Animation-Driven Locomotion For Smoother Navigation

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Format

- Introduction to Animation-Driven Locomotion (ADL)
- Big Huge Motion Planning
- Eidos / IO Interactive Motion Planning
- Hitman: Absolution Case Study

Animation-Driven Locomotion

- Animation defines spatial transformations
  - Movement can reflect kinematic properties of animations.

Motivations for ADL

- Invalid kinematics break immersion
- ADL systems allow complex motion sets
- Animators work directly reflected in game

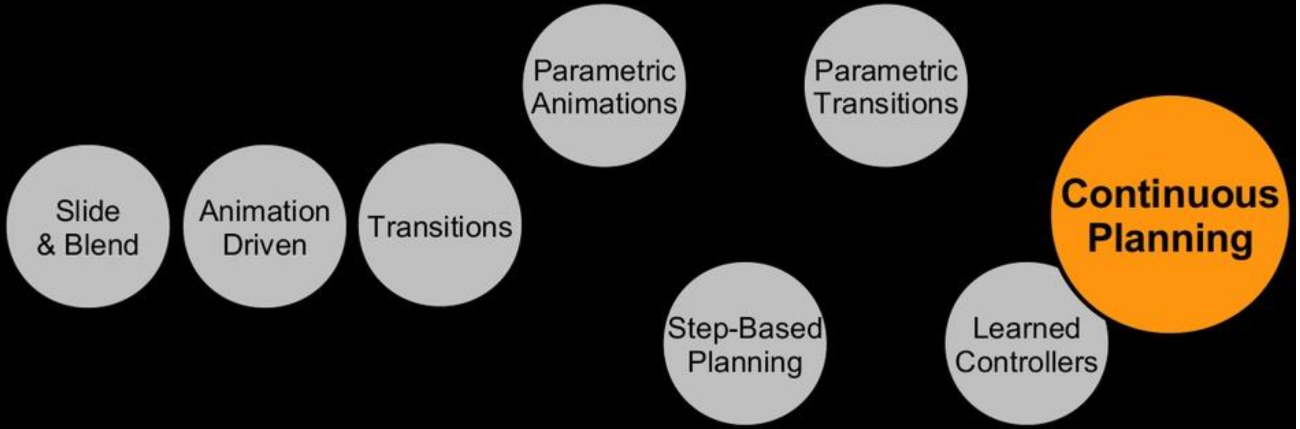
Navigation and ADL

- What is the goal of using ADL for Agents?
  - Realistic, high fidelity visualization with complex continuous ranges of movement
  - Navigate within the constraints of the system.

Using ADL

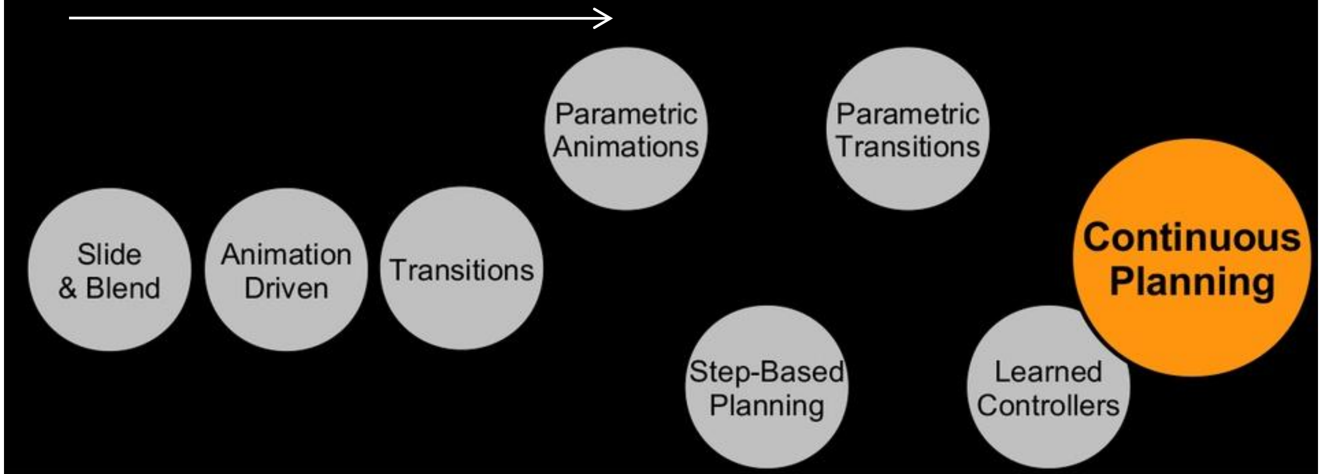
- ADL is simple, usage patterns are hard!
  - Multiple approaches
  - Varying complexity

The Prototypes



The Prototypes

Complexity and Fidelity



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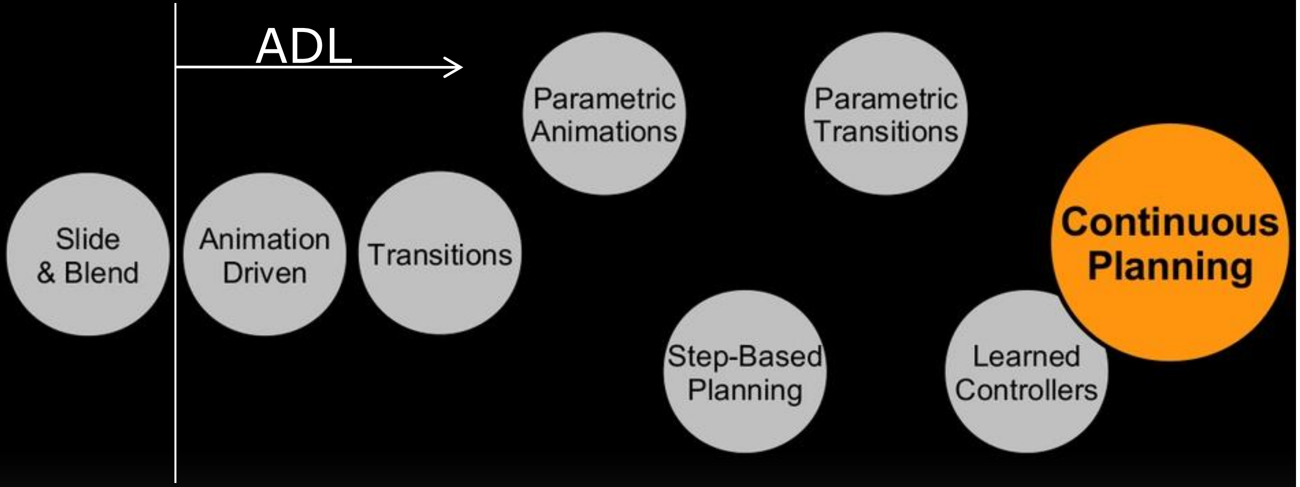
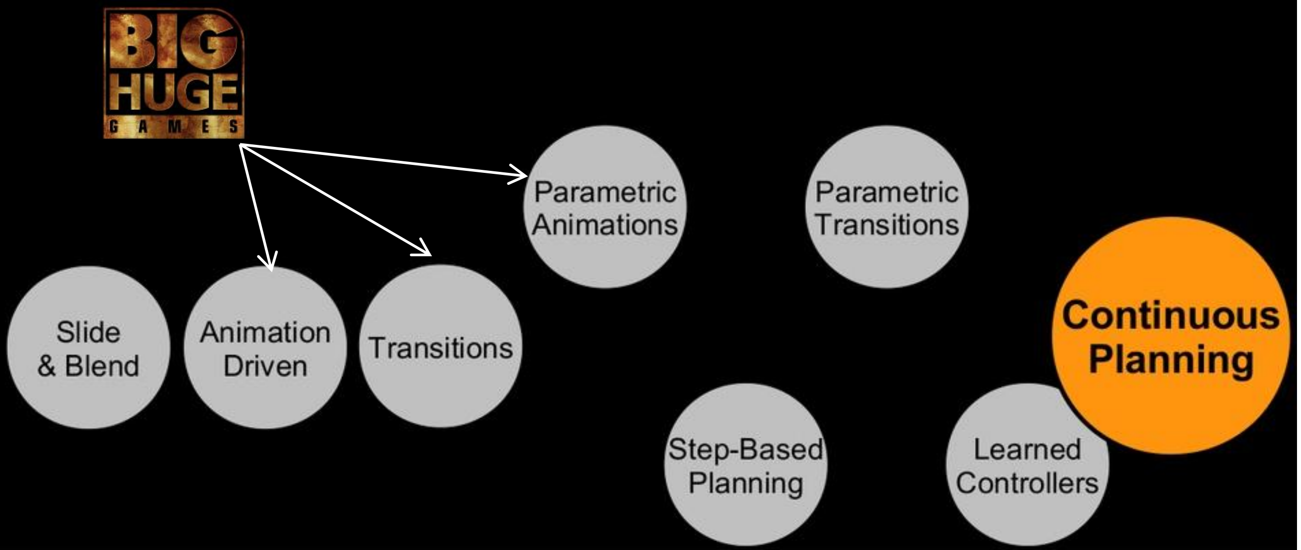


Common Thread

- Same Problem
- Multiple Solutions
- Choosing the best approach is difficult

The Prototypes



Reckoning’s ADL System

- ADL Roadmap
- Motion Planning

Reckoning ADL Roadmap–Player Movement

- Wanted ADL for player character
- Motion graph implemented
- Extracted data from animation node

