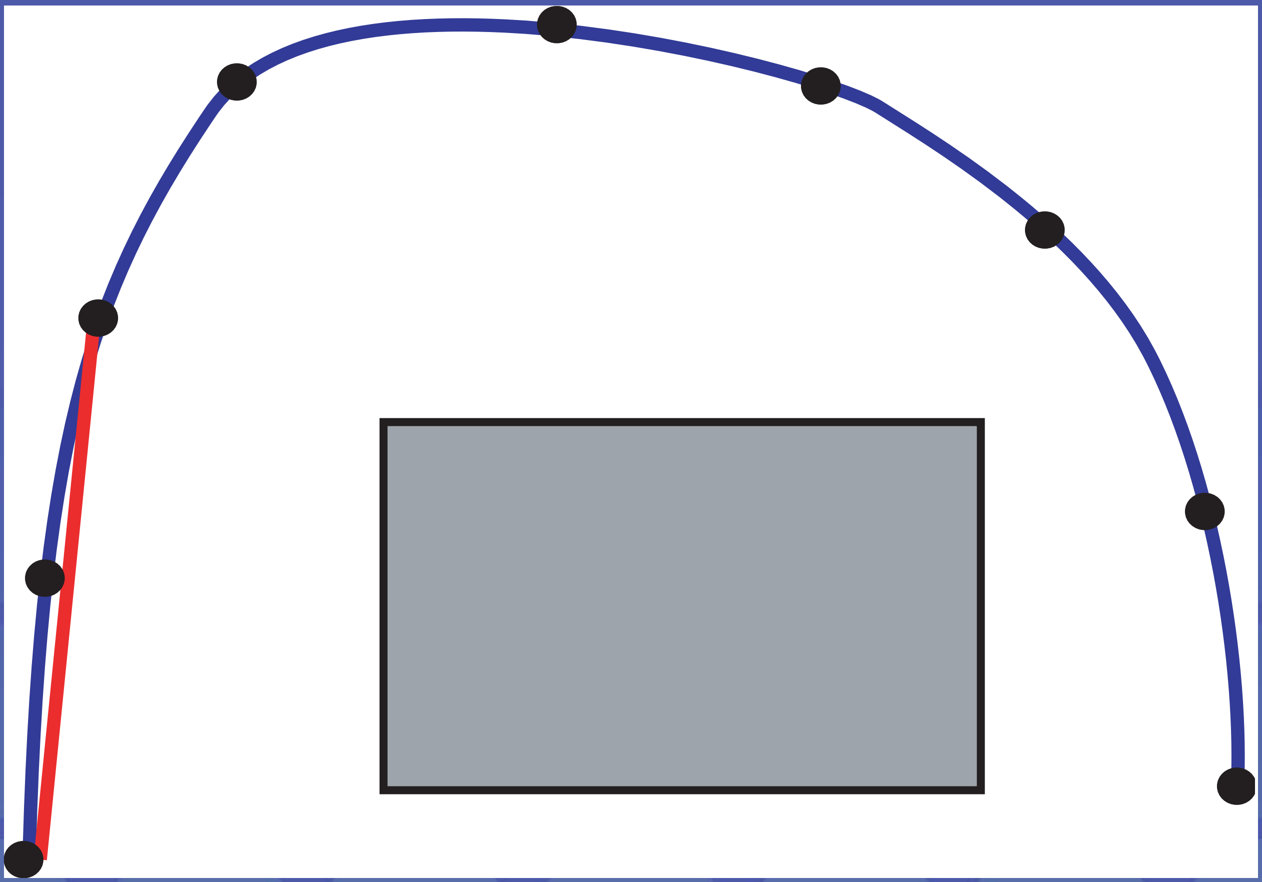

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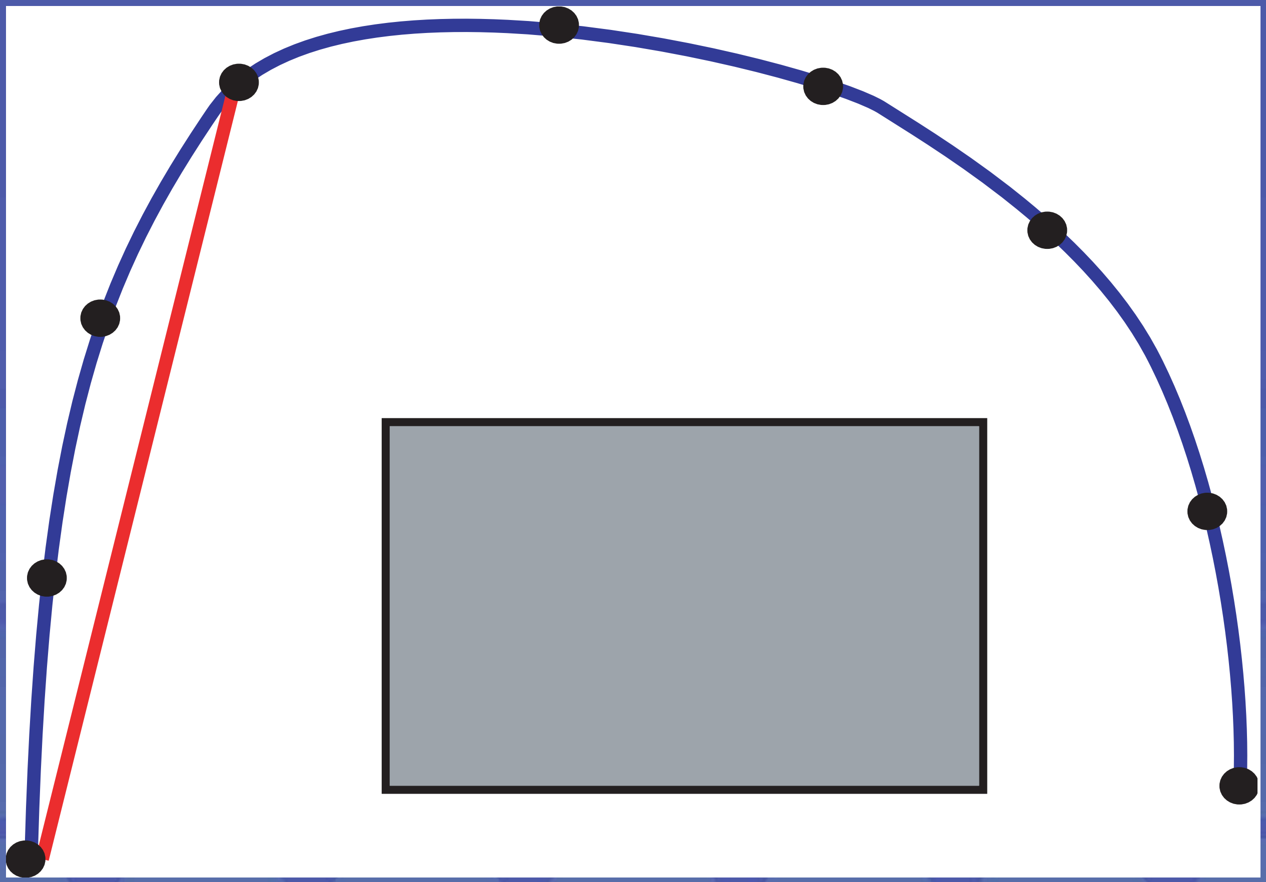

Cords Algorithm

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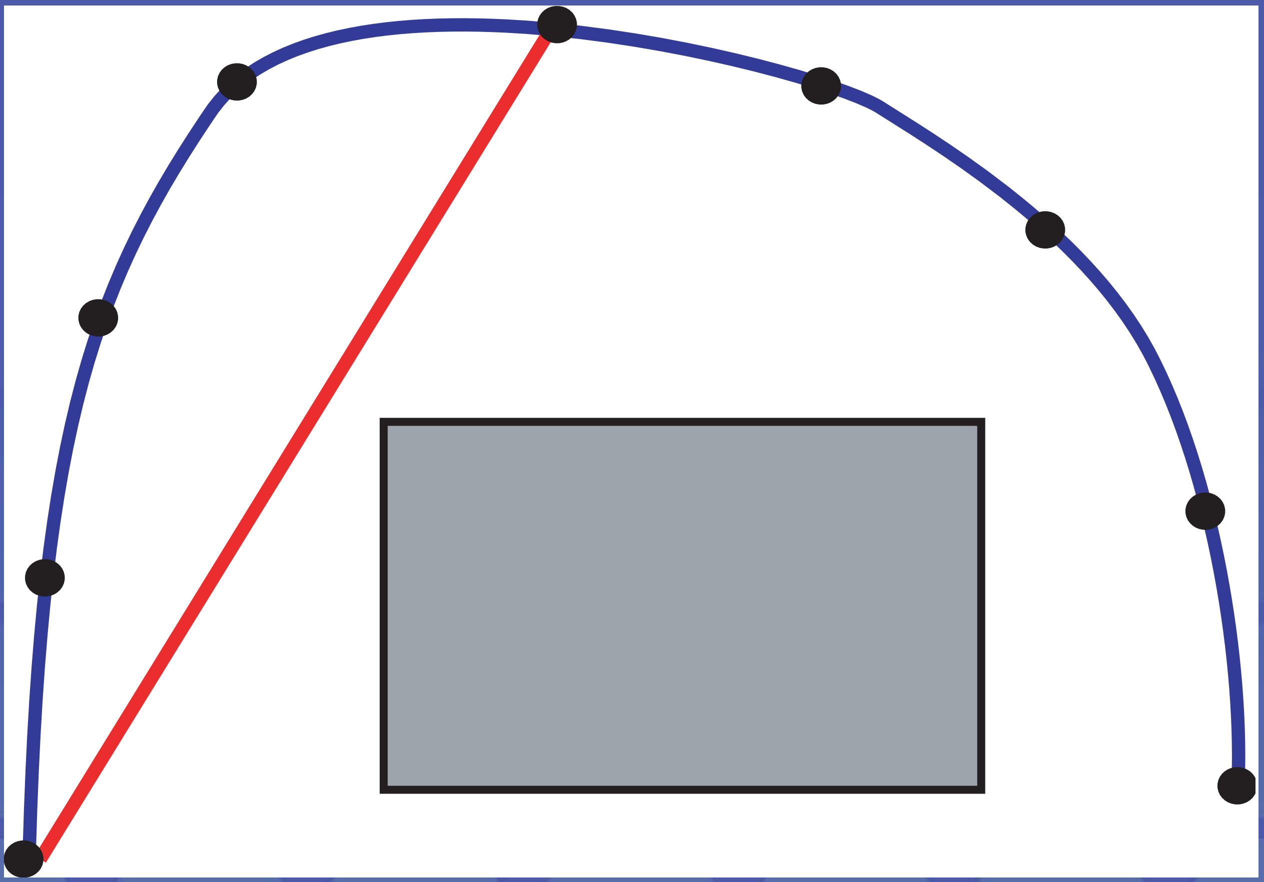

