

March 20-24, 2023 San Francisco, CA

Motion Matching at EA 5 Years Later

JC Delannoy Sr Software Engineer, Electronic Arts





About Me

- JC Delannoy -
- Senior Software Engineer
- @ Electronic Arts since 2004 -











⊘•Team

- Applied R&D group for animation
- Many people contributed to our MM implementation
- Big thanks to Paul McComas and Christian Mendoza







MotionFields: The Road to Next-Gen Animation

Michael Büttner



MOTION MATCHING MOTION MATCHING GAMEPLAY ANIMATION . . . TODAY GAMEPLAY ANIMATION . . . TODAY KRISTJAN ZADZIUK WEISZADZIUK # GDCANIM



What This Talk Is About

- Getting Motion Matching into production can be very challenging.
- Productizing Motion Matching.
- Supporting features we've developed along the way.



Agenda

- Motion Matching Everywhere
- Organizing Your Data
- Tips, Tricks and Timesavers



1. Motion Matching Everywhere

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Locomotion Challenges

Constantly changing inputs



Complex state machine



Frequent Animation Transitions







Pose Features

- position
- orientation
- velocity
- angular velocity

Trajectory Features - current velocity + current facing future position/facing past position/facing



Database of Animations





In Game



Anim A	L L L L
Anim B	R. R. R. R.
Anim C	\mathcal{F} \mathcal{F} \mathcal{F} \mathcal{F}
Anim D	<i>K K K K K K K K K K</i>

Obtain values for pose + trajectory features in game.



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In Game



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2. Calculate cost of each frame



In Game





3. Transition to frame with the lowest cost



In Game





4. Repeat every update.

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Constantly changing inputs



Complex state machine





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Frequent Animation Transitions





Constantly changing inputs



Complex state machine







Frequent Animation Transitions





Constantly changing inputs



Complex state machine









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Frequent Animation Transitions



Selection based on pose + trajectory features.



Constantly changing inputs



Complex state machine







Does not need a state machine.



Frequent Animatio. Transitions



Selection based on pose + trajectory features.



Match Node



Query from the MM database **upon entry**



Match Node Example





Warping To Target





Candidate End Points





Distance To Target Cost





Match Node With Motion Warping





Match Gate Node





Match Gate Node



What's the cost of the best asset in **Match Gate Node**?



Match Gate Node



What's the cost of the best asset in **Match Gate Node**?

Take transition **only** if the best frame's **cost** is below threshold.



Combine it with entry animations





Animation Selection with MM

Easy to build datasets



Great for asset selection



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Animation Selection with MM

Easy to build datasets



Great for asset selection





Doesn't handle conditions on game context.

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MM Linked With Context Database

Motion Matching

Context Database

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Motion Matching

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MM Linked With Context Database

Motion Matching

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Context Database

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MM Linked With Context Database

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ALL ANIMATIONS DATABASE



Problems

- So much complexity in a single place
- Difficult to get the desired frame to play since some assets are very similar

ALL ANIMATIONS DATABASE



Pop Quiz

Start animation or acceleration from turn?











Pop Quiz

Start animation or acceleration from turn?







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Pop Quiz +

Start animation or acceleration from turn?









Pop Quiz +

Start animation or acceleration from turn?











Solutions

- Very carefully authoring animations so they will exactly match requests in game.
- Reducing the amount of selectable frames.

ALL ANIMATIONS DATABASE



Solutions

- Very carefully authoring animations so they will exactly match requests in game.



Take CONIRCL of Animation

Ilkka Kuusela , Principal Gameplay Animator Ville Ruusutie , Principal Animation Programmer





Solutions

- Very carefully authoring animations so they will exactly match requests in game.
- Reducing the amount of selectable frames.

ALL ANIMATIONS DATABASE



Asset Tags

Usual motion types: starts, stops, run cycles, drastic turns, idles, etc.