Reckoning ADL Roadmap–Player Movement

- Orientation - Procedural and ADL
- Blending of movement information

Reckoning ADL Roadmap – NPCs

- Used tech developed for the player
- Attempted real time motion graph search

Reckoning ADL Roadmap – NPCs

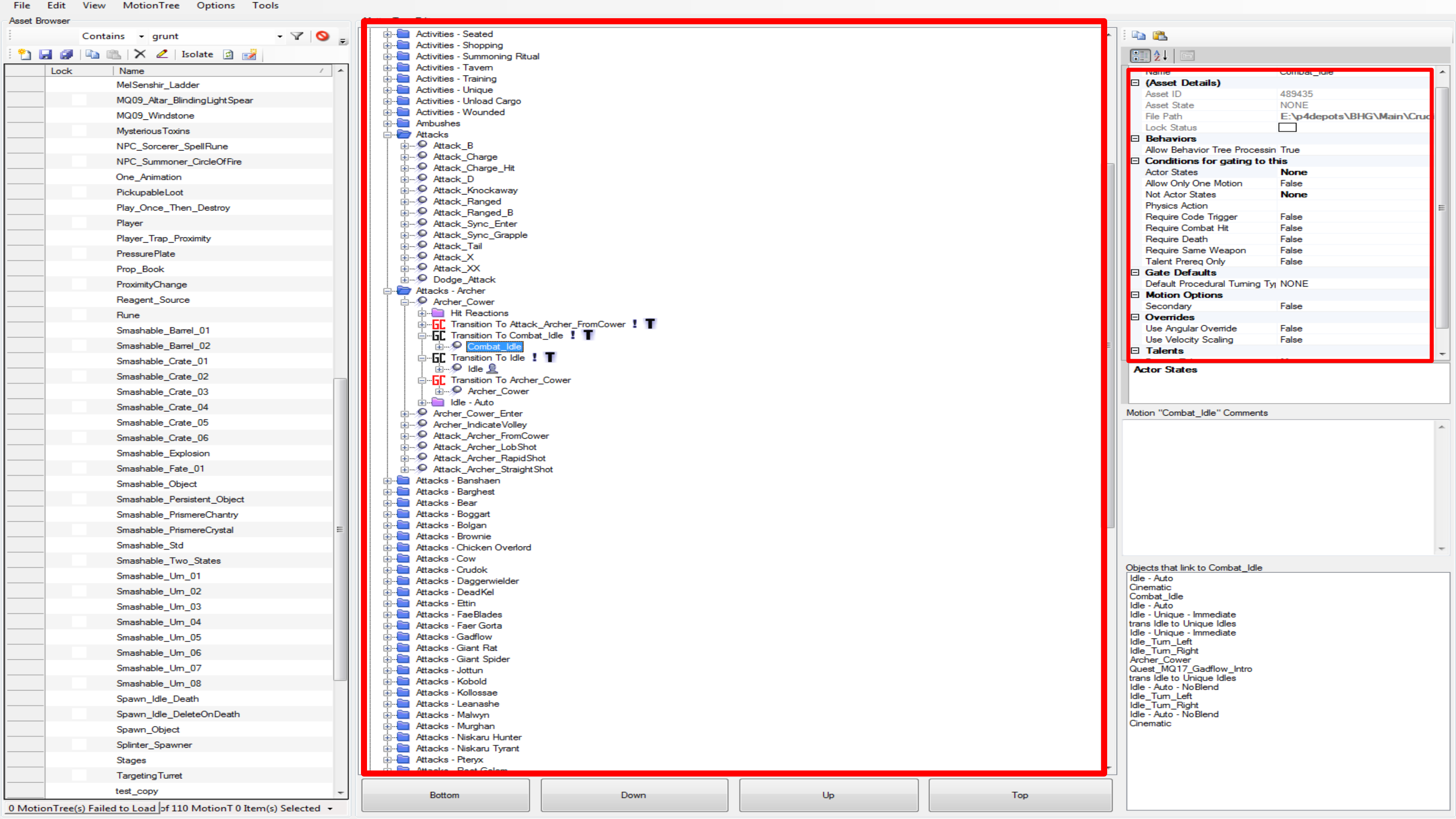
- Used system defined for player character

Motion Planning – Developed Tech

- ADL
  - Linear and rotation data encoded

Motion Planning – Developed Tech

- Motion Graph
  - Defined by designers
  - Conditional Links
  - Tree like interface


File Edit View MotionTree Options Tools
Asset Browser
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Isolate
Lock Name
MelSenshir_Ladder
MQ09_Altar_BlindingLightSpear
MQ09_Windstone
MysteriousToxins
NPC_Sorcerer_SpellRune
NPC_Summoner_CircleOfFire
One_Animation
PickupableLoot
Play_Once_Then_Destroy
Player
Player_Trap_Proximity
PressurePlate
Prop_Book
ProximityChange
Reagent_Source
Rune
Smashable_Barrel_01
Smashable_Barrel_02
Smashable_Crate_01
Smashable_Crate_02
Smashable_Crate_03
Smashable_Crate_04
Smashable_Crate_05
Smashable_Crate_06
Smashable_Explosion
Smashable_Fate_01
Smashable_Object
Smashable_Persistent_Object
Smashable_PrismereChantry
Smashable_PrismereCrystal
Smashable_Std
Smashable_Two_States
Smashable_Urn_01
Smashable_Urn_02
Smashable_Urn_03
Smashable_Urn_04
Smashable_Urn_05
Smashable_Urn_06
Smashable_Urn_07
Smashable_Urn_08
Spawn_Idle_Death
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Splinter_Spawner
Stages
TargetingTurret
test_copy
0 MotionTree(s) Failed to Load of 110 MotionT 0 Item(s) Selected
Activities - Seated
Activities - Shopping
Activities - Summoning Ritual
Activities - Tavern
Activities - Training
Activities - Unique
Activities - Unload Cargo
Activities - Wounded
Ambushes
Attacks
Attack_B
Attack_Charge
Attack_Charge_Hit
Attack_D
Attack_Knockaway
Attack_Ranged
Attack_Ranged_B
Attack_Sync_Enter
Attack_Sync_Grapple
Attack_Tail
Attack_X
Attack_XX
Dodge_Attack
Attacks - Archer
Archer_Cower
Hit Reactions
Transition To Attack_Archer_FromCower
Transition To Combat_Idle
Combat_Idle
Transition To Idle
Idle
Transition To Archer_Cower
Archer_Cower
Idle - Auto
Archer_Cower_Enter
Archer_IndicateVolley
Attack_Archer_FromCower
Attack_Archer_LobShot
Attack_Archer_RapidShot
Attack_Archer_StraightShot
Attacks - Banshaen
Attacks - Barghest
Attacks - Bear
Attacks - Boggart
Attacks - Bolgan
Attacks - Brownie
Attacks - Chicken Overlord
Attacks - Cow
Attacks - Crudok
Attacks - Daggerwielder
Attacks - DeadKel
Attacks - Ettin
Attacks - FaeBlades
Attacks - Faer Gorta
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Attacks - Giant Rat
Attacks - Giant Spider
Attacks - Jottun
Attacks - Kobold
Attacks - Kollossae
Attacks - Leanashe
Attacks - Malwyn
Attacks - Murghan
Attacks - Niskaru Hunter
Attacks - Niskaru Tyrant
Attacks - Pteryx
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Asset State NONE
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Allow Only One Motion False
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Require Combat Hit False
Require Death False
Require Same Weapon False
Talent Prereq Only False
Gate Defaults
Default Procedural Turning Ty NONE
Motion Options
Secondary False
Overrides
Use Angular Override False
Use Velocity Scaling False
Talents
Actor States
Motion "Combat_Idle" Comments
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Idle - Auto
Cinematic
Combat_Idle
Idle - Auto
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Idle_Turn_Right
Archer_Cower
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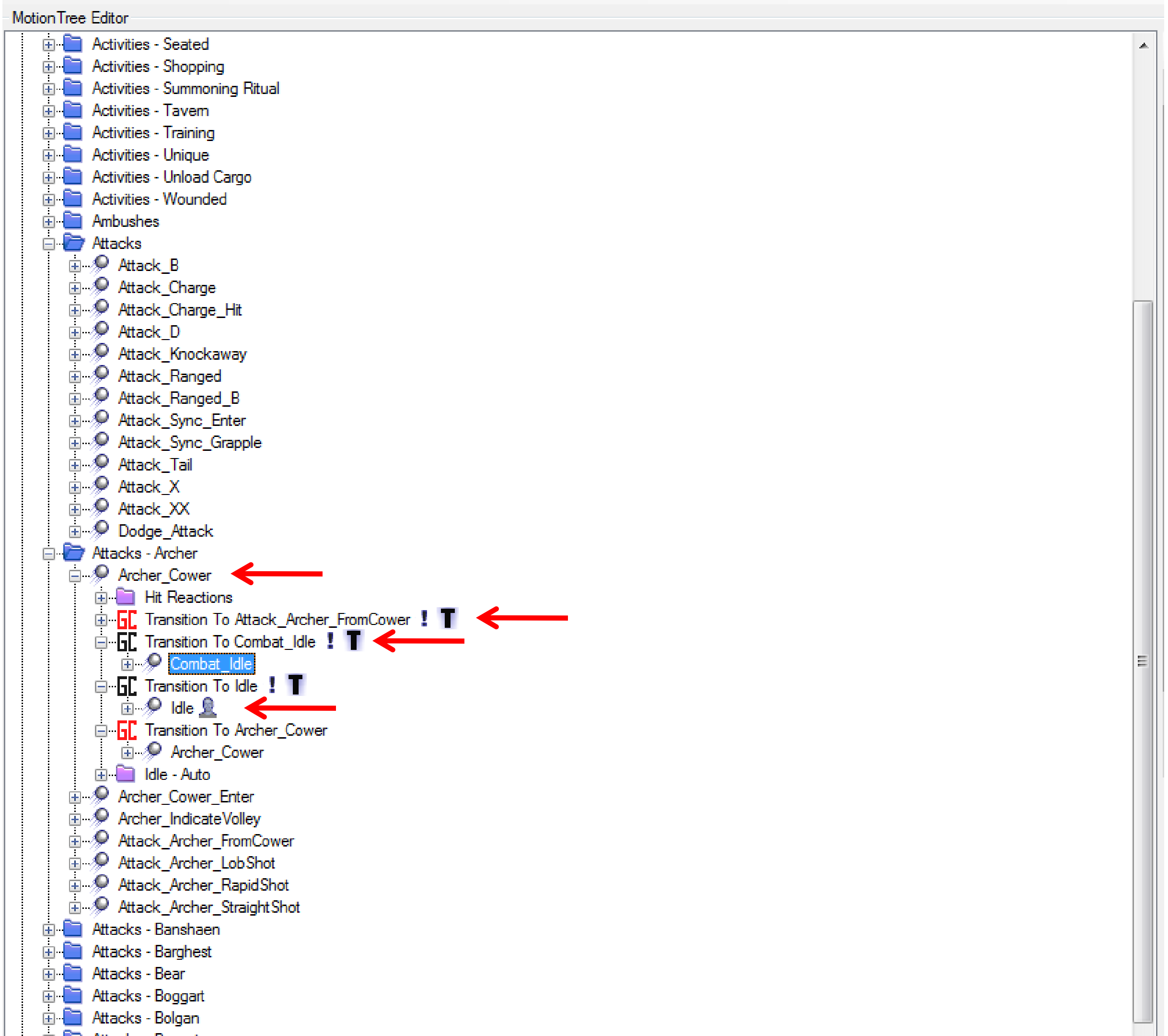
Idle - Auto - NoBlend
Cinematic