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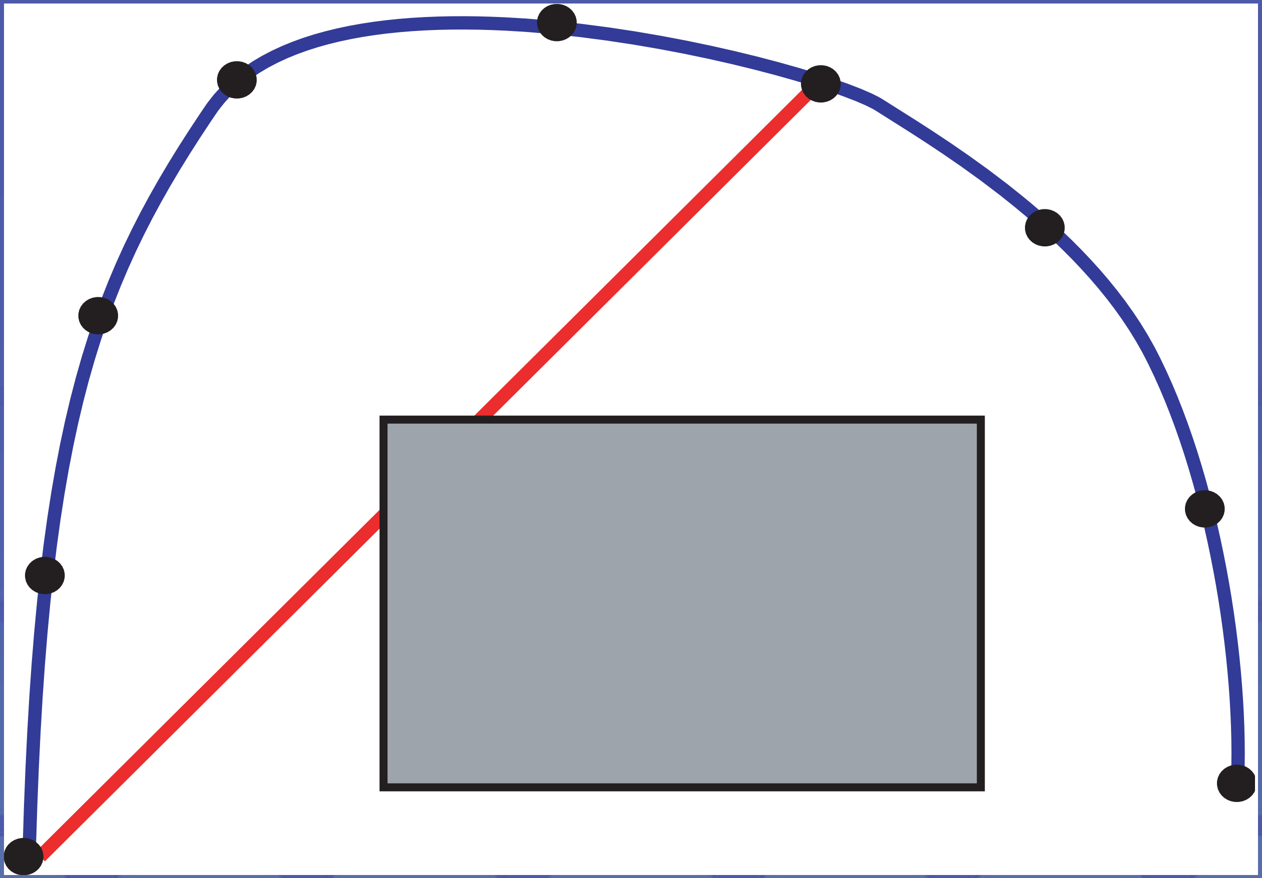

Cords Algorithm

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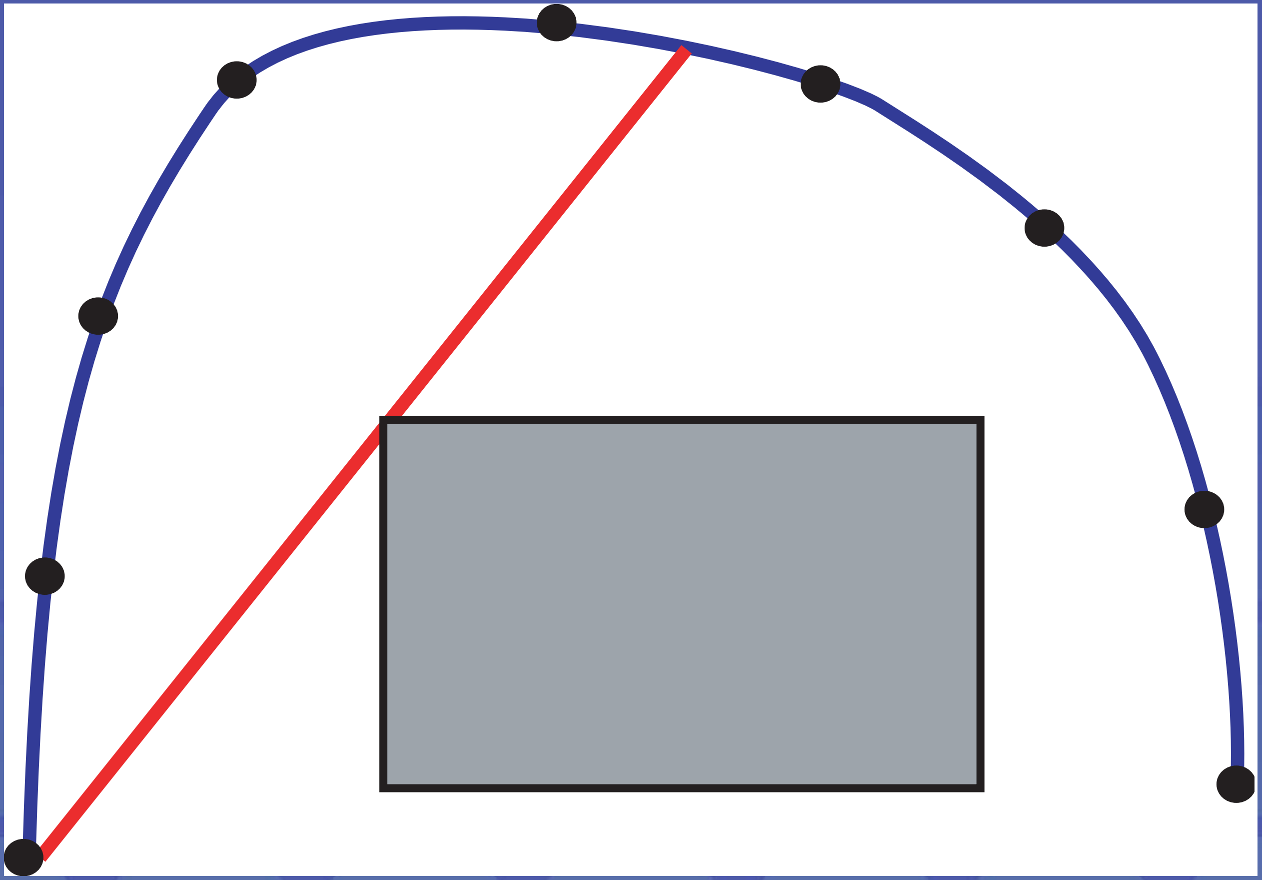

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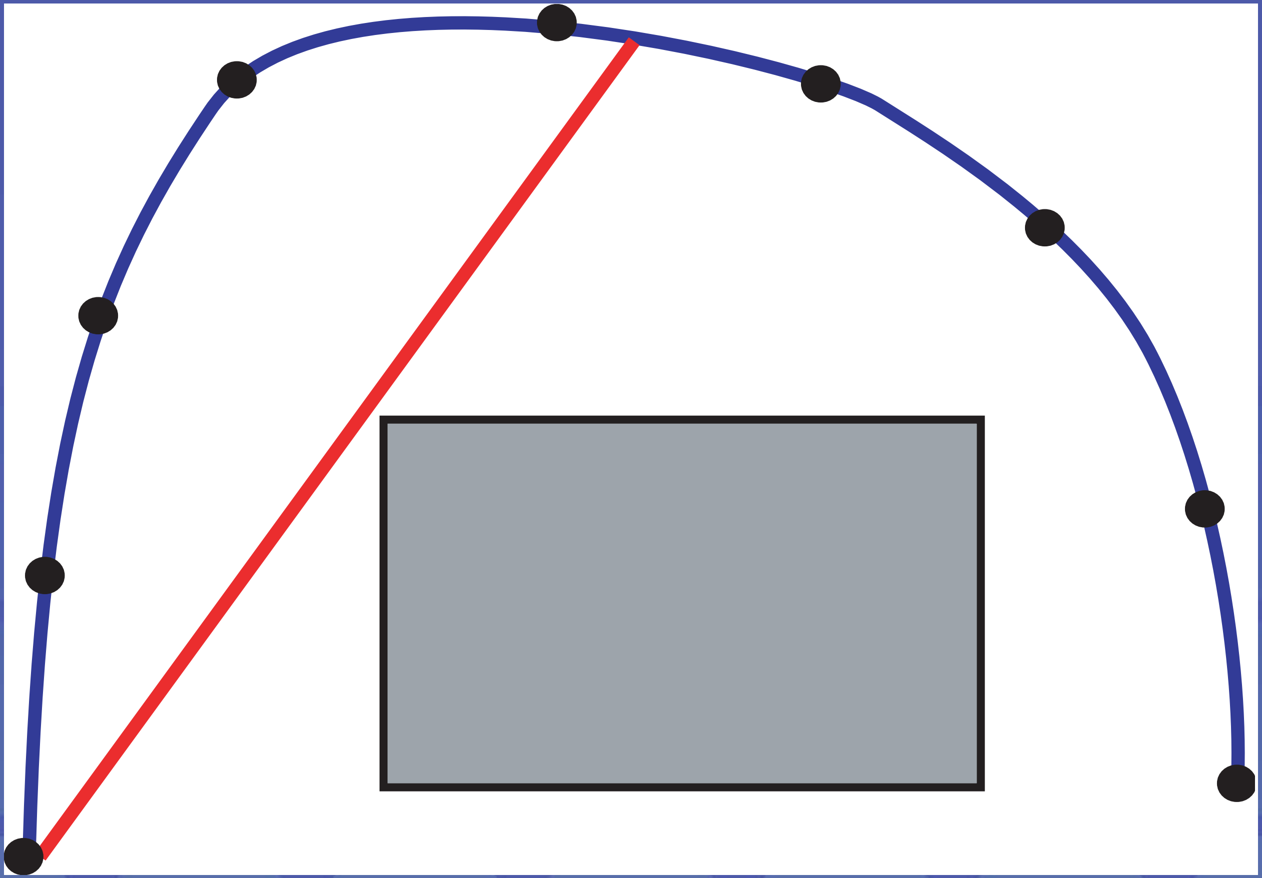