Asset Tags: Filtering

Usual motion types: starts, stops, run cycles, drastic turns, idles, etc.





Asset Tags



- Tagging is time consuming and error prone.
- Constantly opening assets to view tags.



Bucketing

Database broken up into the same categories: starts, stops, cycles, drastic turns, facing changes.





Bucketing

- Searching only from data that is appropriate for the situation
- Becomes very easy to see all assets of one type.
- Easier to vary the MM parameters and feature weights per database.
- Faster to drop an asset into a database than it is to open it up and add the appropriate tag





Asset Tags & Bucketing

- Both systems can co-exist.
- Can choose to use one or the other, or combine them.
- Give your team options. Allow them to work however they feel most comfortable



Context Specific Data

- Prioritize certain animation over others.
- Want a different run forward animation without creating a full locomotion set.
- How do we solve this?





Priority Databases

- Separate database of **prioritized** assets.
- Referenced by the default database.
- If the cost of the best asset in the priority database is below a threshold, then take that asset.
- If not, query the default database. Select between the lowest cost of the two frames.





Priority Databases

Disabled







Disabled



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Enabled



Pros

- Prioritized assets don't need to compete with default assets.
- Don't need extra tags on assets.
- The priority database can be loaded dynamically and only used if available.





3. Tips, Tricks and Timesavers

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Tags: DoNotChoose



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Tag: NextNaturalOnly



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Tag: NextNaturalOnly



Can enter in this zone

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Tag: NextNaturalOnly

Don't skip over important segments of the animation. -





Root Motion Weight

- driven by physics or motion model
- consistent motion feel

0

- lower fidelity



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root motion driven by animation can feel inconsistent higher fidelity



Root Motion Weight





Root Motion Weight



Can change values at runtime

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Zero Root Motion

Variable Root Motion





Debugging





Diagnostics

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Diagnostics

PTM Status

clip:'Fifa_loco_ptm_strafe_circle_jog_02':412.85 (+2.12) mir:0 dt:2.00 database:'Fifa.Loco.StrafeJog.PTMDB.Default' compressed:0 evaluated:40 Path: 'Fifa.Jostle.Friction.Path' cost:36.82 pose:7.54 traj:29.27 other:0.00 ticksSinceSearch:2.00 rootWeightT:0.25 horizon:40.0 pastHorizon:40.0 inspeed:1.37m/s desiredspeed:1.37m/s clipspeed:1.41m/s outspeed:1.38m/soutaccel:0.768m/s^2 futureaccel:0.000m/s^2 speeddiff:-0.00m/s moveanglediff:-3.7deg facediff:0.0deg faceanglevel:0.0deg/sec clip motionType:[Default] clip looping:0 want stop:0 ==> avgFutureVel(0.08) >= stopSpeedThreshold(0.02) want turnOnSpot:0 ==> BelowTurnOnSpotSpeed:0 && wantStop:0 && (isNotFacingCorrect:0 || isTurningFast:0) want start:0 ==> wantStartFromStop(0) : velocity(0.08) >= startSpeedThreshold(0.03) wantStartFromIdle(0) : recentlyStopped(0) | rollingStart(0) phase tol:0.5 footsweep:0 lastFilter: incl:ffffffff[All Flags Set], excl:000a[DoNotChoose|NextNaturalOnly], and:0, clip:-1, KDFound:1 Pose Scale:1.00 Trajectory Scale:1.00 Path Scale:1.00 TrajAdjust: speedmult:1.18 (timescale:1.06 footwarp:1.11) angleadj:17.55 DeltaTrajOut: trans:(x:0.128 y:0.000 z:-0.080) mag:0.151 RootMotionWeightQ:0.00, Rot: path:0.00deg anim:0.17deg adjust:-0.17deg out:0.00deg footwarp:1 motionwarp:0.00

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clip:'Fifa_loc database:'Fi Path: 'Fifa.J cost:36.82 p

PTM Search

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Top Candidates

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Clip Name Fifa loc Fifa_loco