MotionTree Editor
Activities - Seated
Activities - Shopping
Activities - Summoning Ritual
Activities - Tavern
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Attacks - Bolgan

Motion Planning – Developed Tech

- Motion Graph
  - Became very large
  - Grouping for organization needed

Motion Planning – Facilities Available

- Animation Blending
- Additive Animation Blending

Motion Planning – Facilities Available

- Procedural ADL Adjustments
  - Ability to adjust linear and rotational output

Motion Planning

- How is motion planning completed?
  - Motion graph does all planning
  - Graph considers graph state, input, and game state.
- How do we ensure orientation?
  - Procedural orientation
  - Foot slide still occurs

Motion Planning

- How is navigation fidelity improved through this system?
  - Straight line movement looks great and foot slide is prevented
  - Overall increase in fidelity in movement and combat

Motion Planning-Detriments

- Fidelity to time cost high
- Foot sliding still occurs

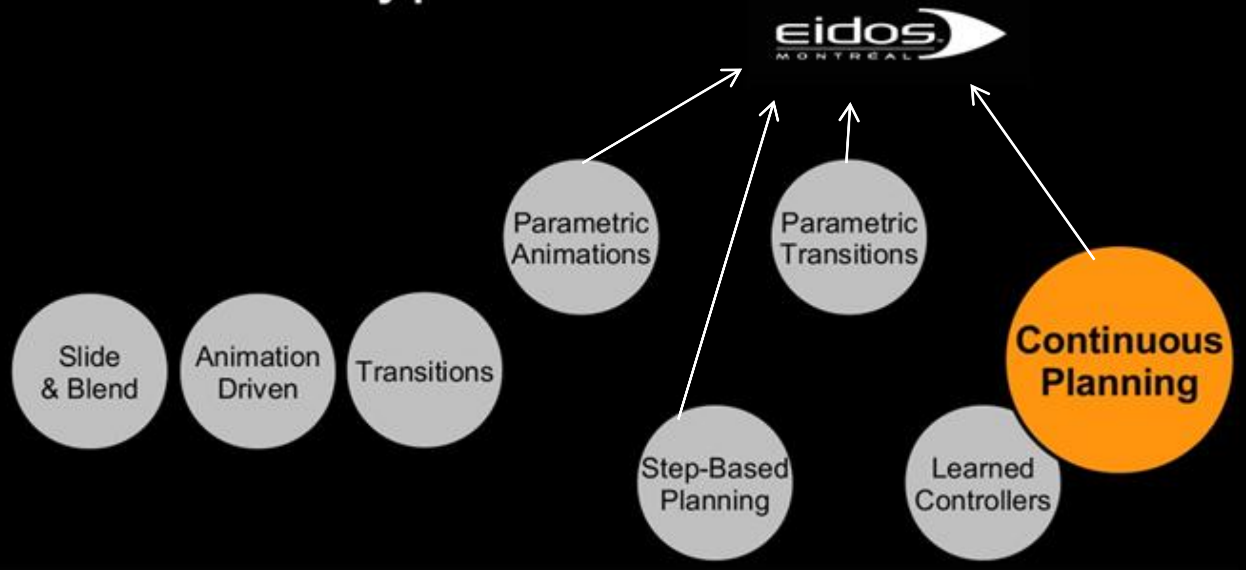
Motion Planning - Benefits

- Low overhead for motion planning code
- Non-emergent results
- Easy addition of animation fidelity
- Good stepping stone

An ADL Approach to Foot Step Planning

- This system will:
  - Respect the kinematics of walking at all times
  - Reach destinations precisely with proper orientation
  - Use a per segment navigation approach without steering

The Prototypes



An ADL Approach to Foot Step Planning

- Why bother ? Our needs:
  - Stay exactly on a path at all times
    - To support planned interactions during locomotion
    - Full body IK can only correct to a certain extent
  - Characters that are able to convey their mood through their navigation
    - Specific clips depending on context and turn angles

An ADL Approach to Footstep Planning

- This system is best suited for:
  - Characters with high constraints on their locomotion
  - Stable targets
  - Slow pace navigation

An ADL Approach to Footstep Planning

- Why slow pace navigation ?
  - Longer strides delay reactivity
  - Runway requirements limit possible paths
  - …probably just not worth it in fast moving clips

Approach Overview

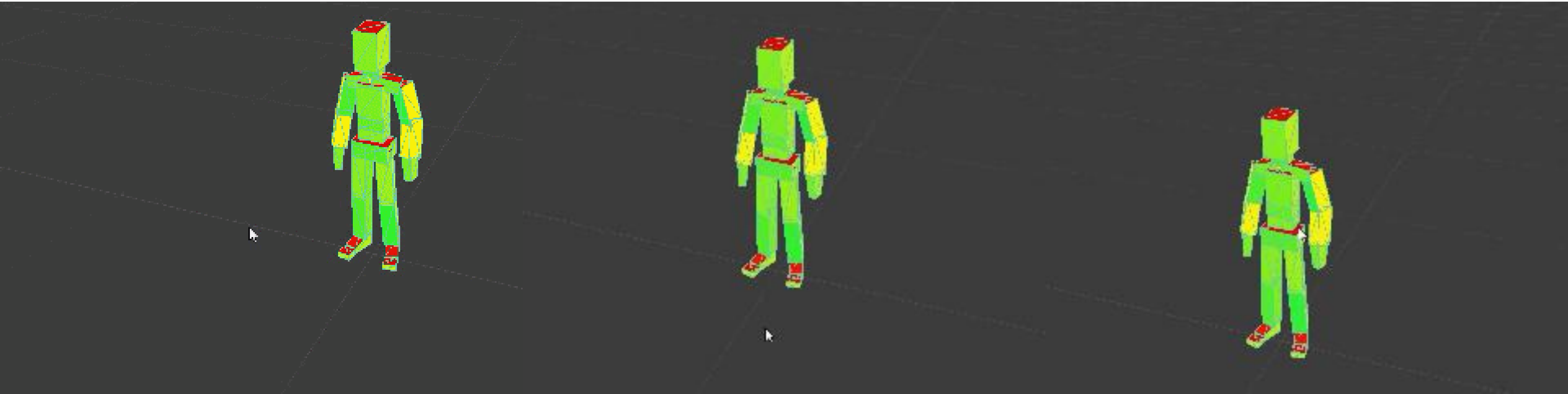
- Requirements
- The footstep planner
- Dealing with foot sliding
- Collision avoidance
- Adding more emotions to locomotion

