Computational Cinematography

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Administrivia

- Introductions
- Format
  - Film production pipeline
  - Theory
  - Tools
  - Implementation
- Expectations
- Assignments
- Grading
Background
Background

- Games becoming pervasive medium for a range of applications
- New modes of Entertainment, Education, Social Interaction, Training, Remote Collaboration, Medical Treatments and many other contexts
- With this increased use comes a demand for new methods of content creation
Background

- Games becoming pervasive medium for a range of applications
  - New modes of Entertainment, Education, Social Interaction, Training, Remote Collaboration, Medical Treatments and many other contexts
  - With this increased use comes a demand for new methods of content creation

- Procedural Content Generation (PCG): the automatic creation of novel game content
  - Dynamic scene geometry
  - Dynamic world states and game context
  - Personable and procedurally animated characters (e.g. Spore)
  - Procedurally generated narrative with complex narrative structures
Narrative-based PCG
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• When interaction within a game is automatically generated, the cinematics for the game cannot be pre-scripted
Narrative-based PCG

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  - Directorial and character goals
  - Character actions and plans
  - Dialog, background music, lighting
Narrative-based PCG

• When interaction within a game is automatically generated, the cinematics for the game cannot be pre-scripted

• Procedural generation of cinematics requires complex computational models
  • Directorial and character goals
  • Character actions and plans
  • Dialog, background music, lighting
  • Camera control, shot selection and sequencing
Automatic Generation of Cinematic Communication
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- Input story (sequence of actions and events) and scene geometry
Automatic Generation of Cinematic Communication

- Input story (sequence of actions and events) and scene geometry
- Exploit computational model of cinematic conventions and communication
Automatic Generation of Cinematic Communication

• Input story (sequence of actions and events) and scene geometry

• Exploit computational model of cinematic conventions and communication

• Generate shot sequences designed to effectively convey the unfolding storyline
Example

Setting: WestWorld
Protagonist: Lazarus Lane (Cowboy, Thug)
Goal: Communicate the story of Lazarus Lane robbing the Lincoln County Bank
Example

Setting: WestWorld
Protagonist: Lazarus Lane (Cowboy, Thug)
Goal: Communicate the story of Lazarus Lane robbing the Lincoln County Bank

[1] Lane walks in the bar
[2] Lane looks at the bartender
[3] Lane threatens the bartender with a gun
[4] The threatens bartender gave Lane the machete
[5] Lane goes to the bank
[6] Lane looks at the teller
[7] Lane bribes the teller with machete
[8] The bribed teller gives Lane gold from the vault
Viz. 1: Overview Shot
Viz. 2: Following the actor

You better give that to me if you want to live.

Please don’t hurt me. Here take this Machete, just let me go.

Please don’t hurt me. Here take this Machete, just let me go.
Outline

• Related Work
• Problem and Solution
  • Desired Properties
  • Representation
  • Reasoning algorithm
  • Execution Environment
• Evaluation
• Contributions
• Future Work
Procedurally generated story and cinematics

WestWorld Demo
Liquid Narrative Group
February 08
Motivation
Motivation
Motivation

Dawn breaks, waves pounding the vast empty beach.

**LE** - Making his way amongst the tide line of flotsam and jetsam is a **BEACHCOMBER**, clad in scruffy shorts, battered sand shoes and a threadbare shirt.

He stops, eyes scanning amongst the rubbish and stoops.

**BEACHCOMBER**

**MO** - He holds up what looks to be a bottle. He turns it over in his hands, holds it to his ear and shakes it - listening. Tentatively he tries the cork. It is stuck.

He pulls hard on the cork using the full force of his wiry frame. **GRRRRRR!** No luck. Exasperated he bites the cork between his teeth and pulls. **HUUUGGGHHH! POP!**

He flies back, the cork arcs through the sky. The bottle falls to the sand.

Picking himself up he takes the bottle between his hands. Smoke begins to pour from its neck.
Motivation

DAY - BEACH - DAY

Dawn breaks, waves pounding the vast empty beach.