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_ptm_stra .Loco.Stra tle.Friction e:7.54 traj ch:2.00 ro n/s desirec m/s outac 0m/s mov	afe_circle_jog_02':412.85 (+2.12) m afeJog.PTMDB.Default' compressed n.Path' ;29.27 other:0.00 otWeightT:0.25 horizon:40.0 pastH dspeed:1.37m/s clipspeed:1.41m/s ccel:0.768m/s^2 futureaccel:0.000n eanglediff:-3.7deg facediff:0.0deg f	ir:0 d d:0 ev lorizo 1/s^2 facea	t:2.00 valuated:40 nn:40.0 nglevel:0.0deg/					

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p Name	DB Name	Ticks	Fi
fa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau		2
a_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	414.00	2

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Details All Cost Summary	PoseFeatures	PoseFeaturesBrea	k Trajec	tory	Bias	Events	
	DB Name		Ticks	Fran	ne	Mirrored	
ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_spiral_cw_jog_0 ttm_strafe_spiral_cw_jog_0 ttm_strafe_slalom_fwdback ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02 ttm_strafe_circle_jog_02	Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe Fifa.Loco.Strafe	eJog, PTMDB.Defat eJog, PTMDB.Defat	412.85 414.00 412.00 376.00 378.00 448.00 844.00 846.00 50.00 416.00 380.00	206 207 206 188 189 224 422 423 25 208 190		False False False False False True False False False False	-1
otm_strafe_circle_jog_02	Fifa.Loco.Strafe	eJog.PTMDB.Defat	446.00	223		False	



Diagnostics

PTM Searches

Order	Clip Name	DB Name	Ticks	Frame	Mirrored	Filtered	Thre	Cost
0 n n	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.DefaL	412.85	206	False		-1.00	36.82
1	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	414.00	207	False		-1.00	42.19

PTM Diagnost

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clip:'Fifa_loc database:'F Path: 'Fifa.J cost:36.82 p

PTM Searches

Top Candidates

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election	Actor_FB_Biped_Physics ~	1 Result	0			4
ategory	PTM ~	Draw Pose	Animate Poses			
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5						
_ptm_stra Loco.Stra tle.Friction e:7.54 traj rch:2.00 ro n/s desired Bm/s outac 0m/s mov	afe_circle_jog_02':412.85 (+2.12) mir:0 (afeJog.PTMDB.Default' compressed:0 e n.Path' j:29.27 other:0.00 otWeightT:0.25 horizon:40.0 pastHoriz dspeed:1.37m/s clipspeed:1.41m/s cccel:0.768m/s^2 futureaccel:0.000m/s^: eanglediff:-3.7deg facediff:0.0deg face	dt:2.00 valuated:40 on:40.0 2 anglevel:0.0deg				

p Name	DB Name	Ticks	
fa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau		
a_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	414.00	1

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Details All Cost Summary	PoseFeatures	PoseFeaturesBreak	k Trajec	tory	Bias	Events
	DB Name		Ticks	Fran	ne I	Mirrored
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	412.85			False
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	414.00	207		False
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	378.00	189		False
tm_strafe_spiral_cw_jog_0	Fifa.Loco.Strafe	Jog.PTMDB.Defau	846.00	423		True
tm_strafe_slalom_fwdback	Fifa.Loco.Strafe	Jog.PTMDB.Defau	50.00	25		False
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	416.00	208		False
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	380.00	190		False
f	rife (and other	DTHOD D-f	450.00	225		I