Animation requirements

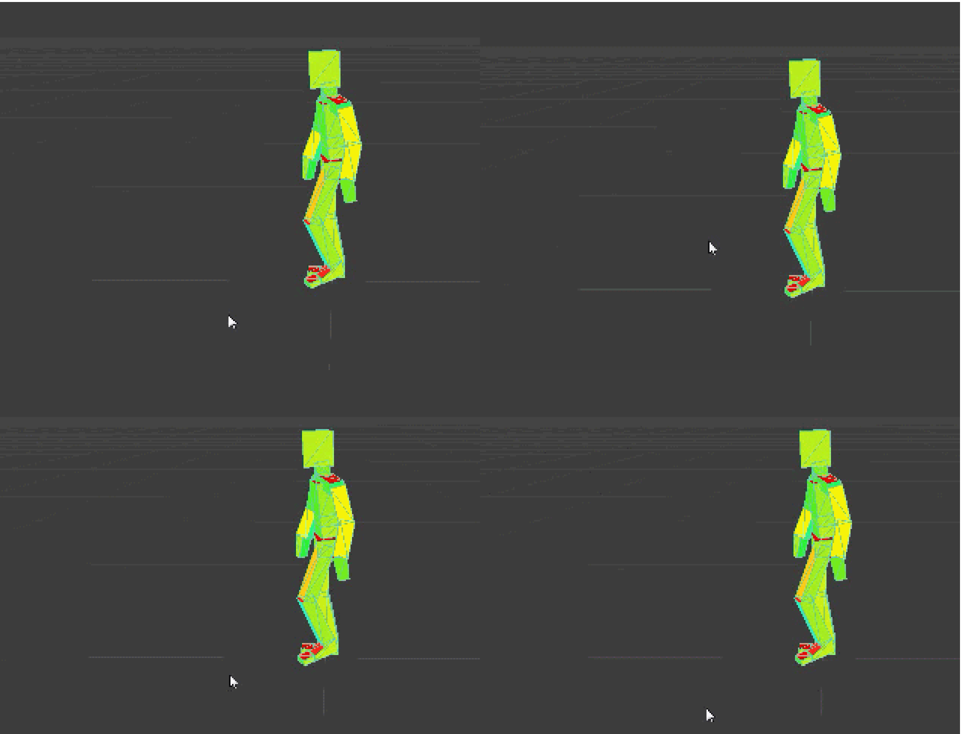
- A complete animation set that covers what your character can achieve
  - Start, Move, Turn and Stop clips
- Detailed clips with information on current feet status
- Extracted information on translation and rotation

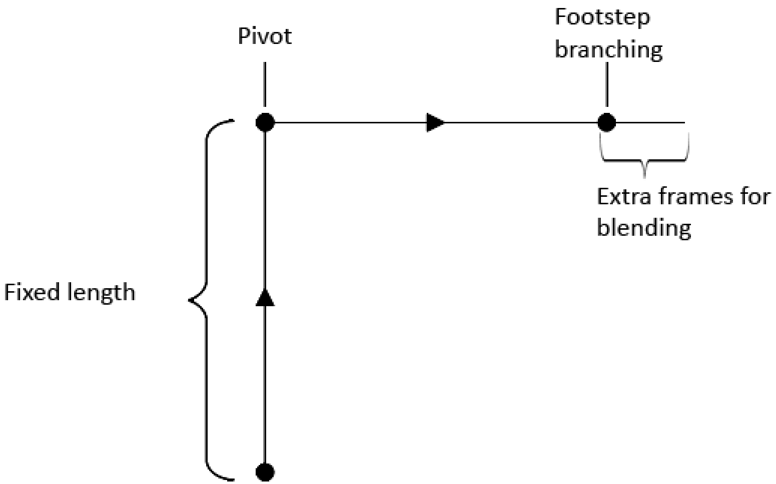
A typical animation set

- Start animations that covers all angles
  - -180^0, -90^0, 0^0, 90^0, 180^0



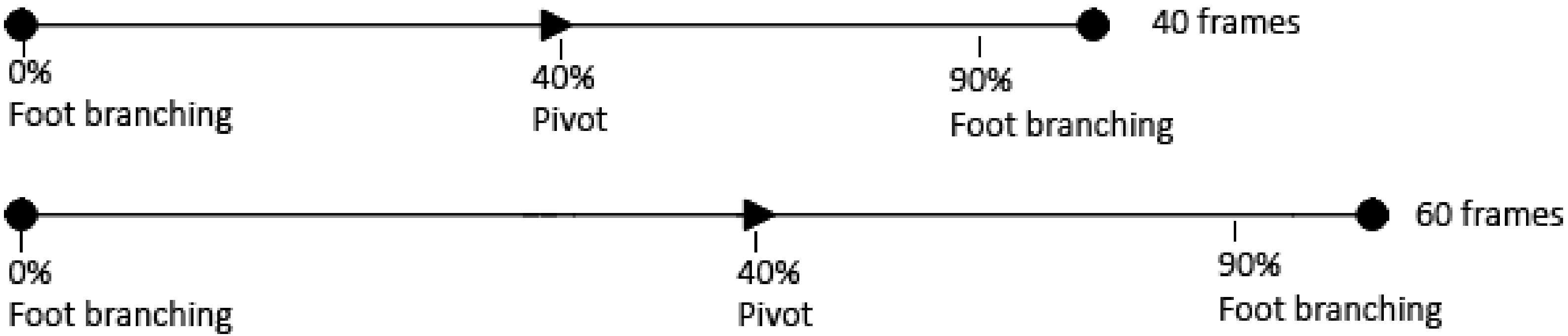
A typical animation set *(turns)*





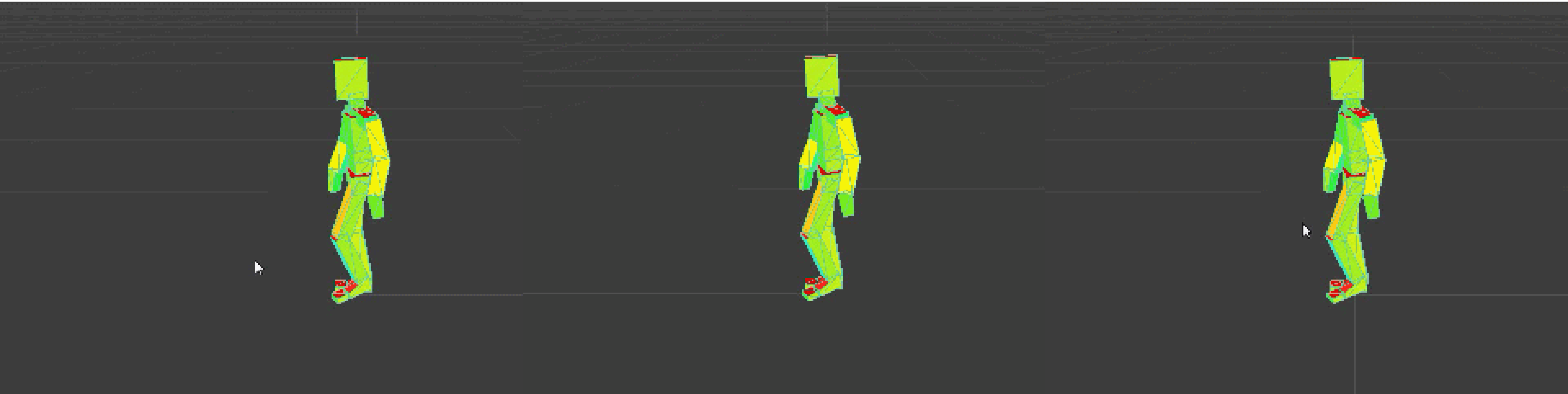
A typical animation set

- Give some slack to your animators !
- Animation clips can have different length as long as they reach critical points at the same percentage of the clip
- Failure to do so can result in bad blends



A typical animation set

- Stop animations for each leg, every angle
  - We choose this to eliminate NPCs stopping and then turning on themselves to reach final orientation



A typical animation set

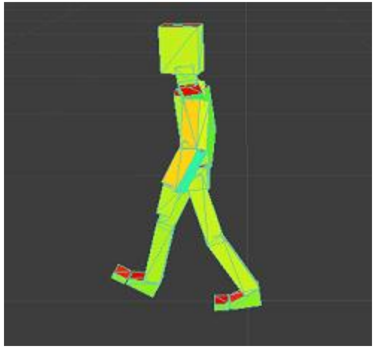
- To build a complete navigation set for one stance:

  6 start clips
  8 turn clips
  1 move cycle
  10 stop clips

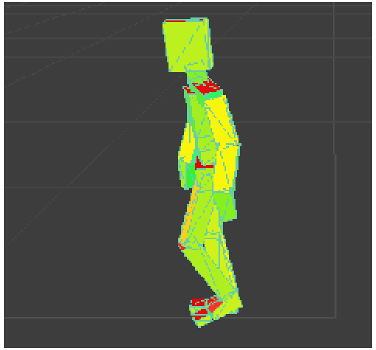
- At ~50 frames per clip, this requires more or less 1250 frames
- 410KB in our test bed after compression
- Double that if you need to support variable speeds
  - Not a must in this system

Clip details

- Need information on foot ground contacts, foot passing to properly branch to different clips
  - Annotations or analysis
- **Contact** will be more responsive but with less acting compared to **Passing**



Foot contact



Foot passing

Let your animators decide!