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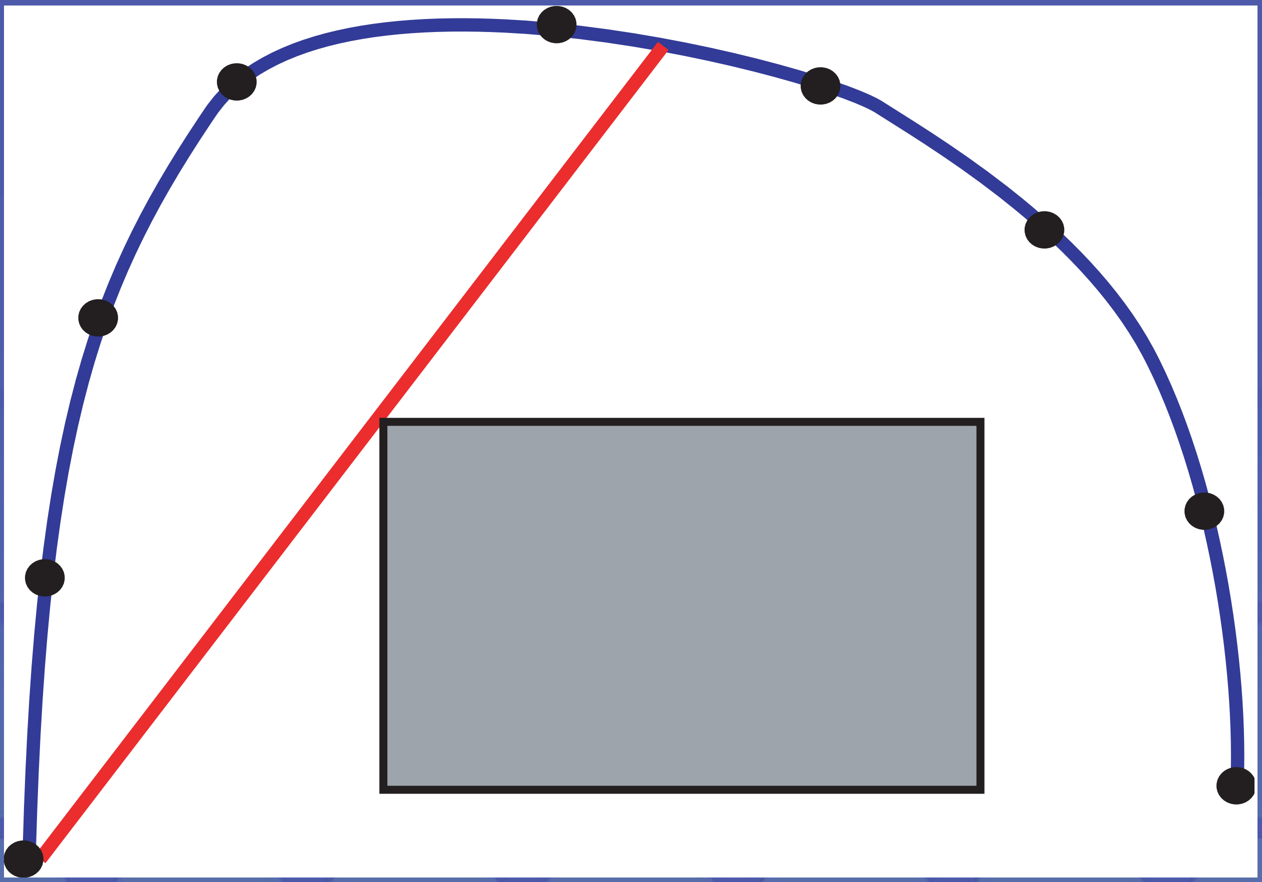

Cords Algorithm

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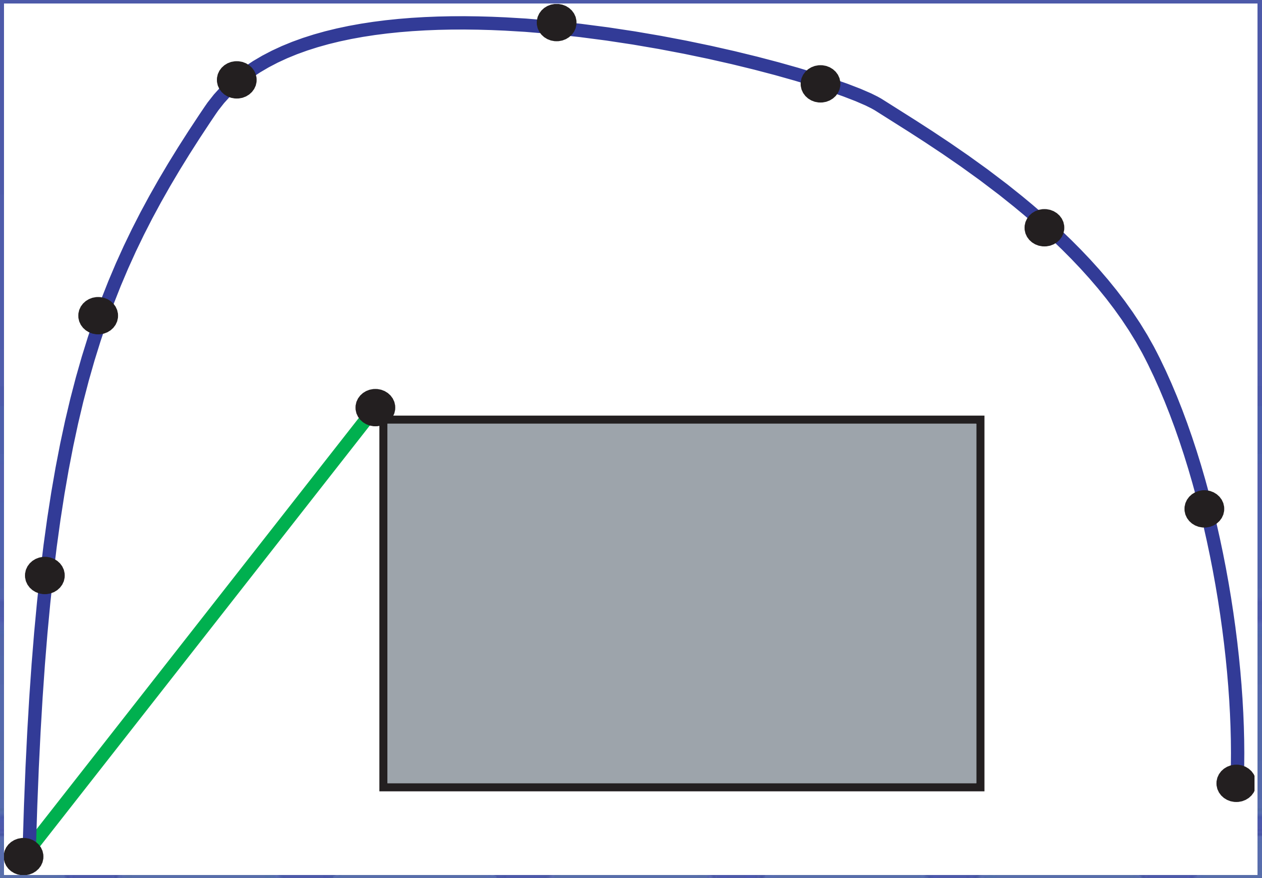

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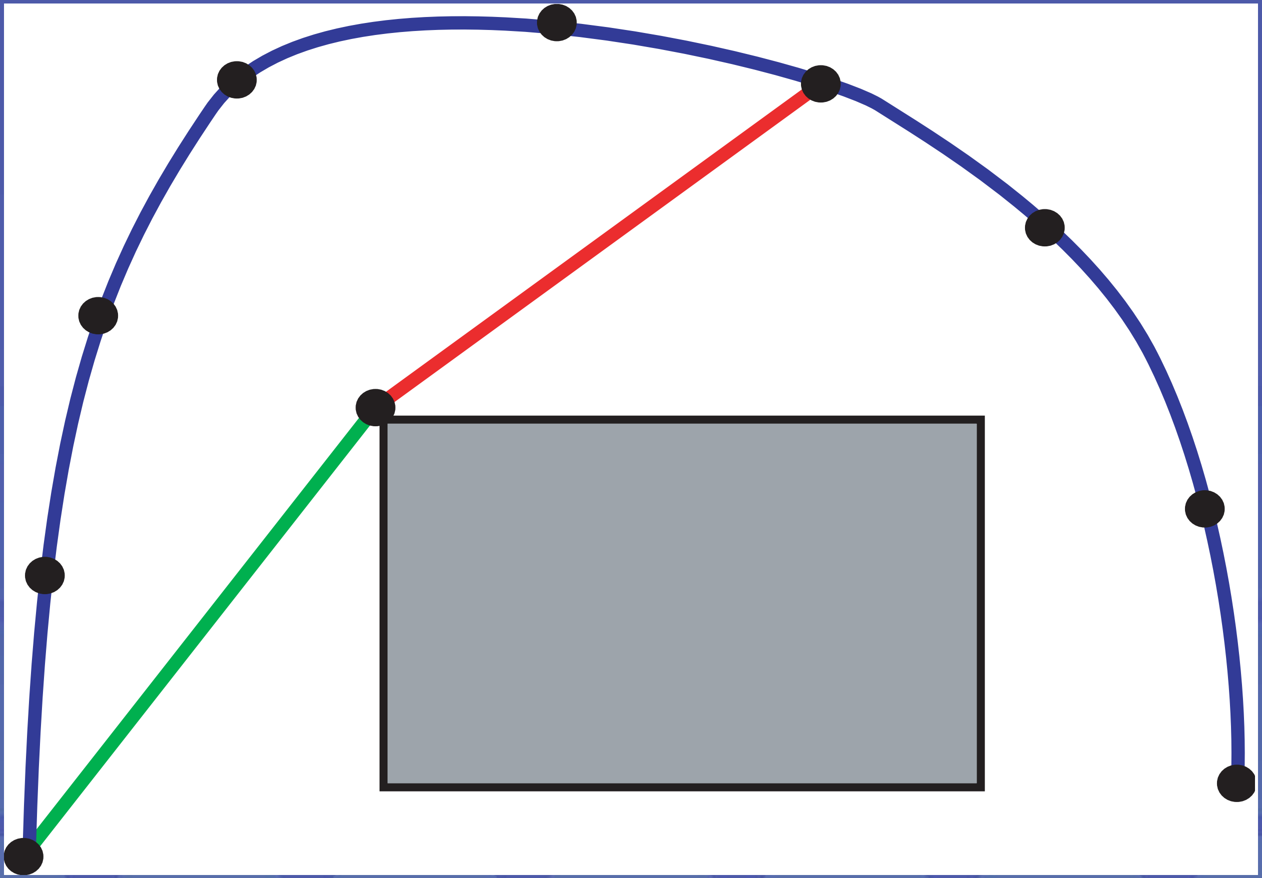

