Motion Commands and Real-Time Programming

15-494 Cognitive Robotics
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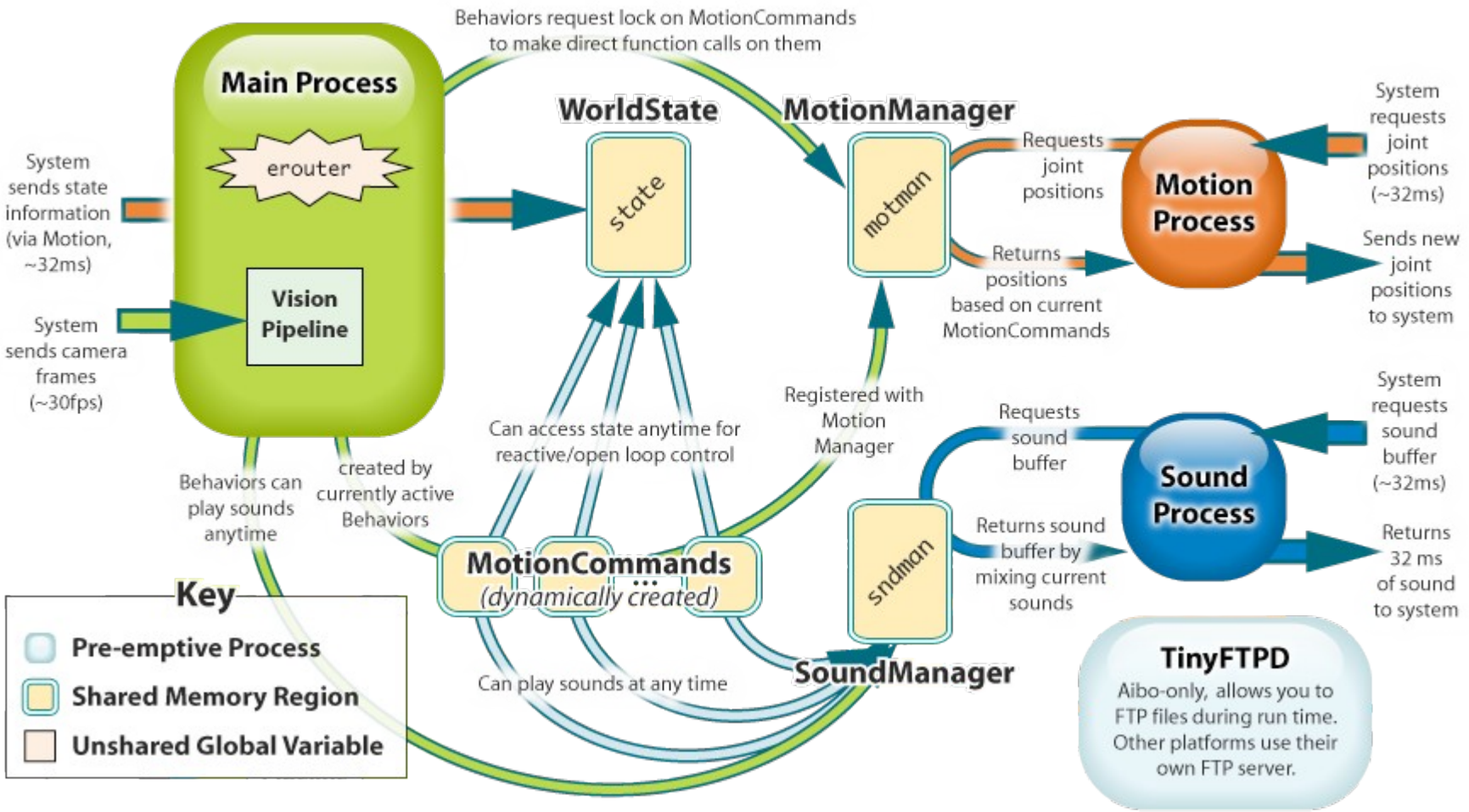
Motion Commands Live in Shared Memory