Diagnostics

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Show C	ost Details All Cost Summary PoseFe	atures PoseFeaturesBreak Traje	ctory Bia	as Event	s		
Rank	Clip Name	DB Name	Ticks	Frame	Mirrored	Filtered	Cost
0 n n	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	412.85	206	False		36.82
1	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	414.00	207	False		42.19
							45.33
							57.54
4	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	378.00	189	False		58.50
							65.20
							72.90
7	Fifa_loco_ptm_strafe_spiral_cw_jog_0	Fifa.Loco.StrafeJog.PTMDB.Defau	846.00	423	True		77.06
8	Fifa_loco_ptm_strafe_slalom_fwdback	Fifa.Loco.StrafeJog.PTMDB.Defau	50.00	25	False		79.67
9	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	416.00	208	False		81.11
10	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	380.00	190	False		83.42
							86.59
12	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	450.00	225	False		88.81
13	Fifa_loco_ptm_strafe_spiral_cw_jog_0	Fifa.Loco.StrafeJog.PTMDB.Defau	848.00	424	True		101.96
							115.52
15	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	418.00	209	False		123.41
16	Fifa_loco_ptm_strafe_slalom_fwdback	Fifa.Loco.StrafeJog.PTMDB.Defau	52.00	26	False		124.00
17	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	382.00	191	False		149.89
							153.41
							156.52
20	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	1,580.00	790	False		163.18
21	Fifa_loco_ptm_strafe_slalom_fwdback	Fifa.Loco.StrafeJog.PTMDB.Defau	268.00	134	True		171.26
22	Fifa_loco_ptm_strafe_slalom_fwdback	Fifa.Loco.StrafeJog.PTMDB.Defau	54.00	27	False		185.15
23	Fifa_loco_ptm_strafe_circle_jog_02	Fifa.Loco.StrafeJog.PTMDB.Defau	1,582.0	791	False		194.20
24	Fifa_loco_ptm_strafe_slalom_fwdback	Fifa.Loco.StrafeJog.PTMDB.Defau	270.00	135	True		214.20
							219.70
26	Fifa loco otm strafe circle iog 02	Fifa Loco Strafe log PTMDR Defai	384.00	192	False		269.91

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Top Candidates

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_ptm_stra .Loco.Stra tle.Frictio e:7.54 traj ch:2.00 ro n/s desired m/s outad 0m/s mov constantC	afe_circle_jog_02':412.85 (+2.12) mir:0 afeJog.PTMDB.Default' compressed:0 e n.Path' ;29.27 other:0.00 otWeightT:0.25 horizon:40.0 pastHoriz dspeed:1.37m/s clipspeed:1.41m/s cccel:0.768m/s^2 futureaccel:0.000m/s^ eanglediff:-3.7deg facediff:0.0deg face ycle is stopped:0	dt:2.00 evaluated:40 on:40.0 2 anglevel:0.0d	eg/sec			
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p Name		DB N	ame	Ticks		Fi
a_loco_pt	tm_strafe_circle_jog_02	Fifa.	Loco.StrafeJog.PTMDB.Defau	412.8	5	2
a_loco_pt	tm_strafe_circle_jog_02	Fifa.	Loco.StrafeJog.PTMDB.Defau	414.0	0	2

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Details All Cost Summary	PoseFeatures	PoseFeaturesBrea	k Traject	tory E	Bias Events	
	DB Name		Ticks	Frame	Mirrored	
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	412.85		False	
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	414.00	207	False	
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	378.00	189	False	
tm_strafe_spiral_cw_jog_0	Fifa.Loco.Strafe	Jog.PTMDB.Defau	846.00	423	True	
tm_strafe_slalom_fwdback	Fifa.Loco.Strafe	Jog.PTMDB.Defau	50.00	25	False	
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	416.00	208	False	
tm_strafe_circle_jog_02	Fifa.Loco.Strafe	Jog.PTMDB.Defau	380.00	190	False	
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Debug Visualization

Candidate pose + trajectory



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ne	Ticks	Frame	Mirrored	Filter	
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co log PTMDR Constant()	42.00	21	True		
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Debug Visualization

Trajectory of all top candidates



Replay System





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Wrapping Up





Leverage MM outside of locomotion



Give options to your teams



Data organization



Debugging



















Thanks for listening!

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Electronic Arts