L - Making his way amongst the tide line of flotsam and jetsam is a BEACHCOMBER, clad in scruffy shorts, battered sand shoes and a threadbare shirt.

He stops, eyes something amongst the rubbish and stoops.

BEACHCOMBER

MS - He holds up what looks to be a bottle. He turns it over in his hands, holds it to his ear and shakes it - listening.

Tentatively he tries the cork. It is stuck.

He pulls hard on the cork using the full force of his wiry frame.

EVERYTHING! No luck. Exasperated he bites the cork between his teeth and pulls. SPLASHHHH! POP!

He flies back, the cork arcs through the sky. The bottle falls to the sand.

Picking himself up he takes the bottle between his hands.

Smoke begins to pour from its neck.

CUT TO..
Motivation

DAY: BEACH - DAY

Dawn breaks, waves pounding the vast empty beach.

L.J. - Making his way amongst the tide line of flotsam and jetsam is a BEACHCOMBER, clad in scuffed shorts, battered sand shoes and a threadbare shirt.

He stops, eyes searching amongst the rubbish and stoops.

BEACHCOMBER

MS - He holds up what looks to be a bottle. He turns it over in his hands, holds it to his ear and shakes it - listening. Tentatively he tries the cork. It is stuck.

He pulls hard on the cork using the full force of his wiry frame. EYEBROWS! No luck. Exasperated he bites the cork between his teeth and pulls. SWINGGGGG! POP!

He flies back, the cork arcs through the sky. The bottle falls to the sand.

Picking himself up he takes the bottle between his hands.

Smoke begins to pour from its neck.

CUT TO:

Tuesday, October 1, 13
Motivation

Dawn breaks, waves pounding the vast empty beach.

**LJ** - Making his way amongst the tide line of flotsam and jetsam is a BEACHCOMBER, clad in scruffy shorts, battered sand shoes and a threadbare shirt.

He stoops, eyes something amongst the rubbish and stoops.

**BEACHCOMBER**

**NO**

MS - He holds up what looks to be a bottle. He turns it over in his hands, holds it to his ear and shakes it - listening. Tentatively he tries the cork. It is stuck.

He pulls hard on the cork using the full force of his wiry frame.

**EVERGEE!!** No luck. Exasperated he bites the cork between his teeth and pulls. **ARGHARH!! POP!!**

He flies back, the cork arcs through the sky. The bottle falls to the sand.

Picking himself up he takes the bottle between his hands.

Smoke begins to pour from its neck.

CUT TO:

**?**
Motivation
Problem Statement

Given,

1. a story
   • set of actions
   • causal and temporal relationships between actions

2. a set of communicative goals

construct a schedule of camera shots

such that the resulting visualization

• is coherent
• comprehensible
• follows acceptable cinematic conventions
Related Work
### Related Work

#### Geometric Camera Placement
- Occlusion free camera view
- Determination of camera parameters to satisfy user specified geometric constraints

#### Linguistics
- Syntactic constraints on generation
- Discourse relations in multi-sentential text
- Communicative acts

#### Film Theory
- Cinematic Idioms

#### Narrative Theory
- Dramatic Patterns
- Narrative Comprehension
# Related Work

## Geometric Camera Placement
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Related work: Geometry-based camera placement

Goal: Procedural camera placement in 3D environments to satisfy user specified constraints

Previous Approaches:

- Visual primitives [Drucker et al. 94]
- Film Idioms [He li wei et al. 96]
- Constraint Solver [Bares, Lester 97]
- Genetic Algorithms [Halper, Olivier 01]
- Neural Networks [Hornung 03]
Related Work: Geometry-based camera placement
Related Work: Geometry-based camera placement

(a) View of two subjects featuring occlusion-avoidance
(b) Overview with one inset and color-coded highlights
(c) Overview with two multi-shot insets
(d) Overview and inset of cop but cut of multi-shot of bank
Related Work
## Related Work

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Related Work: Discourse Generation