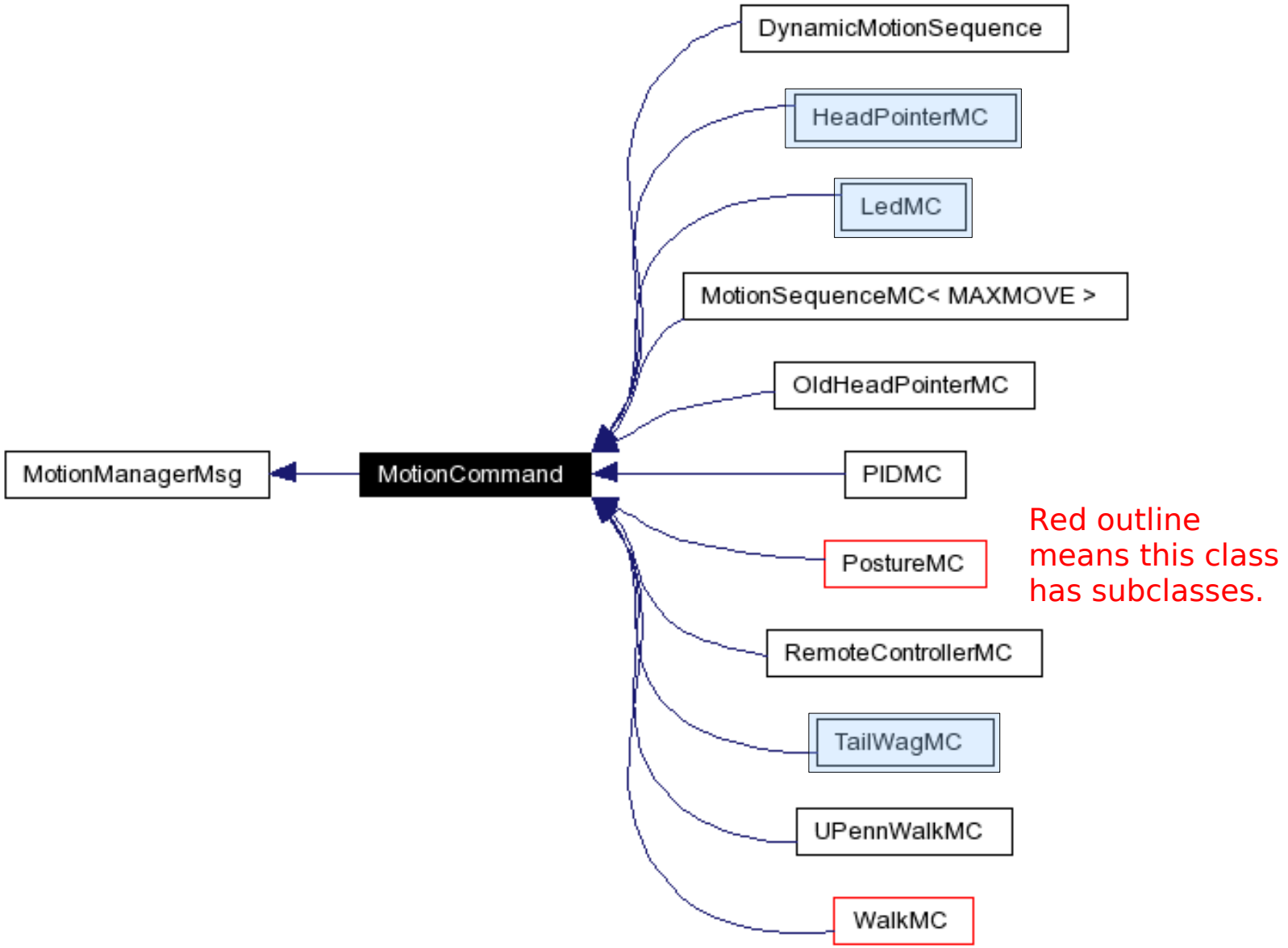
Motion Commands Are Objects

A MotionCommand is an object with 2 kinds of methods:

1) Command methods for telling it what you want it to do.
   - Called by user code running in Main.

2) An `updateOutputs()` method for computing new effector values (joint angles, LED brightness, etc.)
   - Called every 32 ms by the motion manager, running in Motion.

