# Concurrent Interactions in The Sims 4 

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## Outline

## Outline

- Interactions


## Outline

- Interactions
- Constraints


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- Constraints
- Interaction Queue


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- Interactions
- Constraints
- Interaction Queue
- Transitions


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- Interactions
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- Socials


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- Interactions
- Constraints
- Interaction Queue
- Transitions
- Socials
- Q\&A


## The Sims Architecture

- The world is built using game objects


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- Game objects provide interactions
- Sims are objects too!


## The Sims Architecture

- The world is built using game objects
- Game objects provide interactions
- Sims are objects too!
- Sims run interactions
- Interactions are fundamental unit of behavior


## Multitasking

- Natural
- People do multiple things at the same time


## Multitasking

- Natural
- People do multiple things at the same time
- Frequently requested feature


## Multitasking

- Natural
- People do multiple things at the same time
- Frequently requested feature
- Systematic approach is valuable
- Ad hoc implementation is lots of work, inconsistent results


## Concurrency vs Multitasking

- No true concurrent execution
- This is a hard problem
- Deadlock, race conditions, etc...


## Concurrency vs Multitasking

- No true concurrent execution
- This is a hard problem
- Deadlock, race conditions, etc...
- Multitasking
- Context switching
- Cooperative


## Multitasking





## Multitasking



## Multitasking

| Grab | Sip | Sip | Discard |
| :---: | :---: | :---: | :---: |
| Drink | Drink | Drink | Drink |

Sit
Yawn


Read

## Interactions



## Running Interactions

- Each Sim has
- A set of active interactions
- An ordered queue of pending interactions


## Running Interactions

- Each Sim has
- A set of active interactions
- An ordered queue of pending interactions
- Sub-actions run "inside" active interactions


## Sub Actions

- Compatible with all running interactions


## Sub Actions

- Compatible with all running interactions
- Selected using weighted random


## Sub Actions

- Compatible with all running interactions
- Selected using weighted random
- Can be limited with additional tests


## Rules

- Can I perform an action?


## Rules

- Can I perform an action?
$\neg$ Condition $\rightarrow \neg$ Action


## Rules

- Can I perform an action? $\neg$ Condition $\rightarrow \neg$ Action
- How do I perform an action?


## Rules

- Can I perform an action? $\neg$ Condition $\rightarrow \neg$ Action
- How do I perform an action? Action $\rightarrow$ Condition


## Rules

- Can I perform an action? $\neg$ Condition $\rightarrow \neg$ Action
- How do I perform an action? Action $\rightarrow$ Condition
- Avoids duplicated logic


## Constraints

- Data-driven rules


## Constraints

- Data-driven rules
- Preconditions on running an interaction


## Constraints

- Data-driven rules
- Preconditions on running an interaction
- Answer the questions
- Can I run an interaction?
- How do I run an interaction?


## Position

## ALPHA SOFTWARE

## Orientation



## Animation Slot

## Posture



## Posture

## Examples



## Posture

## Examples



## Carrying

## Doesn't need hands



## Carrying

Object in hand


## Carrying

Needs hands


## Surfaces

## Object on

 Surface

## Surfaces

## Empty surface



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## Line of Sight



## Scoring Functions



## Constraint Authoring

- Data driven
- Animation: Position, posture, carry
- XML Tuning: Geometry, orientation, surface
- Script: Scoring function, line-of-sight


## Constraint Combination

- Multitasking combines constraints


## Constraint Combination

- Multitasking combines constraints
- Supported operations
- Intersection
- Union




## Interaction Compatibility

Q: Are interactions compatible?

## Interaction Compatibility

Q: Are interactions compatible?
A: Yes, if the intersection of their constraints is non-empty



## Interaction Queue

## Interaction Queue

- Each Sim has
- A set of active interactions
- An ordered queue of pending interactions


## Interaction Queue

- Each Sim has
- A set of active interactions
- An ordered queue of pending interactions
- Interactions have priority
- High (User directed)
- Low (Autonomous)
- Idle (Finished but still running)


## Queue Processing

Can Next Interaction Run?

## Queue Processing



## Queue Processing



## Queue Processing



## Interaction Processing Example

| Grab | Sip | Sip <br> Drink |
| :---: | :---: | :---: |
| Drink | Discard |  |
|  |  |  |

Sit
Yawn


Read

## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example

Queued Interactions

| Sit | Watch TV | Read Book | Where | How | Hands |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Drink ${ }^{\text {Next interaction }}$ |  |  |  |  |  |
|  |  |  | Anywhere | Anything | Drink |
| Active Interactions |  |  |  | Anything |  |
|  |  |  | Anywhere |  | Don't |

## Interaction Processing Example

Queued Interactions

| Sit | Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: | :---: |
|  | Anywhere |  | Hands |  |
| Next interaction | Answ |  |  |  |
| Drink |  | Anywhere | Anything | Don't <br> Care |
| Active Interactions |  |  |  |  |