Footstep planning

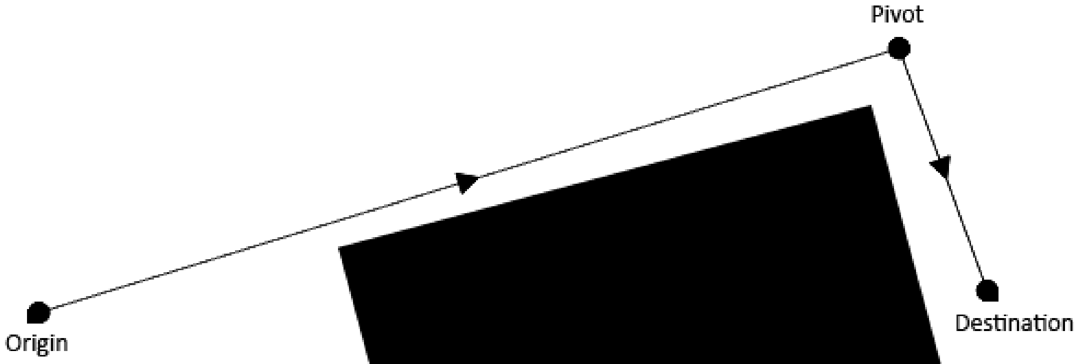
- We do not want to start out stop clips unless we are exactly on the branching position
- In ADL there are two critical spots where we need to be precisely on our foot branching position:
    - Before a pivot
    - Before our goal
    - Before interactions

Footstep planning

- Path needs to be stable for planning to work

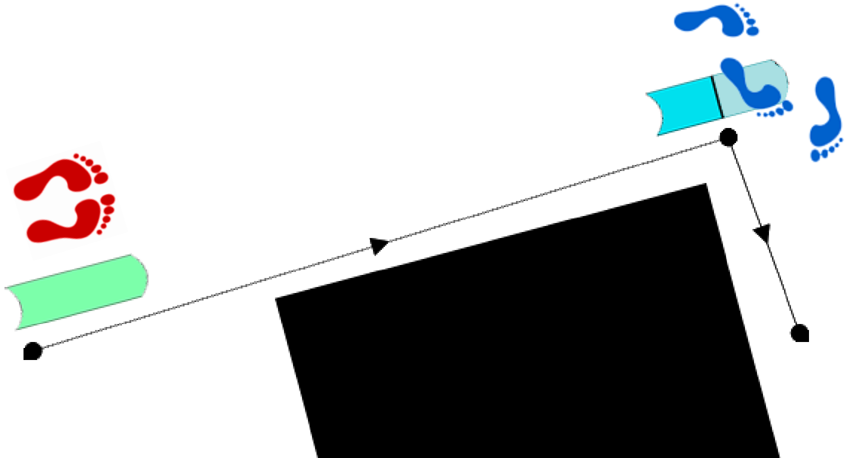
Footstep planning

- Simple path containing two segments
- Plan will contain a **start**, a **turn**, a **stop** and several **steps**
- Need to stay on the funneled path at all times to prevent hitting obstacles (i.e. walls)
- First we need to turn exactly on the pivot



Footstep planning

- We know we'll need at least our **Start** and the first part of the **Turn** clip, so let's insert them in our plan

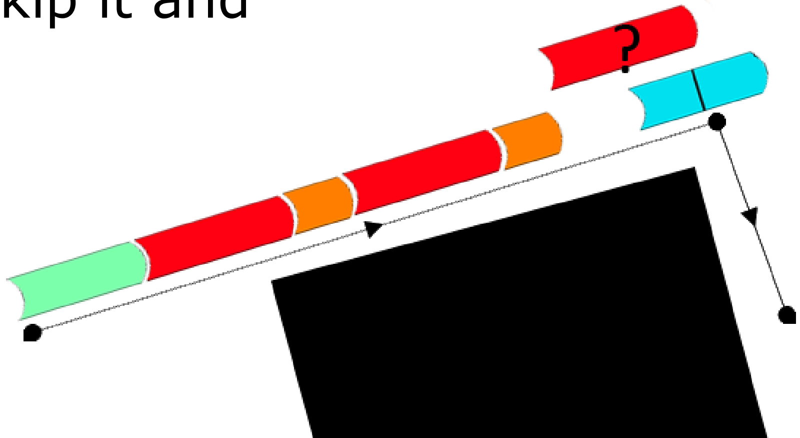


Footstep planning

- We can now insert **Steps**, one leg after the other, until we reach our **Turn** clip

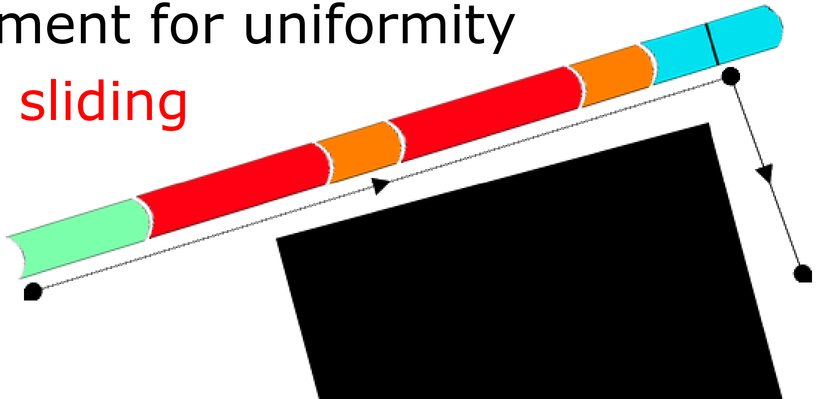
Footstep planning

- We can now insert **Steps**, one leg after the other, until we reach our **Turn** clip
- As expected, we will almost never fit properly.
- We can either take the extra step and *reduce* the displacement of every clip or skip it and *augment* them



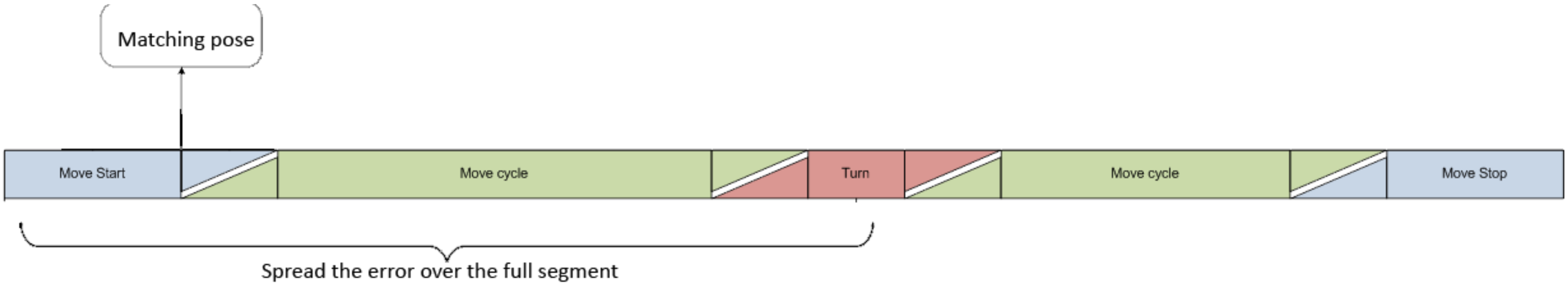
Footstep planning

- We want to select the plan that will minimize the modification to the displacements
- In this case, we will go with fewer steps but make them longer
- We want to spread the distance we were missing with 4 steps through the whole segment for uniformity
- Even so, we will introduce foot sliding



Footstep planning

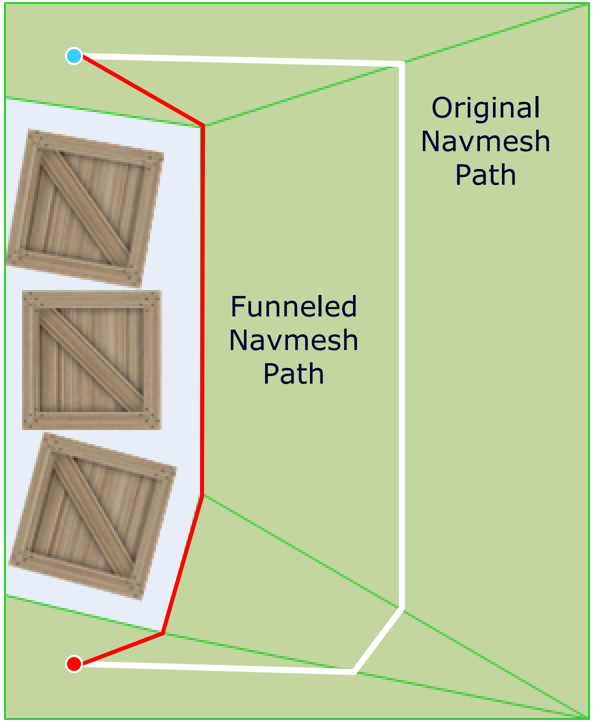
- We repeat this process for every segment
- Calculate by how much you would overshoot or undershoot the current target and annotate the path with that information



Dealing with foot sliding

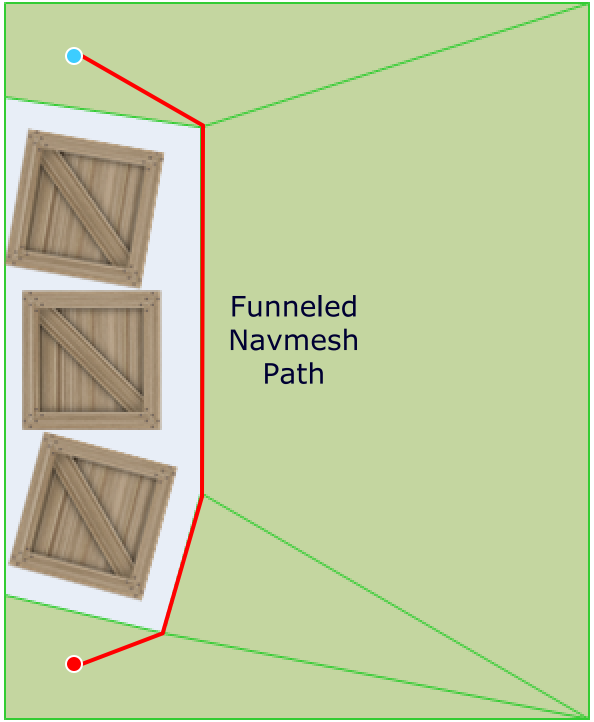
- With this type of planning the error will be at max half a footstep span
    - IK can usually hide this error well enough
- Path post processing is an elegant way to eliminate sliding altogether