Types of Motion Commands

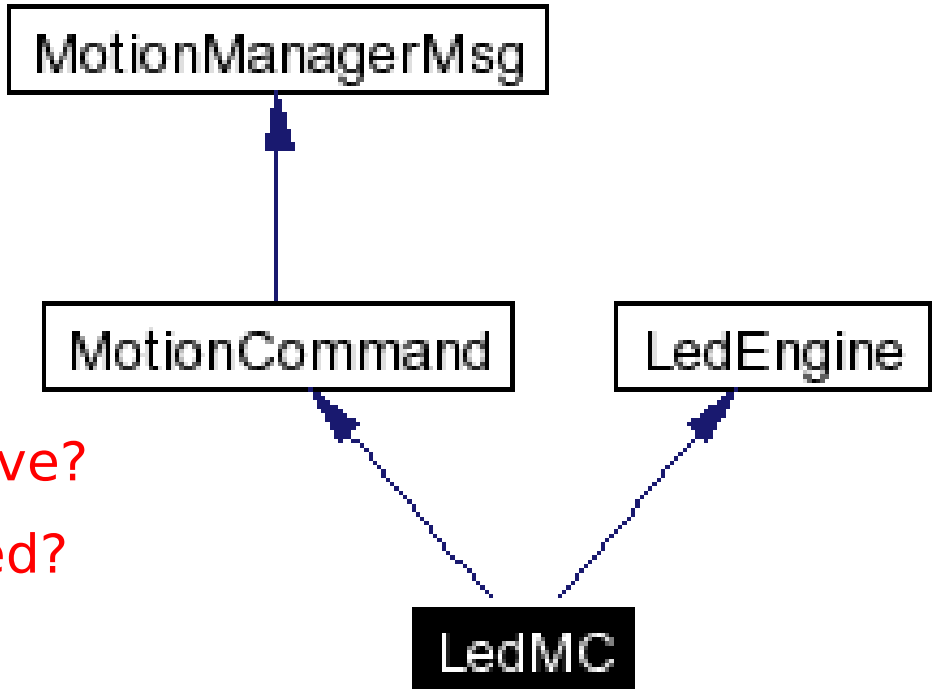


Creating a Motion Command

- `SharedObject<LedMC> leds_mc;`
- The actual LedMC object is created in shared memory.
- The SharedObject named leds_mc lives in Main's address space, and holds a pointer to the shared memory region.
- Two ways to refer to a motion command within Main:
  - via the shared object
  - via the MC_ID (Motion Command ID) assigned to it by the Motion Manager (motman) when the motion command is active

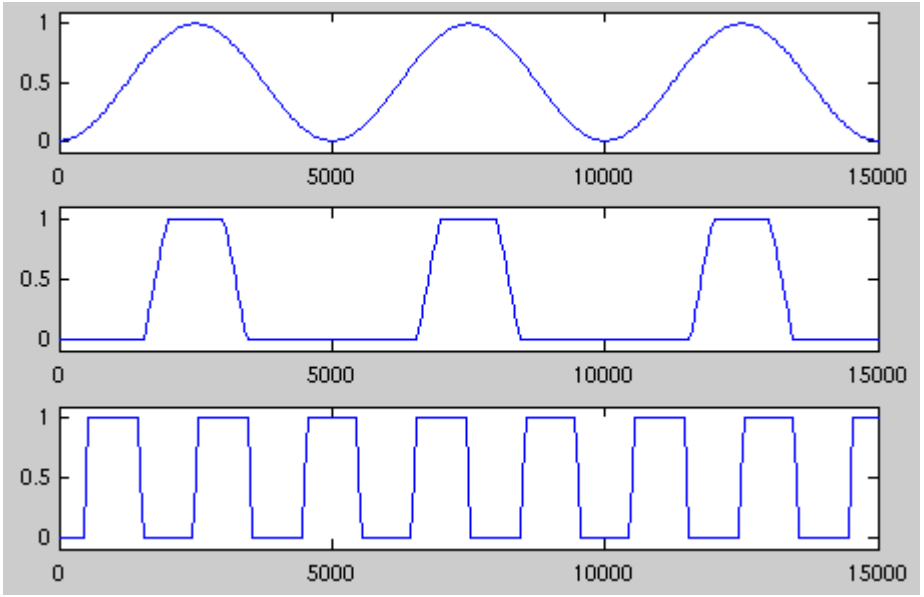
LedMC

- Defined in Motion/LedMC.h
- LedMC inherits from two parent classes.
- MotionCommand:
  - updateOutputs()
  - isAlive() : is this command active?
  - isDirty() : have outputs changed?
- LedEngine:
  - cycle(...) : cycle these LEDs (sine wave pattern)
  - flash(...) : flash these LEDs for n msecs, then end
  - invert(...) : invert the status of these LEDs
  - etc.