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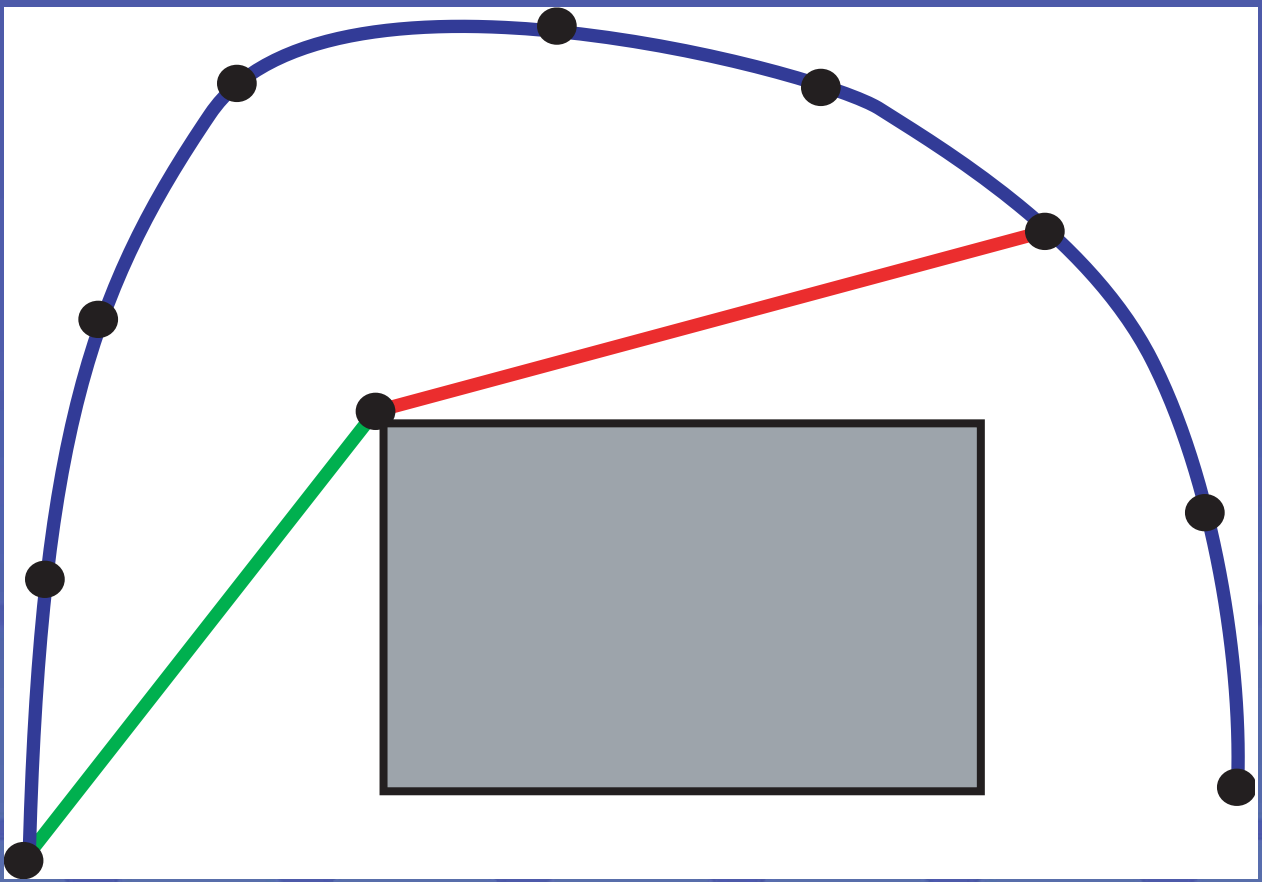

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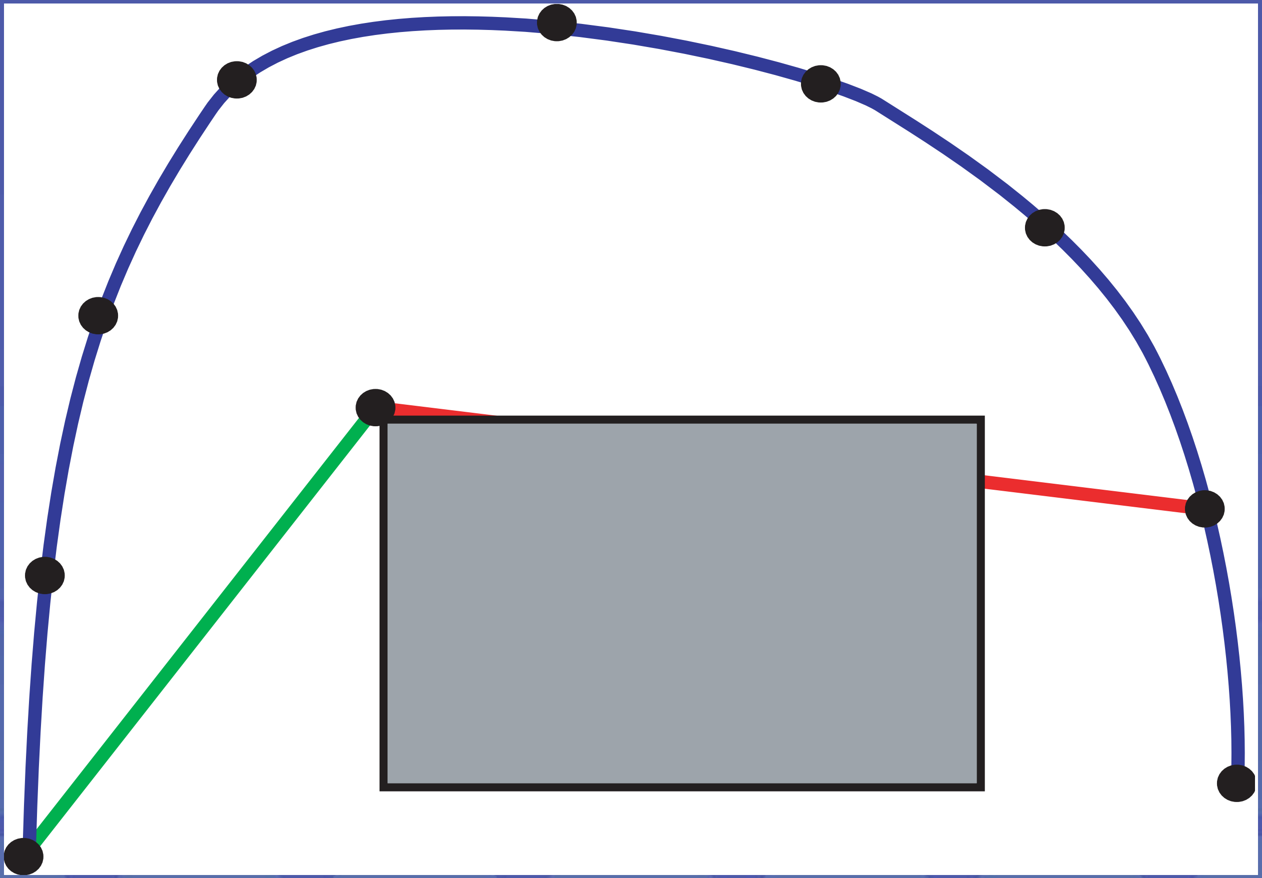

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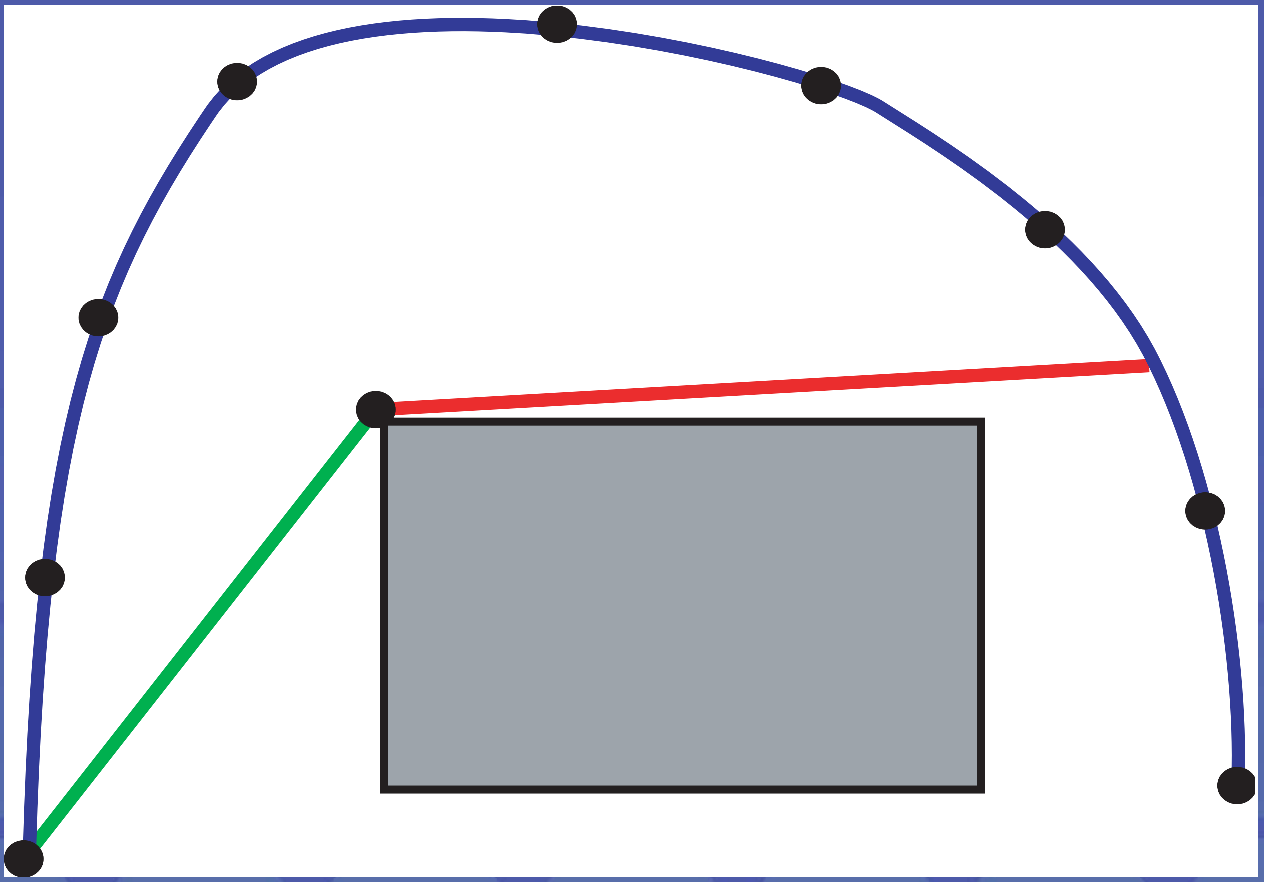