Goal: Generation of coherent multi-sentential text for satisfying communicative goals

Previous Approaches:

Theory of Discourse Structure [Grosz et al. 86]
Rhetorical Structure Theory [Mann et al. 87]
Planning approaches [Moore and Paris 89, Maybury 92, Hovy 93]
Related Work: Discourse Generation

Goal: Generation of coherent multi-sentential text for satisfying communicative goals

Previous Approaches:

Theory of Discourse Structure [Grosz et al. 86]
Rhetorical Structure Theory [Mann et al. 87]
Planning approaches [Moore and Paris 89, Maybury 92, Hovy 93]

**Communicative act** (Discourse action): Intentional linguistic action executed to manipulate beliefs of the hearer (Inform, Command, Request, Ask)
Related Work
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Desired Solution Properties

- Selection of Salient Elements
  - Discourse action should select elements of the story that best achieve communicative goals
Desired Solution Properties

- **Selection of Salient Elements**
  - Discourse action should select elements of the story that best achieve communicative goals

- **Coherence**
  - Discourse actions collectively communicate the story such that viewers are able to identify relationships between story and discourse actions
Desired Solution Properties

• **Selection of Salient Elements**
  - Discourse action should select elements of the story that best achieve communicative goals

• **Coherence**
  - Discourse actions collectively communicate the story such that viewers are able to identify relationships between story and discourse actions

• **Consistency**
  - Discourse actions do not introduce causal or temporal inconsistencies
Darshak’s Approach

- Operator Library
- Story Plan
- Communicative Goals

Discourse Planning Algorithm

- Story+Camera Plan

Execution Manager (Game Engine) - Constraint Solver

Viewer
Darshak’s Approach

Representation

Narrative Patterns
Camera placement idioms

Diagram:
- Discourse Planning Algorithm
  - Operator Library
  - Story Plan
  - Communicative Goals
- Story+Camera Plan
- Execution Manager (Game Engine)
- Constraint Solver
- Viewer
Darshak’s Approach

Representation

Narrative Patterns
Camera placement idioms

Reasoning

Hierarchical Planning
Temporal Scheduling
Darshak’s Approach

Representation
   - Narrative Patterns
   - Camera placement idioms

Reasoning
   - Hierarchical Planning
   - Temporal Scheduling

Execution
   - Procedural Action Classes
   - Execution Management
Why Planning?

- Automatic generation of action sequences to achieve specified goals

- Action Operators: Primitive and Abstract

- Relationships between actions:
  - Causal: Preconditions and Effects
  - Hierarchical: Decomposition

- Constraints: Object constraints and temporal ordering constraints
Representation: Cinematic Discourse

- Narrative Patterns
- Episodes/Scenes
- Primitive Operators
Narrative Patterns

Abstract Narrative Patterns serve to:

- Guide the flow of narrative
- Verify plot consistency
- Exploit viewer’s familiarity with idioms
Background
Narrative Theory

- Story and Discourse [Chatman]
- Story Structure
  - Story Grammars [Propp]
  - Dramatic patterns in narrative [Polti]
- Narrative Comprehension
  - Discourse Comprehension [vanDijk]
  - Film comprehension [Branigan]
Scenes/Episodes

Episode operators:

• Represent complex idioms

• Guide the selection of individual shot parameters

**Decomposition:** Conversation

:parameters - ?c, ?dir

:constraints ((conversation ?c) (conv-steps ?c ?slist))

:tconstraints ((starts-at ?T_s (start (first ?slist))))

:steps

  step1: (apex-shot ?c ?dir))

  forall ?step in ?slist

  step2: (film-dialog ?step ?dir)

:orderings ((step1 step2))

:rewrites (BEL V (Occurs ?c))

  forall ?step in ?slist

  (BEL V (Occurs ?step))
Scenes/Episodes

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**Decomposition:** Conversation

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- **T-Constraints:** ((starts-at ?T_s (start (first ?slist)))

