agents in the ADAPT platform are animated with controllers. controllers modify subsets of the character's transform hierarchy, to satisfy some objective. examples include gazing, locomotion, and reaching.

agents that can perform many tasks must have many controllers attached to them. when the number of controllers becomes large, adding new controllers without breaking the older ones is challenging. in addition, adding many controllers without introducing snapping or jerking can be difficult.

**problem**

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- agents that can perform many tasks must have many controllers attached to them. when the number of controllers becomes large, adding new controllers without breaking the older ones is challenging. in addition, adding many controllers without introducing snapping or jerking can be difficult.

**previous approach**

- use controller scripts that follow the typical paradigm for controllers in ADAPT: directly set the transforms of the character.
- since all controllers write to the same data, synchronization problems can arise, tempting the programmer to make individual controllers communicate. if all controllers need to communicate directly, adding new controllers becomes an n^2 problem.
- activating and de-activating controllers produces snapping and jittering artifacts as there is no easy way to blend between arbitrary controller definitions.

**using shadows to coordinate controllers**

- each controller is instantiated with its own skeleton that matches the character's skeleton. we call this "personal skeleton" a 'SHADOW'.

  \[
  \begin{align*}
  \text{Controller A} & : w = 1.3 \\
  \text{Controller B} & : w = 0.5 \\
  \text{Controller C} & : w = 0.2 \\
  \end{align*}
  \]

- the master controller interpolates the skeletons based on per-controller and per-joint blend weights \( [w_a, w_b, w_c] \). it can crossfade controllers by adjusting blend weights. controllers can now be crossfaded rather than turned on and off naively, eliminating snapping.

- the master controller sends messages to each individual controller, thus there is no need for controllers to communicate with each other. as a result, adding new controllers is less likely to turn into an n^2 problem.

- controllers can output their shadow as an ordered array of transforms. controllers can take these arrays as input, modify the transforms, and apply it to the shadow. this allows us implement blend trees INSIDE the master controller. see diagram below for an example.

- blend trees allow us to specify the order in which controllers act on the skeleton's state. in the example above, four controllers are blended FIRST, and then the gazing controller procedurally twists the output. this allows us to twist the character from an arbitrary pose. the gazing controller is blended with the non-twisted skeleton, which allows us to fade the controller in and out.

- existing controllers are modified for use with shadows by inheriting from a C controller interface, and by changing pointers from a character's skeleton \( \text{e.g. this.transform.root} \) to pointers to the shadow's skeleton \( \text{e.g. this.shadowMan.root} \).

**results**

- the snapping exhibited earlier has been eliminated since we can crossfade between controllers.
- character in red uses the OLD set of controllers. character in brown uses NEW set.

**future work**

- the master controller must be modified when new controllers are added. this could be automated with a messaging interface in which controllers are registered with the master controller.
- a GUI could be written to simplify authoring of blend trees like the one in described in "Using Shadows to Coordinate Controllers".
- support for blending skeletal hierarchies different from the character's should be added. e.g. some controllers may only control a partial skeleton, others expect an additional root node.
- adding complex controllers can be painful due to the number of references that need to be changed. some of this could be automated with features like reflection in C#?

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