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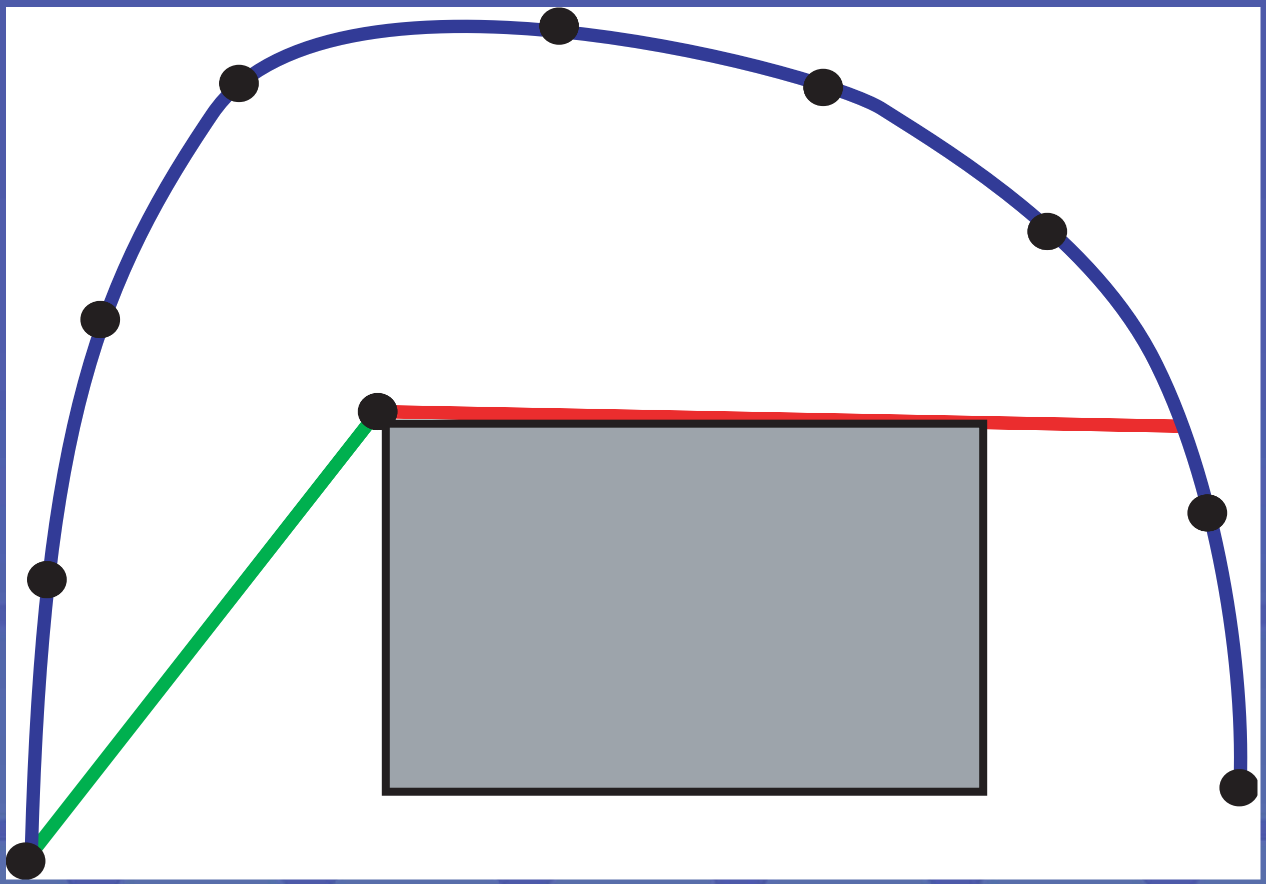

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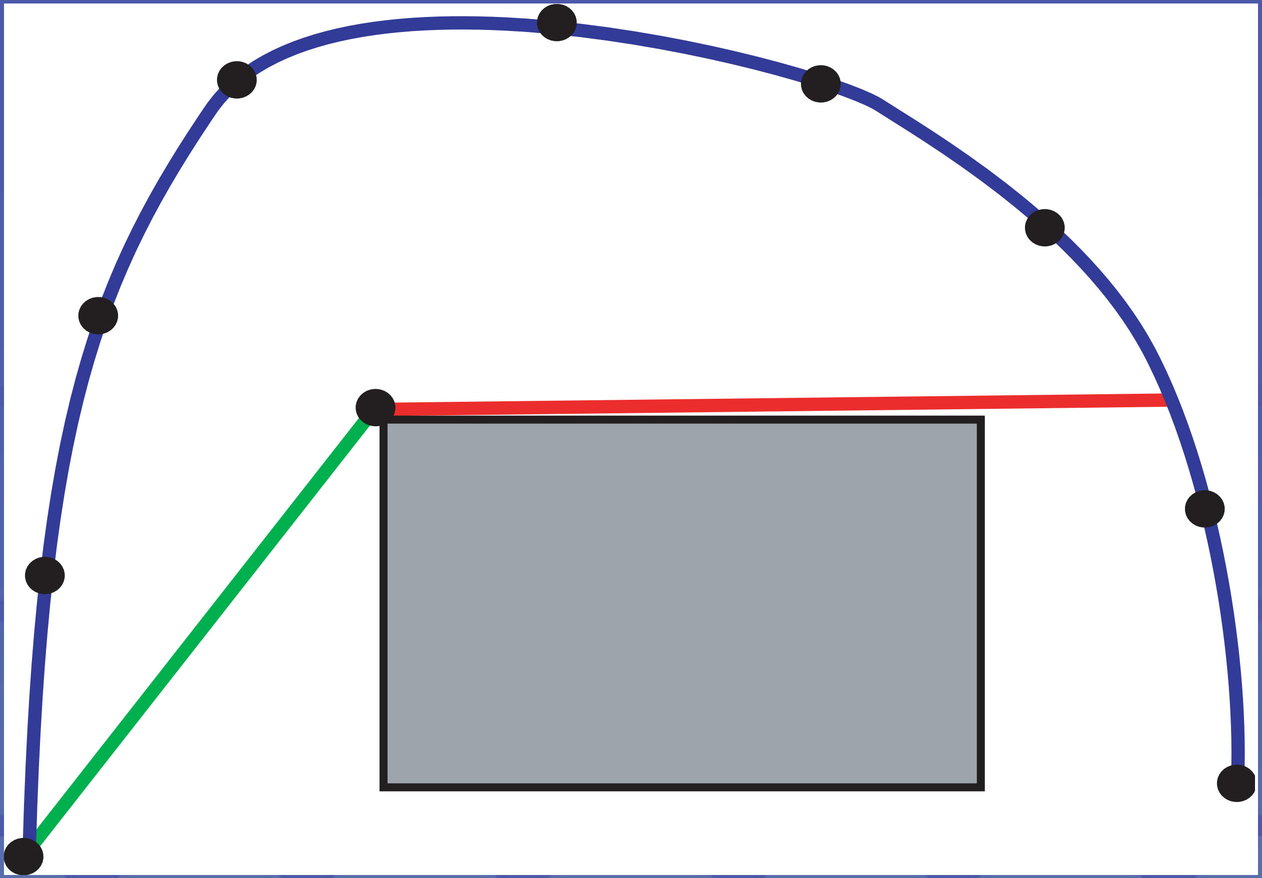

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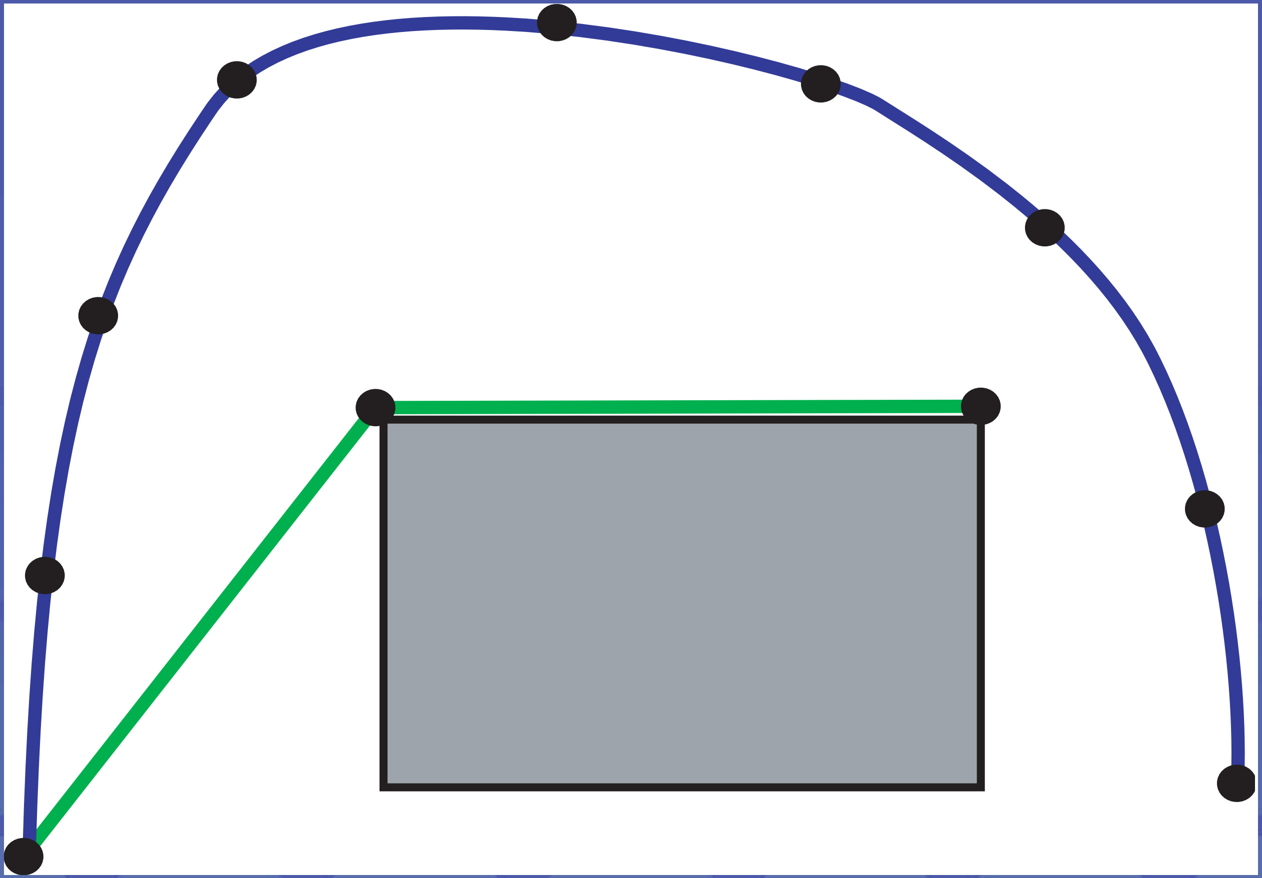