**Steps**

step1: (apex-shot ?c ?dir))

for all ?step in ?slist

step2: (film-dialog ?step ?dir)

**Orderings:** ((step1 step2))

**Rewrites**

(BEL V (Occurs ?c))

for all ?step in ?slist

(BEL V (Occurs ?step))
Scenes/Episodes

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Tuesday, October 1, 13
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Decomposition: Conversation

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:constraints (((conversation ?c) (conv-steps ?c ?slist)))
:tconstraints ((starts-at ?T (start (first ?slist))))
:steps
  step1: (apex-shot ?c ?dir))
  forall ?step in ?slist
  step2: (film-dialog ?step ?dir)
:orderings ((step1 step2))
:rewrites (BEL V (Occurs ?c))
  forall ?step in ?slist
  (BEL V (Occurs ?step))

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Primitive Operators

Primitive operators serve to:

• Establish Focus

• Set Camera Attributes

Type: LookAt

Parameters: ?focus, ?shot-type, ?dir, ?T_{start}, ?T_{end}

Preconditions:

(not (infocus ?focus))@[?T_{start})

Constraints:

(> T_{end} T_{start})

Effects:

(infocus ?focus)@[?T_{start}, ?T_{end})
Primitive Operators

Primitive operators serve to:

- Establish Focus
- Set Camera Attributes

**Type:** LookAt

**Parameters:** ?focus, ?shot-type, ?dir, ?T_{start}, ?T_{end}

**Preconditions:**

$$(\text{not (infocus ?focus)})@[?T_{start}]$$

**Constraints:**

$$ (> T_{end} T_{start})$$

**Effects:**

$$(\text{infocus ?focus})@[?T_{start}, ?T_{end}]$$

**Type:** PanWithActor

**Parameters:** ?focus, ?shot-type, ?dir, ?T_{start}, ?T_{end}

**Preconditions:**

$$(\text{infocus ?focus})@[?T_{start}]$$

$$(\text{not (panning ?shot-type ?dir)})@[?T_{1}, ?T_{start}]$$

**Constraints:**

$$ (> T_{end} T_{start}) ( (< (- T_{end} T_{start}) 10)$$

**Effects:**

$$(\text{infocus ?focus})@[?T_{start}, ?T_{end}]$$

$$(\text{panning ?shot-type ?dir})@[?T_{start}, ?T_{end}]$$
Background
Film Theory

• Composition [Arijon]

• Continuity [Mascelli, Monaco]

• Transition [Mascelli, Katz]

• Coherence [Branigan, Van Sijll]
Background

Film Theory

- Composition [Arijon]
- Continuity [Mascelli, Monaco]
- Transition [Mascelli, Katz]
- Coherence [Branigan, Van Sijll]
Reasoning

- Discourse Planning
  - Input
  - Story Representation
  - Operator Library
- Algorithm
  - Content Selection
  - Causal Planning
  - Temporal Scheduling
- Output: Combined Story and Discourse Plan

Reasoning

• **Input**
  - Story Representation
  - Operator Library
  - Story-World Actions
  - Discourse Actions

Input Story: Bank Robbery

[INIT] I₁ (not (has gold thief))

[S₁] Guard leaves bank
  (effect S₁ (not (at bank guard)))

[S₂] Thief enters bank
  (prec S₂ (not (at bank guard)))
  (effect S₃ (at bank thief))

[S₃] Thief steals gold
  (prec S₃ (at bank thief))
  (effect S₃ (has gold thief))

[S₄] Thief runs away
  (effect S₄ (at hideout thief))

[CL₁] Causal Link: S₁ -- S₂ (not (at bank guard))
[OL₁] Ordering Link: S₃ -> S₄
[Goal] SG₁ (has gold thief)

Reasoning: Plan Space
Reasoning: Plan Space

- Planning Process
  - Plan Space
  - Flaw Repair
  - Search Control
    - Heuristic function
Reasoning: Plan Space

- Planning Process
  - Plan Space
  - Flaw Repair
  - Search Control
  - Heuristic function