Path Post-Processing: Funnel Algorithm



- Standard path-finding only cares about the shortest path
- Post-processing is used on navmesh paths for 'smoothing' usually something like simple funnel algorithm step
- Funneling results in paths hugging exterior navmesh edges so navmeshes are often eroded away from obstacle geometry

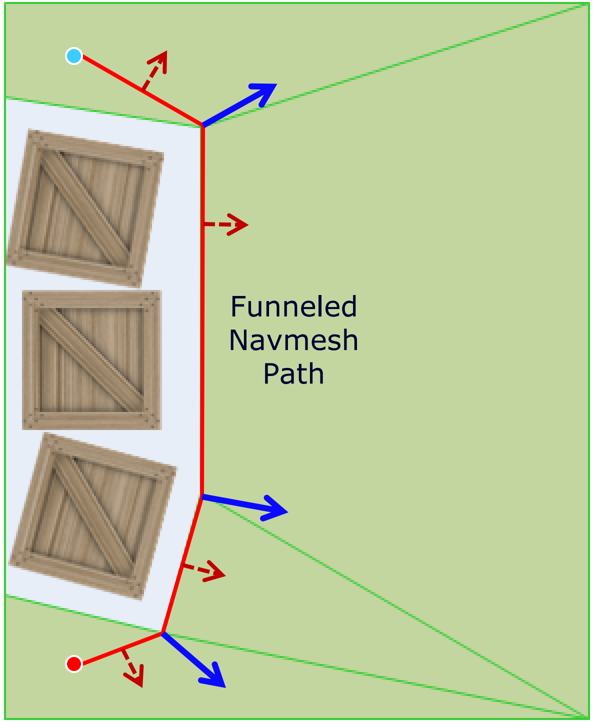
Path Post-Processing: Shortest Paths



- Why the obsession with the shortest path?
  - When path length variations of 10~15% wont be noticed
- Why do we have paths that hug corners
  - When humans don’t walk that way
- Why do we try to hide an error that results from forcing animations onto our paths?

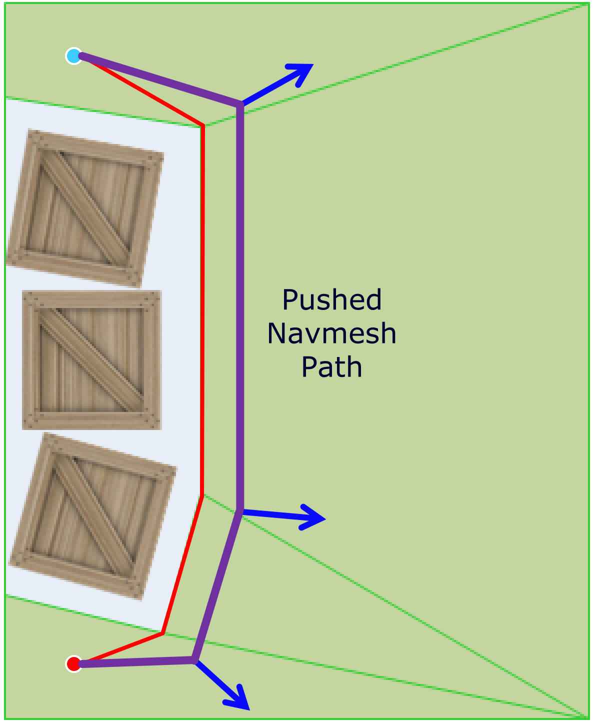
Why don’t we simply force our paths onto our animations

Path Post-Processing: Corner Push Away



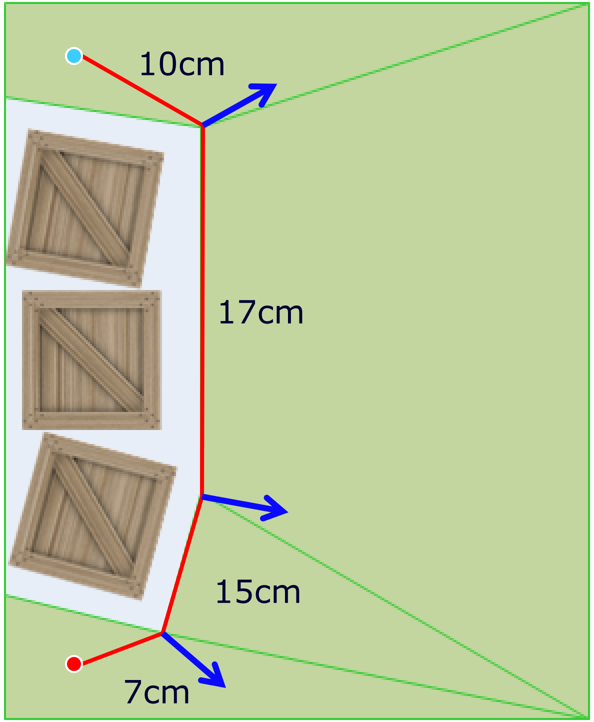
- We create a path push-away vector at each path vertex
- The push-away vector can be any vector directed away from the corner
- One approach is to average the orthogonal vectors of the previous and subsequent path segments at a vertex

Path Post-Processing: Corner Push Away



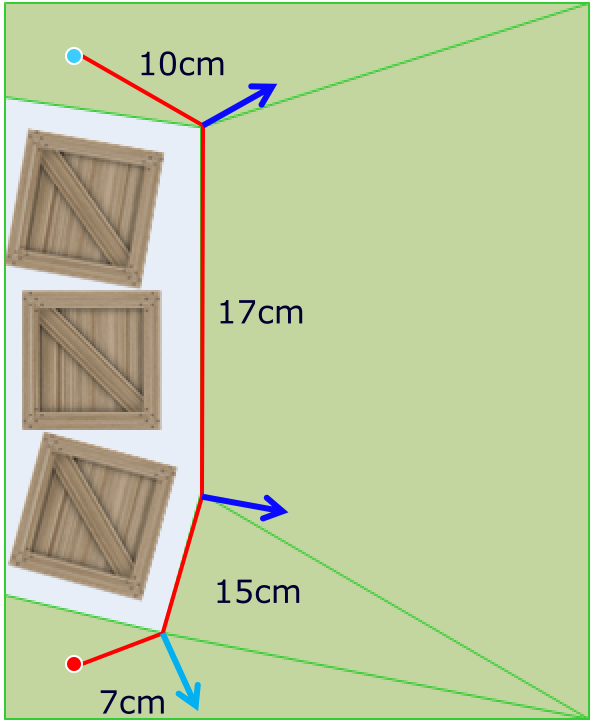
- We create a path push-away vector at each path vertex
- The push-away vector can be any vector directed away from the corner
- One approach is to average the orthogonal vectors of the previous and subsequent path segments at a vertex
- The path can be pushed away from corner and thereby its length can now be dynamically modified

Path Post-Processing: Reducing the Error



- The error per segment is always at most half a footstep
- Once a path is found we plan our footsteps and calculate the distance error per segment
- By pushing away from corners, we can increase the length of the two path segments at that vertex thereby decreasing the error for those segments

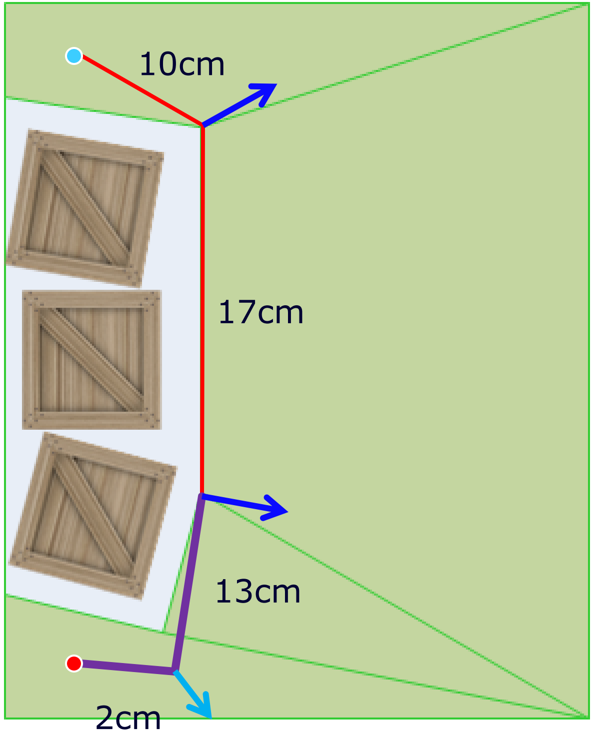
Path Post-Processing: Reducing the Error



- How much do we push per vertex?
- Multivariate optimization problem
- A simple approach can get us most of the way

- We can modify the push direction in favor of the larger error
- While there is an improvement in the error for both segments we keep pushing