## Interaction Processing Example

Queued Interactions

| Sit | Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: | :---: |
|  | Anywhere |  | Hands |  |
| Next interaction | Anywhere | Anything | Don't <br> Care |  |
| Active Interactions |  |  |  |  |

## Interaction Processing Example

Queued Interactions

| Sit | Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: | :---: |
|  | Anywhere | Sit or <br> Stand |  |  |
| Next interaction | Any |  |  |  |
| Drink |  | Anywhere | Anything | Don't <br> Care |
| Active Interactions |  |  |  |  |

## Interaction Processing Example



## Interaction Processing Example

| Queued Interactions |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Sit | Watch |  |
| TV |  |  | \(\left.\begin{array}{c}Read <br>

Book\end{array}\right)\)

## Interaction Processing Example

| Queued Interactions |  |  | Where | How | Hands |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Sit | Watch TV | Read Book |  |  |  |
| Next interaction |  |  | Anywhere | Sit or | Hold |
| Drink |  |  |  | Stand | Drink |
| Active Interactions |  |  | Anywhere |  |  |
|  |  |  | Anything | Care |  |

## Interaction Processing Example

| Queued Interactions |  |  | Where | How | Hands |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Sit | Watch TV | Read Book |  |  |  |
| Next interaction |  |  |  |  |  |
| Drink | ctive In | ractions | Anywhere | Sit or Stand | Hold Drink |

## Interaction Processing Example



## Interaction Processing Example

Queued Interactions

| Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: |
| Next interaction |  |  | Hands |
| Sit |  |  |  |
| Active Interactions | Anywhere | Sit or <br> Stand | Hold <br> Drink |
| Drink |  |  |  |

## Interaction Processing Example

Queued Interactions

| Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: |
| Next interaction | On Seat |  | Hands |
| Sit |  |  |  |
| Active Interactions | Anywhere | Sit or <br> Stand | Hold <br> Drink |
| Drink |  |  |  |

## Interaction Processing Example

Queued Interactions


## Interaction Processing Example

Queued Interactions

| Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: |
| Next interaction | On Seat | Sit |  |
| Sit |  | Sands |  |
| Active Interactions | Anywhere | Sit or <br> Stand | Hold <br> Drink |
| Drink |  |  |  |

## Interaction Processing Example

Queued Interactions

| Watch TV | Read Book | Where | How | Hands |
| :---: | :---: | :---: | :---: | :---: |
| Next interaction |  |  |  |  |
| Sit |  | On Seat | Sit |  |
| Drink | ctive | Anywhere | Sit or Stand | Hold Drink |

## Interaction Processing Example

Queued Interactions

| Watch <br> TV | Read <br> Book | Where | How |
| :---: | :---: | :---: | :---: |
| Next interaction | On Seat | Sit | Don't <br> Care |
| Sit |  | Anywhere | Sit or <br> Stand |
| Active Interactions | Hold <br> Drink |  |  |
| Drink |  |  |  |

## Interaction Processing Example

| Queued Interactions |  |  |  |
| :---: | :---: | :---: | :---: |
| Watch <br> TV | Read <br> Book | Where | How |
| Next interaction |  | On Seat | Sit | | Don't |
| :---: |
| Sit |
| Active Interactions |
| Drink |

## Interaction Processing Example

| Queued Interactions |  |  |  |
| :---: | :---: | :---: | :---: |
| Watch Read <br> TV <br> Book  | Where | How | Hands |
| Next interaction |  |  |  |
| Sit | On Seat | Sit | Care |
| Active Interactions |  |  |  |
| Drink | Anywhere | Stand | Drink |

## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example

## Queued Interactions

| Read Book |  | Where | How | Hands |
| :---: | :---: | :---: | :---: | :---: |
| Next interaction |  |  |  |  |
| Watch TV |  |  |  |  |
|  | Active Interactions Drink | On Seat | Sit | Hold Drink |

## Interaction Processing Example

## Queued Interactions

| Read <br> Book | Where | How | Hands |
| :---: | :---: | :---: | :---: |
| Next interaction | In view, <br> Facing |  |  |
| Watch <br> TV | On Seat | Sit | Hold <br> Drink |
| Active Interactions |  |  |  |
| Sit | Drink |  |  |

## Interaction Processing Example



## Interaction Processing Example

| Queued Interactions |  |  |  |
| :---: | :---: | :---: | :---: |
| Read <br> Book | Where | How | Hands |
| Next interaction |  | In view, <br> Facing | Sit or <br> Stand |
| Watch <br> TV | On Seat | Sit | Hold <br> Drink |
| Active Interactions |  |  |  |
| Sit | Drink |  |  |

## Interaction Processing Example



## Interaction Processing Example

| Queued Interactions |  |  |  |
| :---: | :---: | :---: | :---: |
| Read <br> Book | Where | How | Hands |
| Next interaction |  | In view, <br> Facing | Sit or <br> Stand |
| Watch <br> TV | On Seat | Sit | Don't <br> Care |
| Active Interactions |  | Hold |  |
| Sit | Drink |  |  |