Init $\rightarrow$ Goal

Root Plan
Reasoning: Plan Space

- Planning Process
  - Plan Space
  - Flaw Repair
  - Search Control
    - Heuristic function

Root Plan

Expansion

Init ➔ Goal

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Reasoning: Plan Space

- Planning Process
  - Plan Space
  - Flaw Repair
  - Search Control
  - Heuristic function

Root Plan

Expansion

Init ➔ Goal

Rank: x
Rank: y
Rank: Z

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Reasoning: Plan Space

- Planning Process
  - Plan Space
  - Flaw Repair
  - Search Control
  - Heuristic function

Expansion

Init \rightarrow Goal

Root Plan

Rank: x

Rank: y

Rank: Z

Tuesday, October 1, 13
Reasoning Algorithm

Causal Reasoning

Episode Decomposition
Reasoning Algorithm

Causal Reasoning

Episode Decomposition
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

\begin{align*}
\text{Adv. Enter.} & \quad \text{Robbery} & \quad \text{Regain_Lost} \\
e_1 & \quad e_1 & \quad e_1 \\
\end{align*}

\( \text{(Bel V (has ?object ?person))} \)

\( \text{(Bel V (has gold thief))} \)
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

\( G_1 \)

(\( \text{Bel V (has gold thief)} \))
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Robbery

e$_1$

(Bel V (has gold thief))

G$_1$
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Bindings
?object = gold
?person = thief

Robbery

(Bel V (has gold thief))

G_1
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Bindings
?object = gold
?person = thief

Show-Th-Res

Robbery

Show-Obt-Act

(Bel V (has gold thief))
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Bindings

?object = gold
?person = thief
?step = S₃

Show-Th-Res

Show-Obt-Act

Robbery

(effect ?step (has ?object ?person))

(effect S₃ (has gold thief))

Bel V (has gold thief))

G₁

S₃
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Bindings
?object = gold
?person = thief
?step = S_3

(effect S_1 (not (at bank guard)))

Show-Th-Res

S_1

Show-Obt-Act

S_2

S_3

Robbery

(effect ?step (has ?object ?person))

(Bel V (has gold thief))
Reasoning Algorithm

Causal Reasoning

Episode Decomposition

Bindings
?object = gold
?person = thief
?step = S_3
?agent = thief

(effect S_1 (not (at bank guard)))

Robbery

Show-Th-Res

Show-Obt-Act

(effect ?step (has ?object ?person))

S_1

S_2

S_3

Look-At

(Bel V (has gold thief))

G_1

(infocus ?agent)@[T_{start}^{S_3}, T_{end}^{S_3}]
Planning Algorithm

DPOCL-T (P_c - Partial Plan, ∆-Operator Library, ∧-Domain Definition)
Decompositional Partial Order Causal Link Algorithm with Temporal constraints

Termination: If P_c has no flaws or if there are no steps for expansion

Causal Reasoning
a) Goal Selection:
   Pick an open condition p@[t_a, t_b) from set of goals G
b) Action Selection:
   Select actions with effects that unify with the selected open condition
   and add them to the partial plan

Episode Decomposition
   Nondeterministically select an unexpanded step from P_c and expand

Threat Resolution
   Promotion/Demotion: Add ordering constraint between steps
   Separation: Update co-designation list

Temporal Scheduling

Recursive Invocation
Causal Reasoning

Result of Decomposition and Causal Planning

- Combined Story and Discourse Plan
- Causally consistent
- Partially ordered
Causal Reasoning

Result of Decomposition and Causal Planning

- Combined Story and Discourse Plan
- Causally consistent
- Partially ordered

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Temporal Reasoning

- $S_1$ to $E_1$
- $S$ to $E$
- $S_2$ to $E$
- $S$ to $E$
- $C_2 - 1$ to $E$
- $S$ to $E$
Temporal Reasoning

Temporal Constraints
- Implicit \((\text{Start}_{\text{act}} \rightarrow \text{End}_{\text{act}})\)
- Story \(\rightarrow\) Story
- Camera \(\rightarrow\) Story
- Camera \(\rightarrow\) Camera