Path Post-Processing: Reducing the Error



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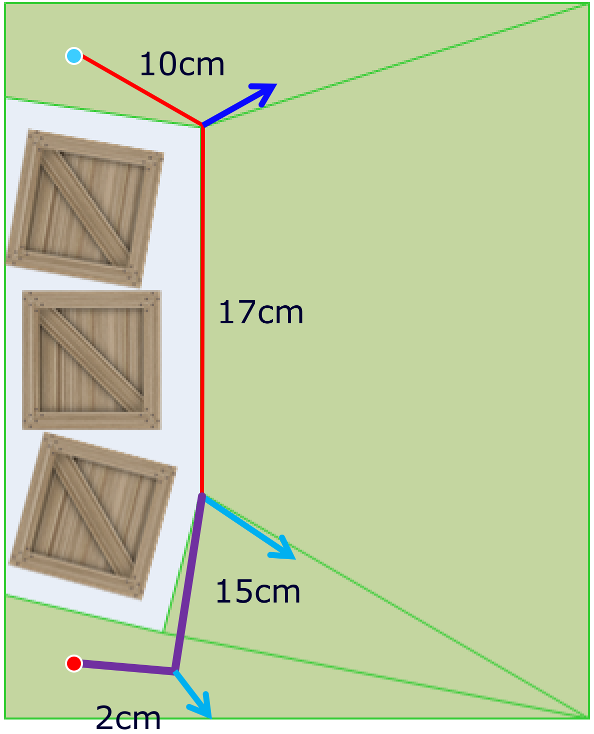

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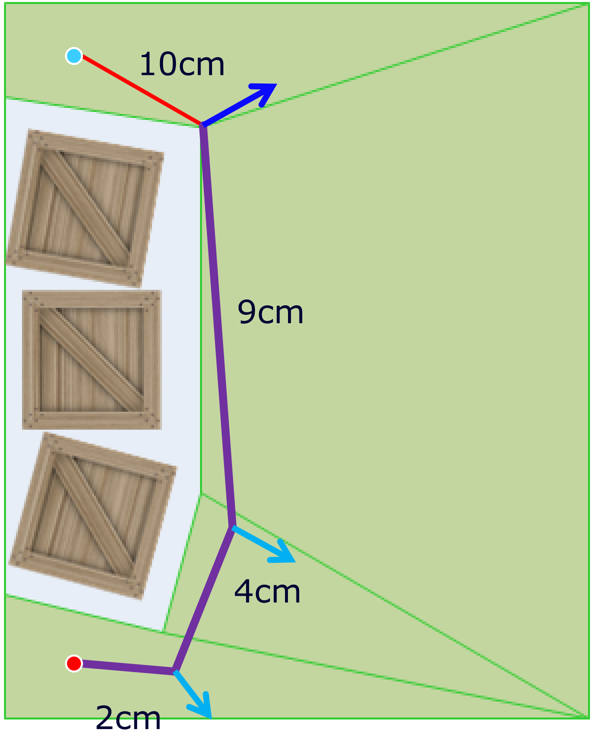

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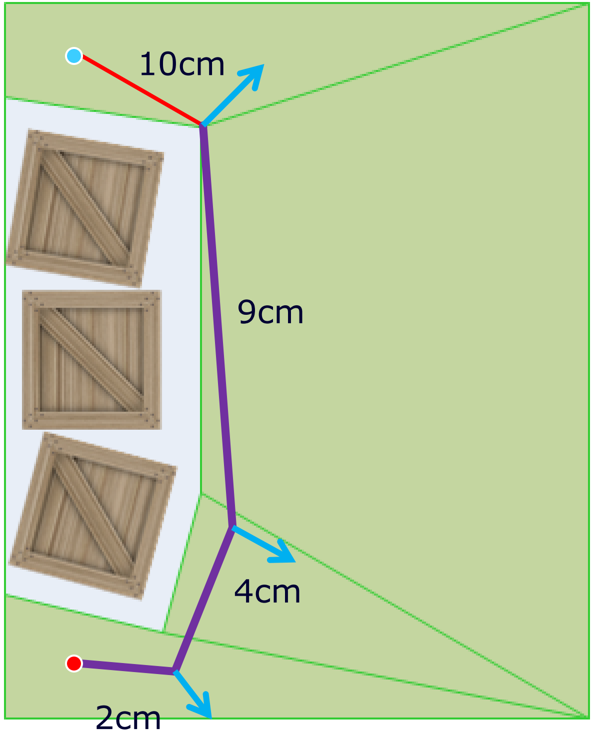

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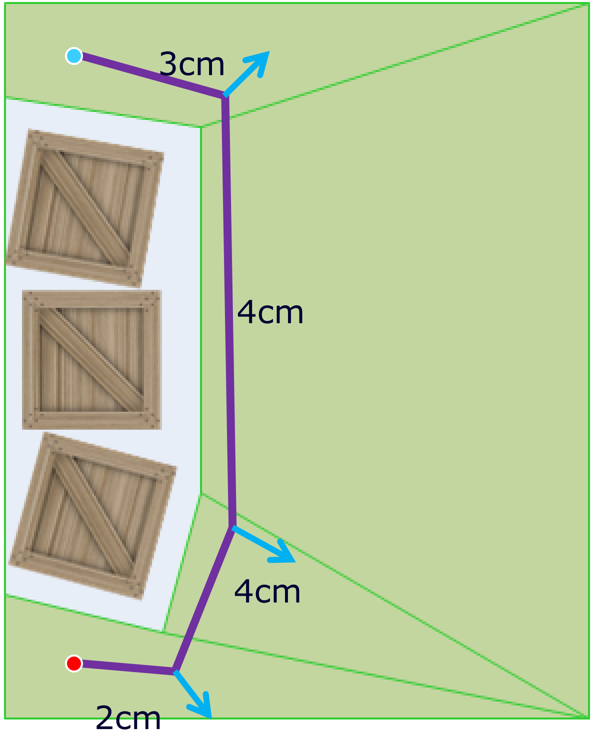

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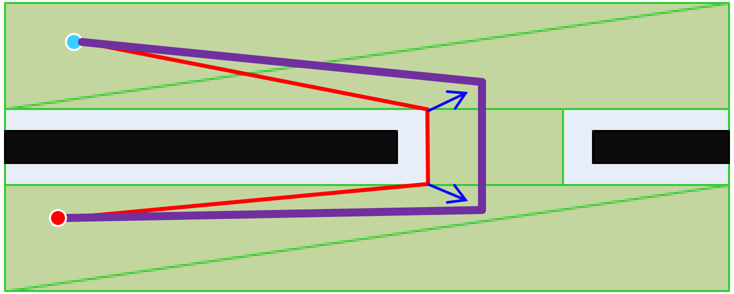
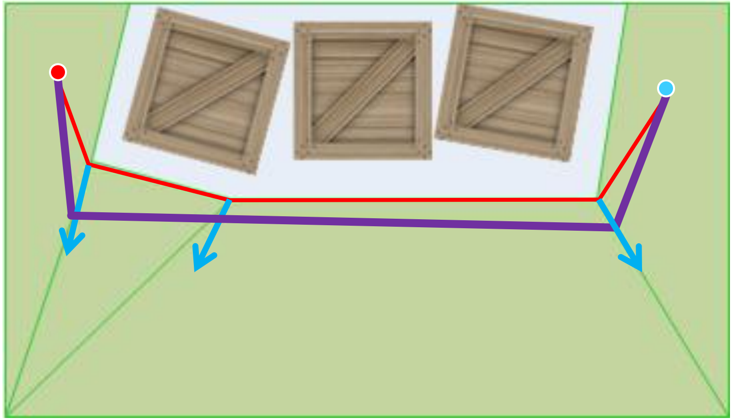
Path Post-Processing: Reducing the Error

- Path post-processing won’t be able to completely reduce all per segments errors in one pass
- The more processing time you give it the better the results
- ~10% error per segment is perfectly acceptable and can be hidden without causing foot sliding

Path Post-Processing: Aesthetics





- By pushing paths away from corners we can improve the visual quality of paths
- Especially useful with regards to tight turns e.g. doorways and staircases
- We can also prevent wall hugging while keeping the navmesh as close to obstacles as possible
- Reduce number of path segments

Using the footstep planner to our advantage

- ADL is all about empowering the animators
- The footstep planner allows customization of the locomotion as well as preparing for interactions

Using the footstep planner to our advantage

- Take this example plan containing two segments
- We can easily alter the plan by cutting a few steps and inserting a custom animation

Using the footstep planner to our advantage

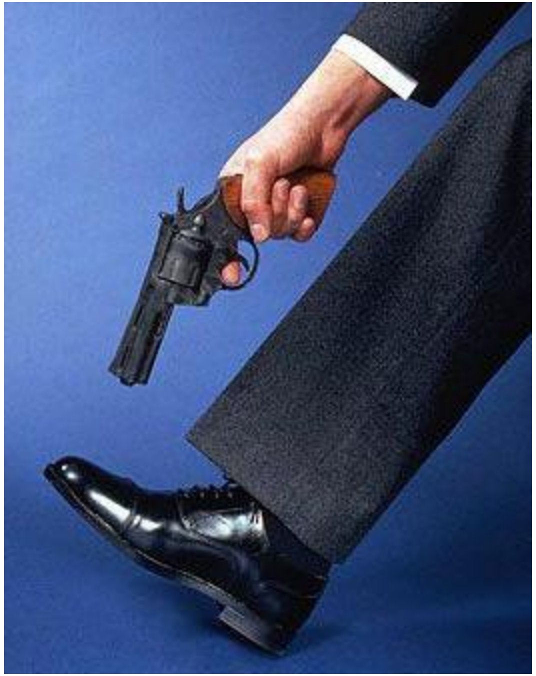
- Take this example plan containing two segments
- We can easily alter the plan by cutting a few steps and inserting a custom animation
- Lets remove 3 steps (right - left - right …)