## Interaction Processing Example

| Queued Interactions |  |  |  |
| :---: | :---: | :---: | :---: |
| Read Book | Where | How | Hands |
| Watch TV | In view, Facing | Sit or Stand | Don't Care |
| Active Interactions <br> Sit <br> Drink | On Seat | Sit | Hold Drink |

## Interaction Processing Example

| Queued Interactions | Where | How | Hands |
| :---: | :---: | :---: | :---: |
| Read Book |  |  |  |
|  | In view, Facing | Sit or Stand | Don't Care |
| Active Interactions Sit Drink | On Seat | Sit | Hold Drink |

## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example




## Interaction Processing Example



## Where



Hands
Both
Hands
Hold Drink

## Interaction Processing Example

| Queued Interactions |  |  |
| :--- | :--- | :---: |
| Rext interaction |  |  |
| Read <br> Book |  |  |
| Active Interactions |  |  |
| Watch <br> TV | Sit Drink |  |

## Where How Hands



## Interaction Processing Example



## Where How Hands

Sit or Stand, Not TV

Both Hands

Hold Drink

## Interaction Processing Example

| Queued Interactions |  |  |
| :--- | :--- | :---: |
| Next interaction |  |  |
| Read <br> Book |  |  |
| Active Interactions |  |  |
| Watch <br> TV |  |  |

Where How Hands


## Interaction Processing Example



## Interaction Processing Example



Where How Hands

| Anywhere | Sit or Stand, <br> Not TV | Both <br> Hands |
| :---: | :---: | :---: |
| On Seat | Sit | Don't <br> Care |

## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example



## Interaction Processing Example

| Queued Interactions |  | How | Hands |
| :---: | :---: | :---: | :---: |
|  | Where |  |  |
| Next interaction |  |  |  |
| Active Interactions | On Seat | Sit, Not TV | Both Hands |




## Transitions

## Generating Behavior

- Constraints define preconditions for performing an interaction


## Generating Behavior

- Constraints define preconditions for performing an interaction
- Can be used generatively


## Generating Behavior

- Constraints define preconditions for performing an interaction
- Can be used generatively
- Requires ability to find transition to constraint


## Transition Graph

- The constraints on each object are stored in an abstract graph


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- The constraints on each object are stored in an abstract graph
- Edges are state changes


## Transition Graph

- The constraints on each object are stored in an abstract graph
- Edges are state changes
- Search graph to generate a transition sequence


## Transition Graph



## Using the Graph

## Stand near table, Carry Drink

stand@object_tablePicnic:0xe6a1d4fbc0000002[2], carry:PostureSpecVariable.CARRY_TARGET, surface:object_tablePicnic:0xe6a1d4fbc0000002[
stand@object_tablePicnic:0xe6a1d4fbc0000002[2], surface:target@object_tablePicnic:0xe6a1d4fbc0000002[2]
sit@object_tablePicnic:0xe6a1d4fbc0000002[2], surtace:target@object_tablePicnic:0xe6a1d4fbc0000002[2]

## Using the Graph



## Using the Graph



## Graph Searching

- Multiple nodes can match requirements


## Graph Searching

- Multiple nodes can match requirements
- Edges are weighted by cost
- Routes weighted by approximate distance


## Graph Searching

- Multiple nodes can match requirements
- Edges are weighted by cost
- Routes weighted by approximate distance
- Search determines optimal path


## Example

Carry Transference


## Example

## Carry <br> Transference



## Search Optimizations <br> - Bidirectional search

## Search Optimizations

- Bidirectional search
- Simplifications
- Carry
- Slot


## Search Optimizations

- Bidirectional search
- Simplifications
- Carry
- Slot
- Node query indexing


## Socials



## Socials



## Socials

## Intersected with

 TV constraint

## Socials

Intersected with TV constraint


## Convex LOS



## Social Clustering



## Social Clustering



## Challenges - Complexity

- Building Features


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- Less tolerance for ad-hoc implementation


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- Authoring content


## Challenges - Complexity

- Building Features
- Less tolerance for ad-hoc implementation
- Must express features using constraints
- Authoring content
- Complexity of data


## Challenges - Player Expectations

- Excessive multitasking


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- Excessive multitasking
- Communicating compatibility


## Challenges - Player Expectations

- Excessive multitasking
- Communicating compatibility
- Uncanny valley


## Takeaway

- The best rules can be used both to restrict and to drive behavior


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- The best rules can be used both to restrict and to drive behavior
- Composable rules are necessary to support multitasking


## Impact

- The spatial relationship between objects is more important


## Impact

- The spatial relationship between objects is more important
- More diverse behavior with the same amount of content


## Questions?

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## Bonus Content!

## Holstering



## Holstering