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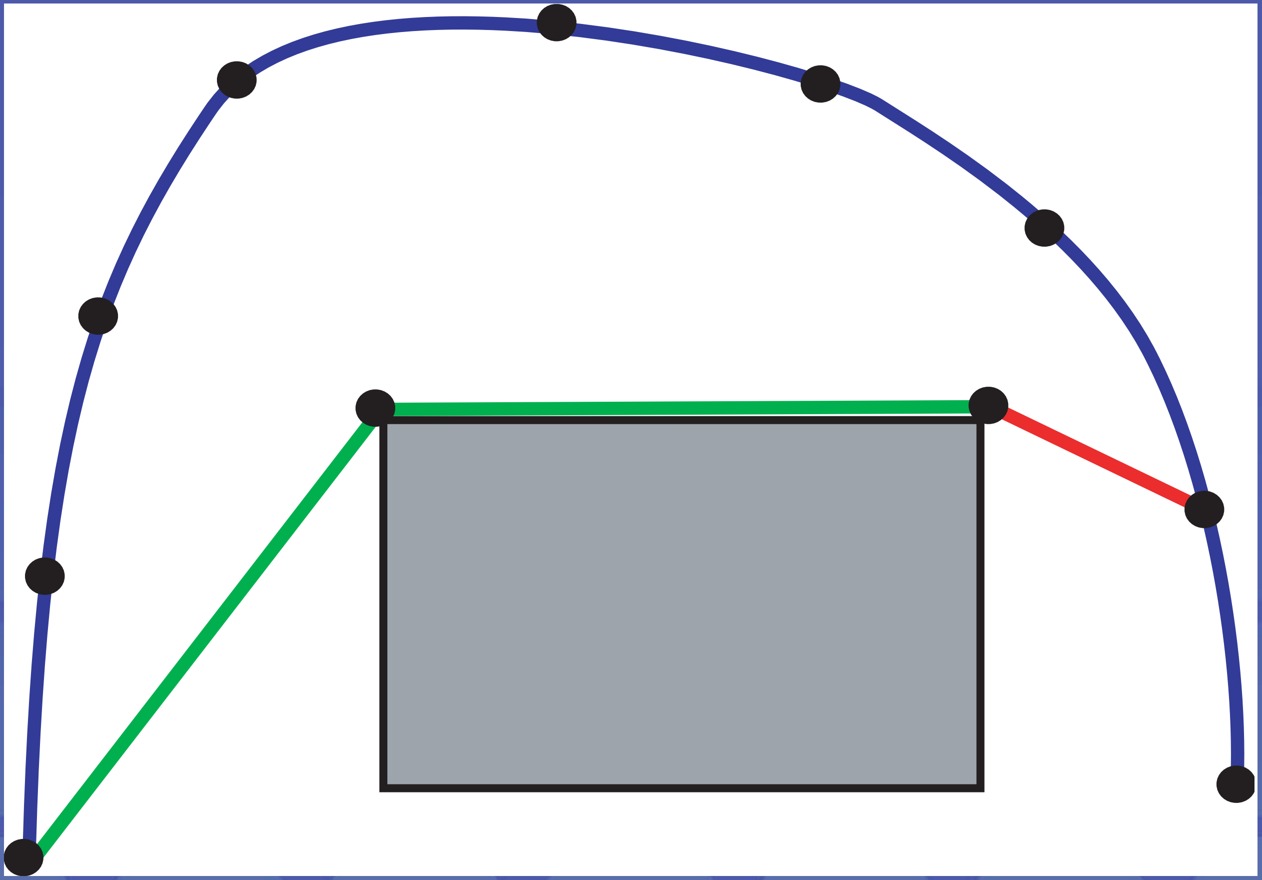

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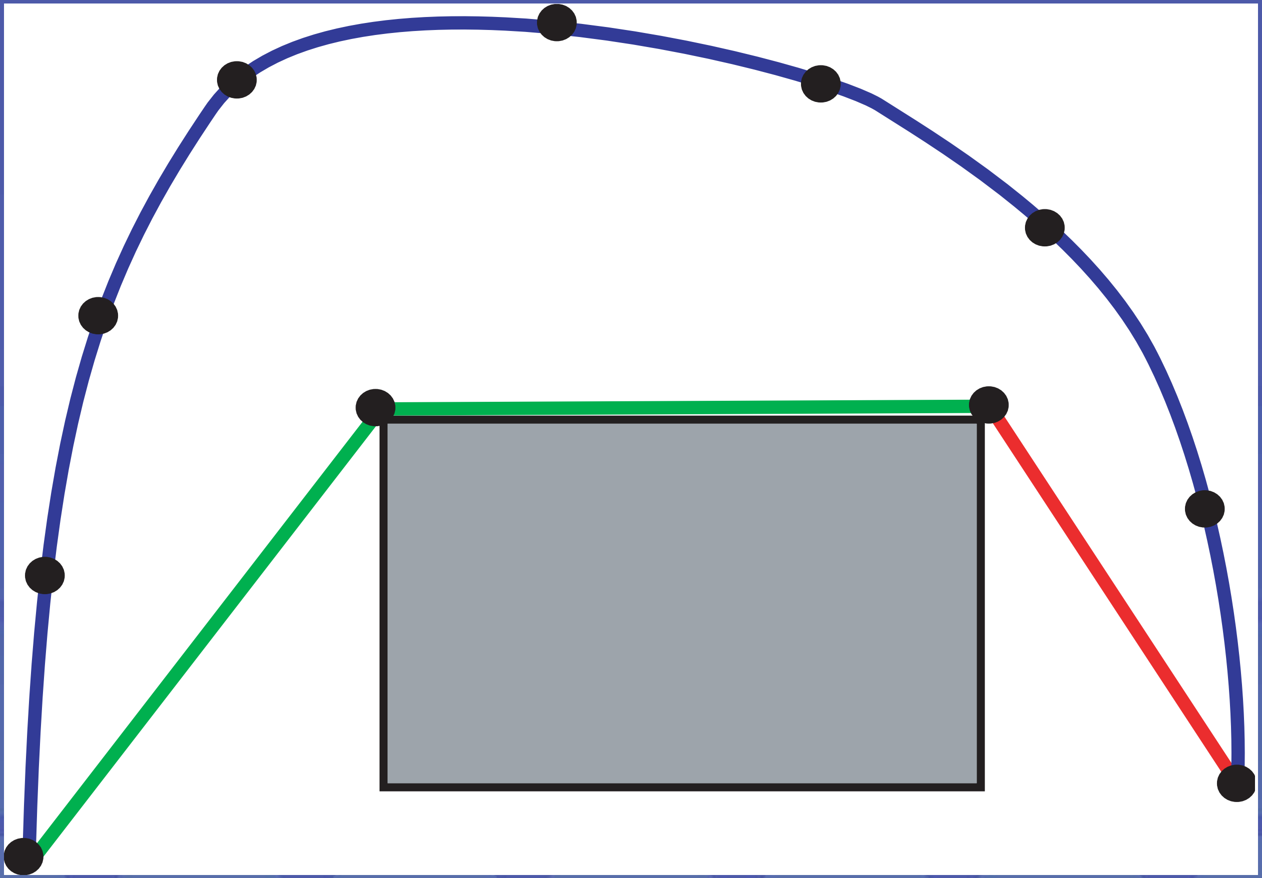

Cords Algorithm

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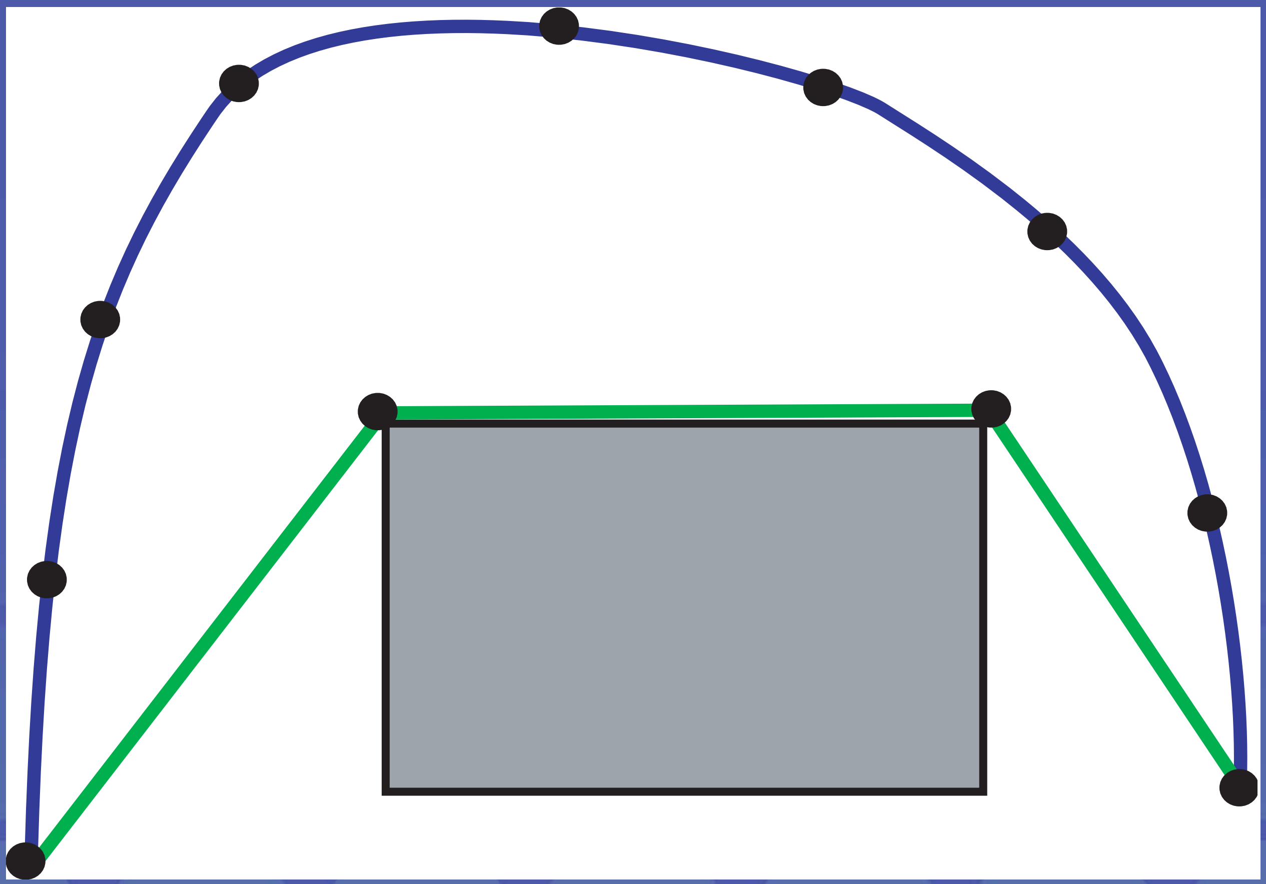