Using the footstep planner to our advantage

- Take this example plan containing two segments
- We can easily alter the path by cutting a few steps and inserting a custom animation
- Lets remove 3 steps (left - right - left …)
- We can replace it by an animation that will break repetition while ensuring we stay on path

Collision Avoidance in ADL

- Cant talk about locomotion without discussing collision avoidance
- Collision avoidance (CA) is tied to the locomotion system used in the game
- CA is a pretty common problem and so can be taken for granted
- There are certain considerations to take into account with ADL CA systems



ADL CA:

ADL has one major drawback when it comes to CA:

Latency

- With most ADL systems, NPCs can only react/transition at footstep events / transition markers
- Reaction latency is the time between footstep events and varies across movement speeds

ADL CA: Latency

- Both the reaction latency and the resultant NPC motion need to be taken into account when doing ADL CA
- Therefore Collisions need to be **predicted** and not simply reacted to
- Reciprocal collision avoidance for pedestrians (RCAP) - 2010
- Latency was also a significant problem in the extremely dense 1200 character HM:A crowds, which made use of a simplified motion graph controller

Crowds in Hitman: Absolution – Kasper Fauerby

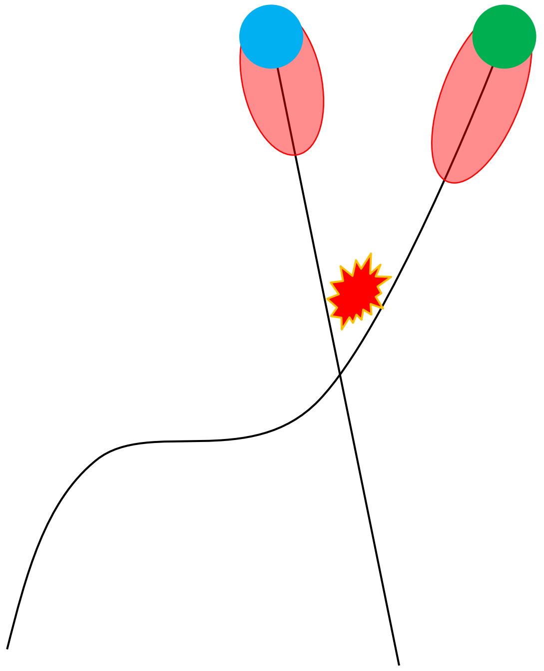
Wednesday,
15:30 - 16:30

Room 2006,
West Hall, 2nd Floor

ADL CA: Lack of Steering

- Most CA techniques make use of velocity obstacles in some form or other – ORCA / RVO / Clearpath
- They also often tend to assume that characters are “steered”
- Steering allows for immediate and fine-grained manipulation of angular acceleration / speed
- Traditional steering often results in foot sliding

ADL CA: Lack of Steering



- Using velocity obstacles for ADL CA can be overkill
- Since we pre-plan motion, we know an NPC's exact position and velocity at any given point in the path
- We simply can perform localized collision detection along NPCs' planned paths

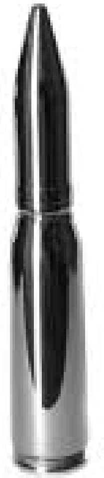
ADL CA: Footstep Re-planning

- Once a collision is detected, we can react to it by either changing speed or by navigating around it
- With footstep planning all avoidance actions will require re-planning of all footsteps along the remaining path.
- This re-planning may also require a new path post process step

ADL CA: Transitions

- Start / Stop transitions can be problematic since NPCs are effectively uncontrollable during the transition
- Transition animation trajectories should be kept as short as possible
- Non-linear motion during transition can make collision detection difficult
- Ensure that NPC’s are guaranteed to be collision free before triggering a start transition

ADL CA: Case Study

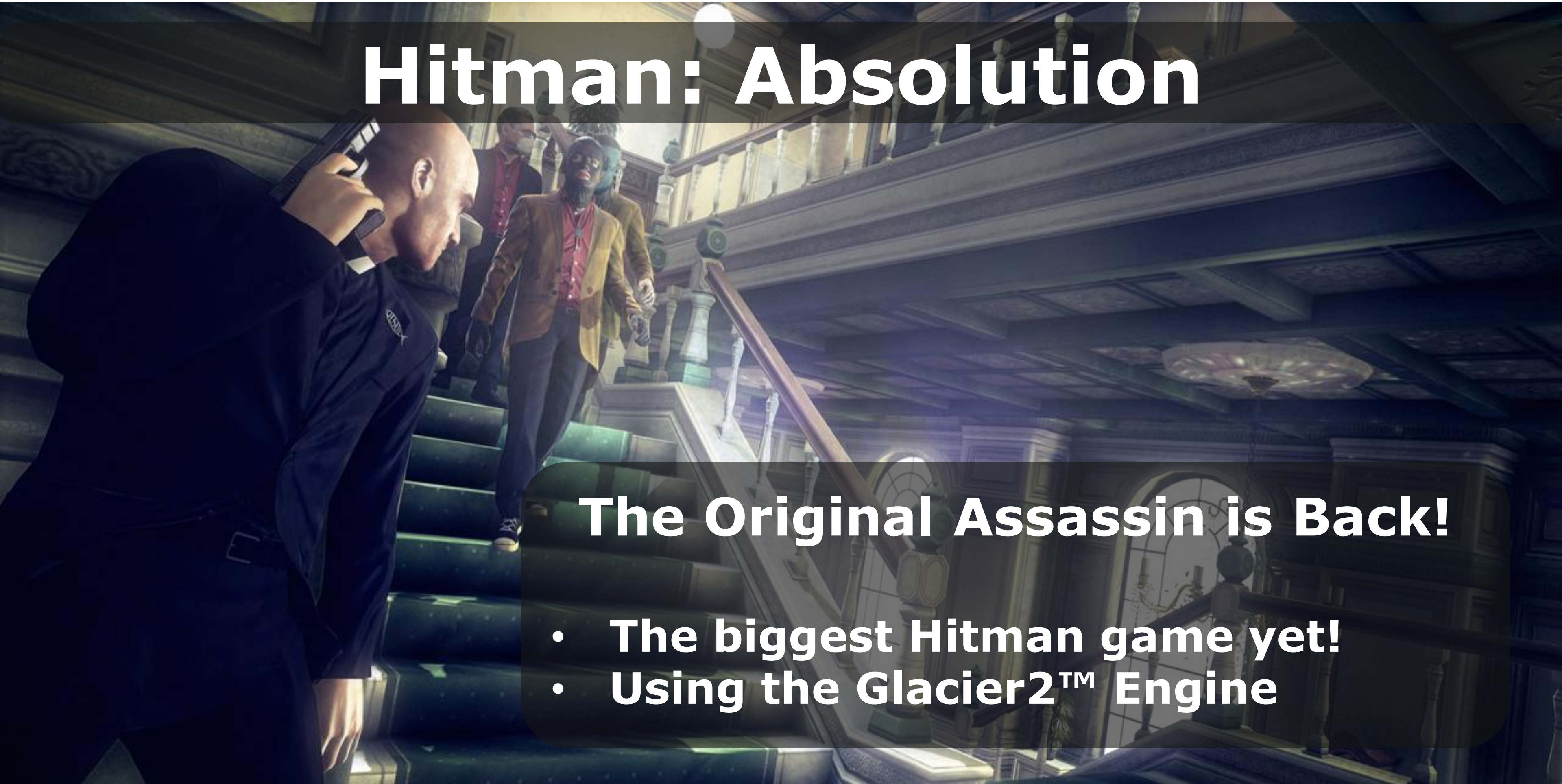


- Collision avoidance is a very game specific problem - **there is no silver bullet**
- Hitman: Absolution also makes use of ADL although we don't use foot step planning
- Even so, HM:A is still a good case study for collision avoidance using pre-planned ADL motion

HITMAN™

ABSOLUTION

Hitman: Absolution



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CA in HM:A – Constraints Design

- In HM:A, we have a new gameplay mode called "**Instinct**" which allows agent 47 to predict all NPC paths

CA in HM:A – Constraints Design

- In HM:A, we have a new gameplay mode called "**Instinct**" which allows agent 47 to predict all NPC paths

- Our NPCs **MUST** follow their paths exactly (on-rails)
- NPC paths need to look good and **NO** foot sliding
- Our post processed paths are converted to a set of quadratic Bezier curves
- We can't constantly modify paths while performing CA

CA in HM:A – Constraints Locomotion

- We don’t use footstep planning
- NPCs don’t have turn animations – we blend in a banking animation when turning
- Discrete movement speeds – walk, jog, sprint, etc…
- In the end we built a really simple system to handle our specific avoidance needs

CA in HM:A – Collision Detection

- We make use of animation metadata to create a local collision horizon
- NPC motion is predicted for that collision horizon along the NPC's path
- Collisions are detected by performing moving sphere intersection tests for the NPC's predicted motion

CA in HM:A – Allowing Collisions & Conclusion

- There are always going to be cases where collisions are unavoidable E.g. During start/stop transitions
- In such cases, we simply allow the collision to occur and play an upper body act to try and hide the collision as much as possible

Conclusion

- This system is not intended to replace all other approaches
- Pick what works best for your requirements

Pro’s

- High fidelity, continuous movement
- Customizable handling of turns
- Interactions can be planned
- Respects the path and destination at all times

Con’s

- Latency can make navigating a dynamic environment difficult
- High memory requirements
- Short distances aren’t friendly

Thanks to:

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