\(S_S\) \(\rightarrow\) \(S_E\) 
\(S_S\) \(\rightarrow\) \(E_S\) 
\(S_E\) \(\rightarrow\) \(E_E\) 
\(S_S\) \(\rightarrow\) \(S_E\) 
\(S_{C_{2-1}}\) \(\rightarrow\) \(E_E\) 
\(S_S\) \(\rightarrow\) \(E_E\) 
\(S_{C_{2-2}}\) \(\rightarrow\) \(E_E\)
Temporal Reasoning

Temporal Constraints

- Implicit \((\text{Start}_{\text{act}} \rightarrow \text{End}_{\text{act}})\)
- Story \(\rightarrow\) Story
- Camera \(\rightarrow\) Story
- Camera \(\rightarrow\) Camera
Temporal Reasoning

Temporal Constraints
- Implicit (Start_{act} -> End_{act})
- Story -> Story
- Camera -> Story
- Camera -> Camera

Tuesday, October 1, 13
Temporal Reasoning

Temporal Constraints
- Implicit \( \text{Start}_{\text{act}} \rightarrow \text{End}_{\text{act}} \)
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Temporal Reasoning

Temporal Constraints
- Implicit \((\text{Start}_{\text{act}} \rightarrow \text{End}_{\text{act}})\)
- \(\text{Story} \rightarrow \text{Story}\)
- \(\text{Camera} \rightarrow \text{Story}\)
- \(\text{Camera} \rightarrow \text{Camera}\)

Tuesday, October 1, 13
Temporal Reasoning

Temporal Constraints
- Implicit (Start\textsubscript{act} -> End\textsubscript{act})
- Story -> Story
- Camera -> Story
- Camera -> Camera
Execution

• Cinematographer
  • Manages execution of story and camera actions
  • Sets geometric constraints
    • Location Constraints (shot length, shot direction)
    • Rotation Constraints (horizontal and vertical angles)
    • Lens Constraints (field of view)
  • Interface with the constraint solver

• Cameraman
  • Continuously maintains the camera at a solution that satisfies all the current constraints

• **Domain: Westworld**

• Established conventions

• Simple story structure

• Silent Western: No audio, no facial expressions, limited lighting changes to reflect the context [Seif el-Nasr, Perlin, Paiva]
Experiments (in progress)

1: Measuring comprehension of generated cinematics
   • Methodology
     • Two sets of participants to watch a movie
     • Neutral camera angle (master shot)
     • Camera placement directed by Darshak

2: Measuring coherence of generated cinematics
   • Methodology
     • Two sets of participants to watch a movie
     • Linear sequence of events through a neutral camera angle
     • Darshak’s output using different narrative patterns
     • Viewers respond to questions after watching the video
     • Pre-questionnaire (movie preferences, familiarity with western genre, etc.)

   Q: Why did A kill B?
      A: (A) Revenge (B) B was preventing A from robbing (C) Jealousy (D) Don’t Know
Contributions

- **[AI]** Representation and reasoning of cinematic conventions and narrative patterns in a computational model

- **[Discourse]** Better understanding of cinematic discourse

- **[Graphics]** Intelligent algorithms for camera control in games and virtual environments

- **[Digital Media]** A working platform for further research in multi-modal communication and intelligent visualization
Serious Games
Serious Games

- Leaders project
  - Branching storyline with cinematics for leadership training

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- America’s Army: Adaptive Thinking and Leadership
  - Multiplayer training simulation
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Conclusion

- Darshak
  - uses a novel computational model of cinematic discourse
  - provides an end-to-end system for procedural generation of 3D cinematics

- Discourse generated by Darshak
  - Encodes narrative patterns and cinematic idioms
  - Contains salient elements of the story
  - Is coherent
  - Executes in a temporally consistent manner on a real-time game engine
Authoring Tools for Machinima

- Easy to author tools for communicating stories

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