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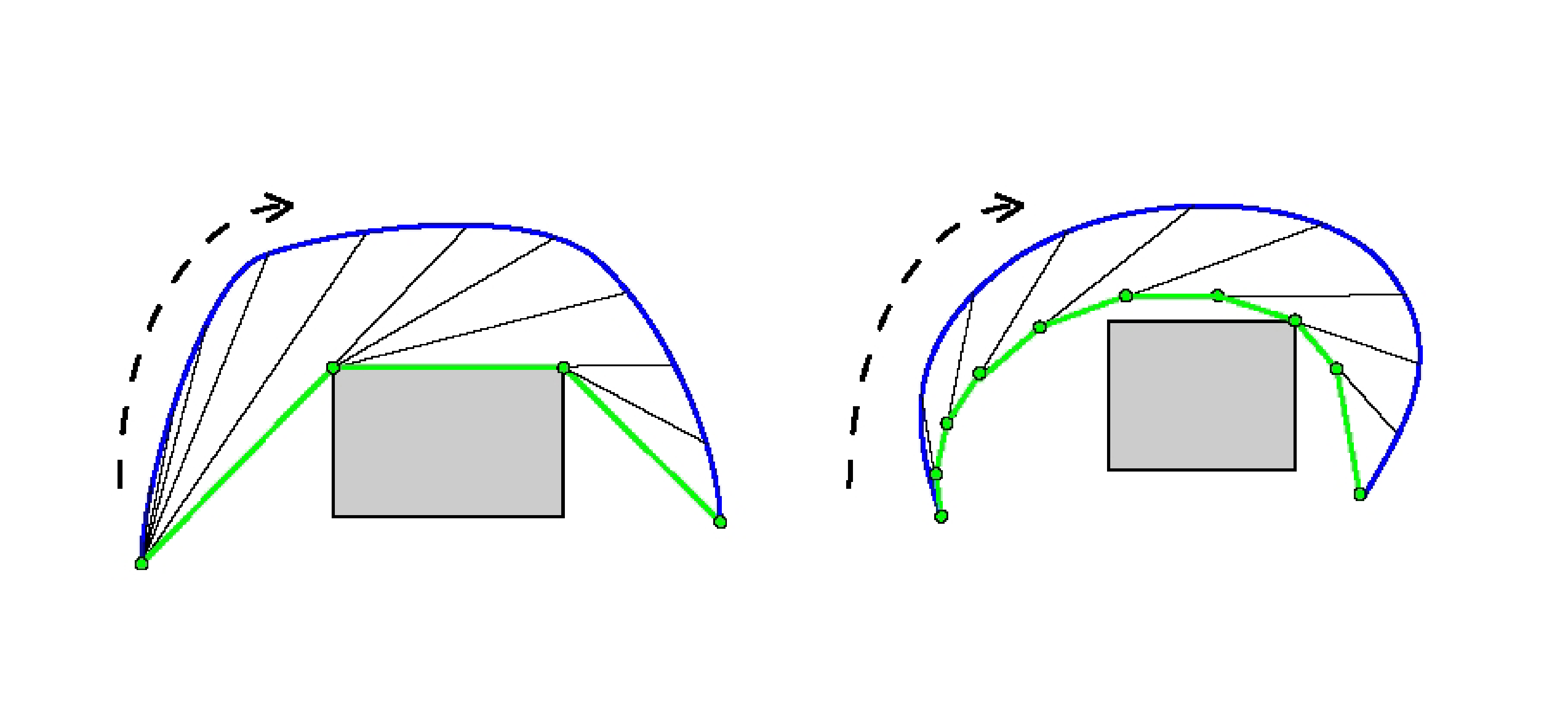

Cords Algorithm

- Adjust Cord to given length, elasticity:

  stretched length: length to reach f(1)

  elastic length: linear interpolation between length and stretched length

  if (elastic length < stretched length) clip cord

  else extend cord along final tangent

- Maintains continuous response to parameters

Cords Analysis

- Cords have a piecewise analytic form
  - Regions of "bending:" small linear steps
  - Longer straight regions when intersection found
- Notation for any region: p_0, p_1, p_2 …
  - First region: $p_0 = f(0)$

Cords Analysis

- We want the stiffness user parameter to be invariant to the guide curve step size Δt.
- $s = \text{stiffness} * \Delta t$ will accomplish this.
- stiffness = 0
  - No proportional steps
  - String-like appearance
- stiffness = 1
  - Linear approximation of guide curve
  - Bounds cord shape

Analytic Form

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Proportional step:

$$p_i = p_{i-1} + s * \left(f(i\Delta t) - p_{i-1}\right)$$

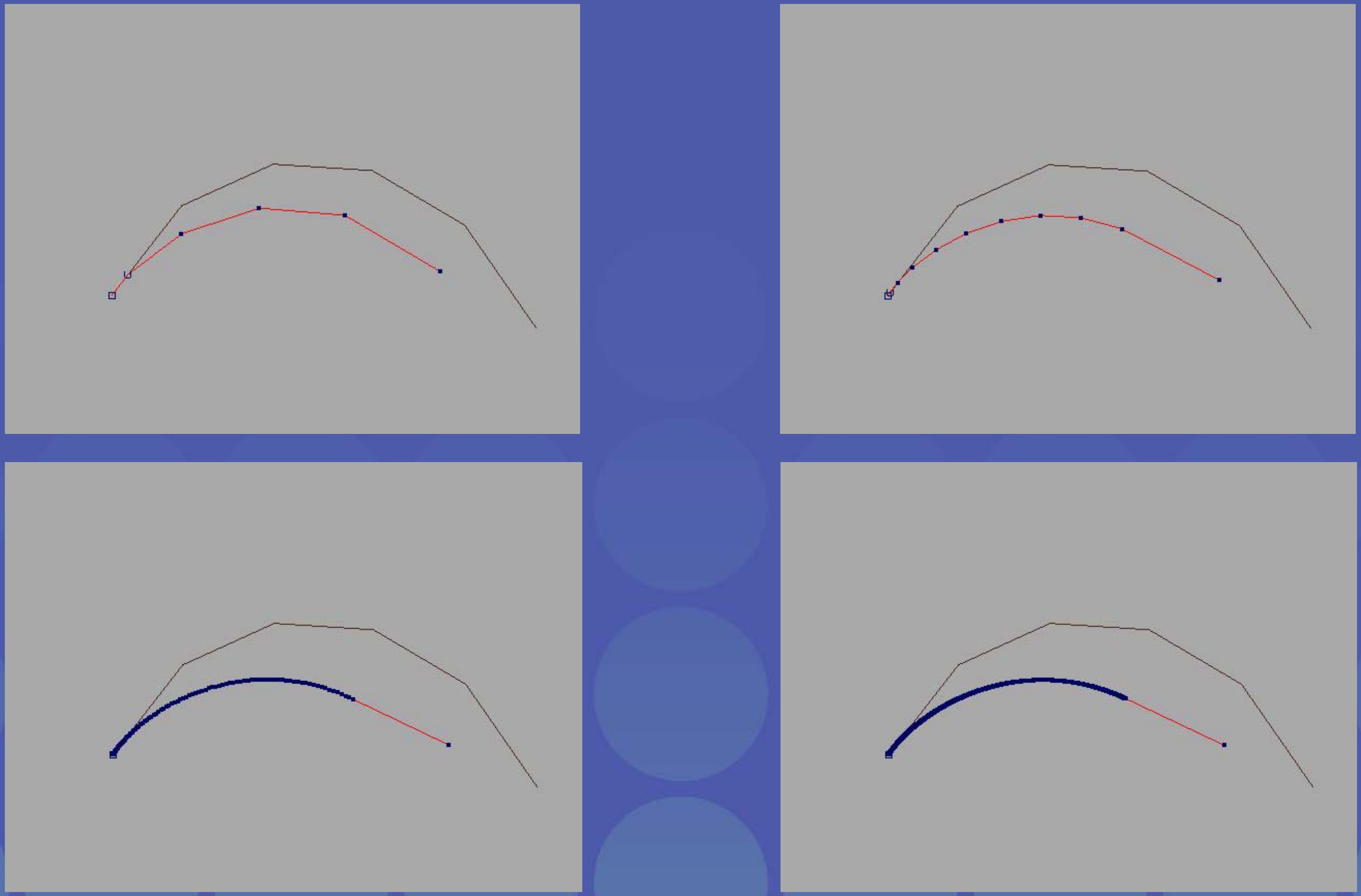
Recurrence relation:

$$p_m = (1-s)^m p_0 + s\sum_{i=1}^{m} f(i\Delta t)(1-s)^{m-i}$$

Analytic form as Δt → 0:

$$g(t) = e^{-at}p_0 + ae^{-at}\int_0^t f(x)e^{ax}dx$$

Invariance to Δt



Continuity

- G1 continuity at join points, when
  stiffness > 0

- Cord has continuity characteristics of guide curve along bending regions

Wide and Thick Cords

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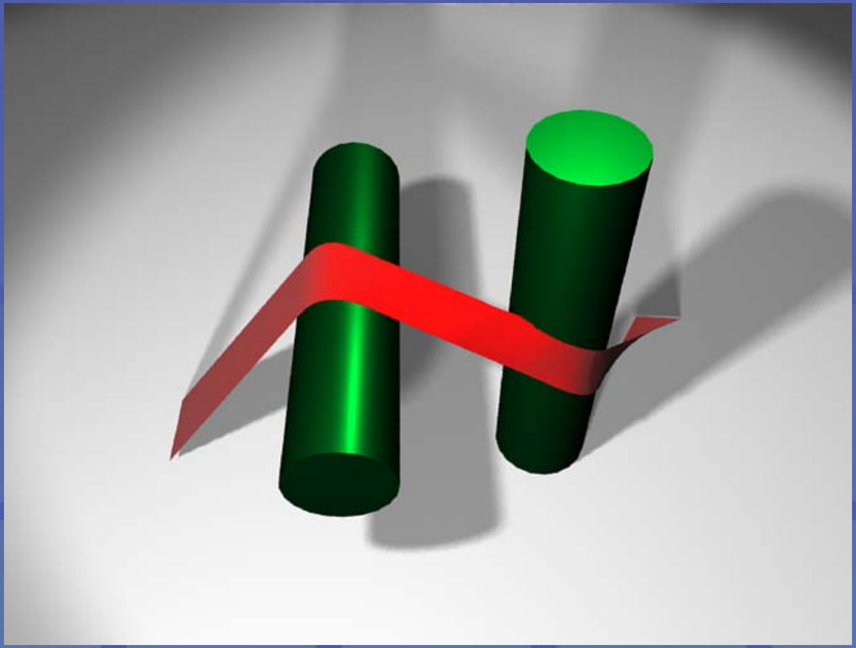
- Replace ray intersection with shape intersection
- Apply parameterized orientation



Ryan Larkin

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*

Psychorealism and *Ryan*

*

Cords in *Ryan*

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- Fit a cubic polynomial curve with uniform parameterization
- Attach paint effects brush strokes that procedurally generate hair effect
- Animators “grew” the hair as it wrapped around characters

Cords in *Ryan*

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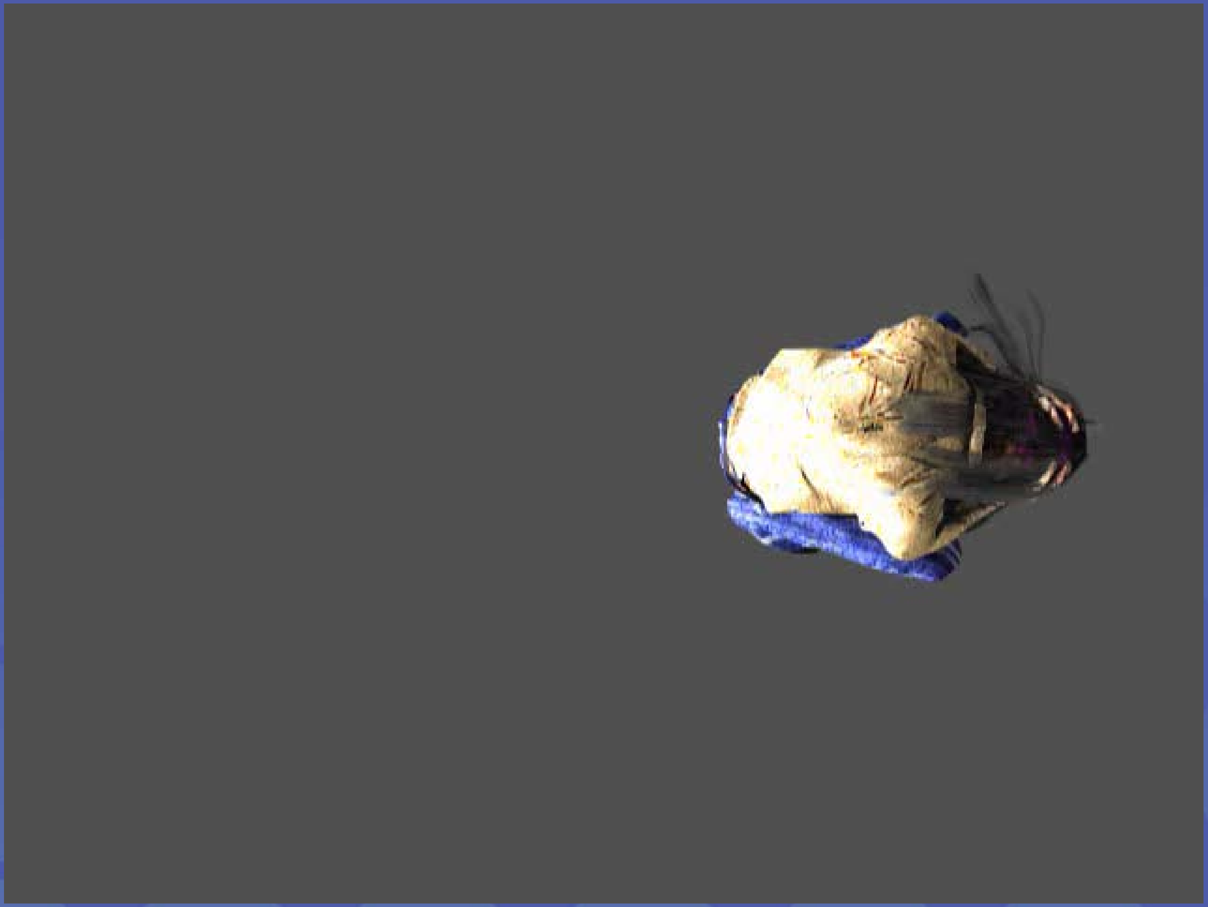
Cords in *Ryan*



Cords in *Ryan*

Cords in *Ryan*

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Conclusions

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- Interactive curve primitive with physical appearance properties
- Precise, analytic control for keyframe animation
- Bending and wrapping around 3D scene geometry

Future Work

- Generation algorithms incorporating the analytic form
- Higher order continuity along cord
- Surfaces
- Hybrid models incorporating simulation

More on *Ryan*

Special Electronic Theater Presentation

Chris Landreth, Director

Electronic Theater Hall K

Today, 4:00 pm

Open to all attendees

Acknowledgments

- Chris Landreth and the *Ryan* crew
- DGP Lab at the University of Toronto
- NFB Canada, Seneca College
- Alias, Pixar

More Information

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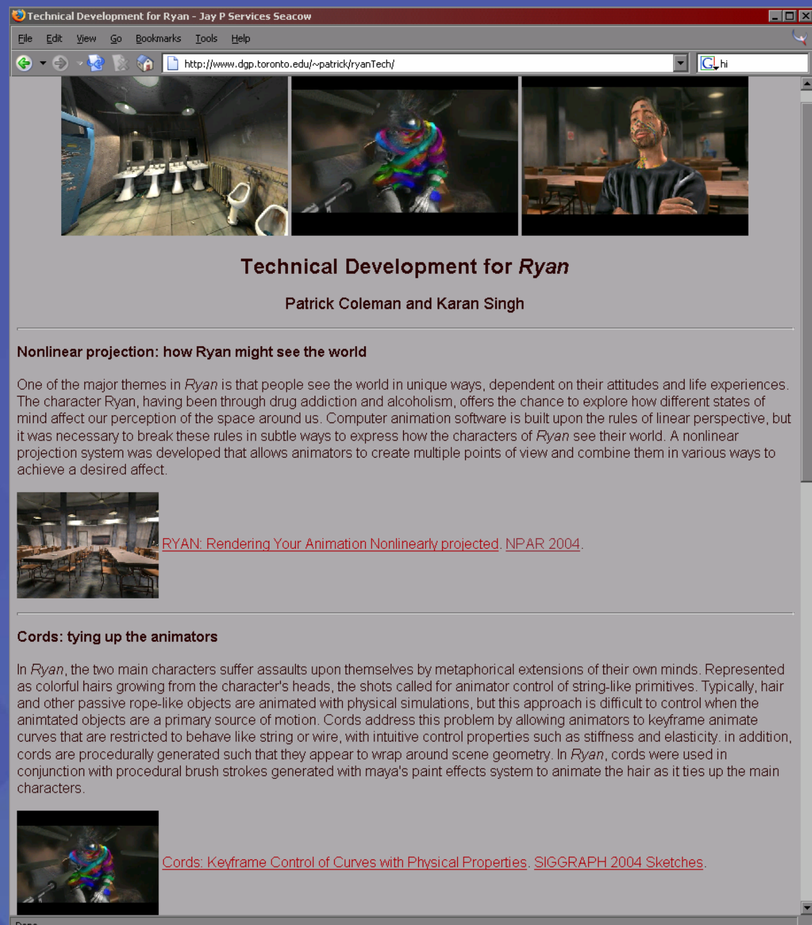
Technical Development for Ryan - Jay P Services Seacow

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http://www.dgp.toronto.edu/~patrick/ryanTech/

Technical Development for *Ryan*

Patrick Coleman and Karan Singh

Nonlinear projection: how Ryan might see the world

One of the major themes in *Ryan* is that people see the world in unique ways, dependent on their attitudes and life experiences. The character Ryan, having been through drug addiction and alcoholism, offers the chance to explore how different states of mind affect our perception of the space around us. Computer animation software is built upon the rules of linear perspective, but it was necessary to break these rules in subtle ways to express how the characters of *Ryan* see their world. A nonlinear projection system was developed that allows animators to create multiple points of view and combine them in various ways to achieve a desired affect.

RYAN: Rendering Your Animation Nonlinearly projected. NPAR 2004.

Cords: tying up the animators

In *Ryan*, the two main characters suffer assaults upon themselves by metaphorical extensions of their own minds. Represented as colorful hairs growing from the character's heads, the shots called for animator control of string-like primitives. Typically, hair and other passive rope-like objects are animated with physical simulations, but this approach is difficult to control when the animtated objects are a primary source of motion. Cords address this problem by allowing animators to keyframe animate curves that are restricted to behave like string or wire, with intuitive control properties such as stiffness and elasticity. in addition, cords are procedurally generated such that they appear to wrap around scene geometry. In *Ryan*, cords were used in conjunction with procedural brush strokes generated with maya's paint effects system to animate the hair as it ties up the main characters.

Cords: Keyframe Control of Curves with Physical Properties. SIGGRAPH 2004 Sketches.

Done

www.dgp.toronto.edu/~patrick/ryanTech