LedEngine

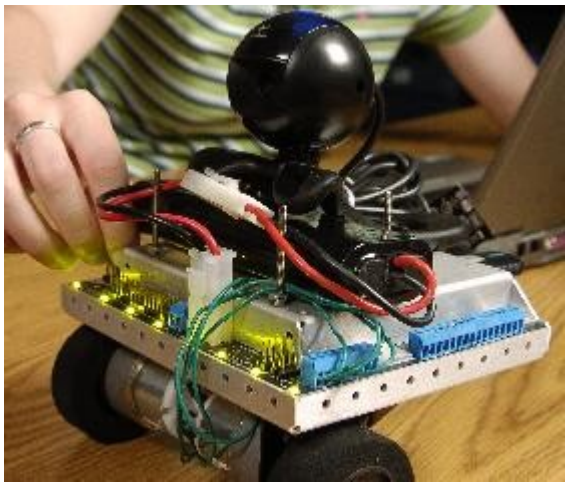
- cycle(LEDBitmask_t *bitmask*,
  unsigned int *period*,
  float *amplitude*,
  float *offset=0*,
  int *phase=0)*



period = 5000 ms
amplitude = 1

period = 5000 ms
amplitude = 5
offset = -1

period = 2000 ms
amplitude = 200



Sample LedMC Program

```
#include "Behaviors/BehaviorBase.h"
#include "Motion/LedMC.h"
#include "Motion/MotionManager.h"

class DstBehavior : public BehaviorBase {

protected:
  MotionManager::MC_ID leds_id;    // id of MotionCommand

public:
  DstBehavior() : BehaviorBase("DstBehavior"),
                  leds_id(MotionManager::invalid_MC_ID) {}
```

Sample LedMC Program

```
virtual void DoStart() {

    BehaviorBase::DoStart();
    cout << getName() << " is starting up." << endl;

    SharedObject<LedMC> leds_mc;
    leds_mc->cycle(RobotInfo::FaceLEDMask, 1000, 100.0);
    leds_id = motman->addPersistentMotion(leds_mc);

  }
```

- SharedObjects and MCs are both reference counted.
- What happens to `leds_mc` when DoStart returns?
- What happens to the motion command?

Operator Overloading

- leds_mc is of type SharedObject
- cycle(...) is a method of LedEngine, not SharedObject.
- So why does this work?

```
leds_mc -> cycle(RobotInfo::FaceLEDMask, 1000, 100.0);
```

- The arrow operator is overloaded by SharedObject. It will dereference the pointer to the actual LedMC in shared memory, and call its cycle(...) method.

Sample LedMC Program

```
virtual void DoStop() {

    motman->removeMotion(leds_id);
    leds_id = MotionManager::invalid_MC_ID;

    cout << getName() << " is shutting down." << endl;
    BehaviorBase::DoStop();

  }
```

- We needed to keep leds_id around so we could reference the motion command in DoStop().
- You should always remove motion commands when you're done with them, unless autopruned.
- cycle() can't be autopruned. Why not?

Mutual Exclusion: MMAccessor

- Suppose we want to change the parameters of a motion command while it's active.
- Example: change the cycle period of a LedMC.
- Not safe for Main to change an active MC while Motion is trying to use it. Need a mutex mechanism:

```
{
    MMAcessor<LedMC> leds_acc(leds_id);
    leds_acc->cycle(RobotInfo::FaceLEDMask, 250, 100.0);
}
```

- Constructor handles checkout; destructor handles checkin. Within scope of leds_acc, motman locked out.
- Don't lock it out for too long!

Changing the Cycle Period When a Button Is Pressed

```
virtual void DoStart() {

    BehaviorBase::DoStart();
    cout << getName() << " is starting up." << endl;

    SharedObject<LedMC> leds_mc;
    leds_mc->cycle(RobotInfo::FaceLEDMask, 1000, 100.0);
    leds_id = motman->addPersistentMotion(leds_mc);

    erouter->addListener(this,
                         EventBase::buttonEGID,
                         RobotInfo:LFrPawOffset);

  }
```

Changing the Cycle Period When a Button Is Pressed

```
virtual void processEvent(const EventBase &event) {

  int const new_period =
    event.getMagnitude() == 0 ? 1000 : 250;

  MMAccessor<LedMC> leds_acc(leds_id);
  leds_acc->cycle(RobotInfo::FaceLEDMask,new_period,100.0);

  }
```

Using MMAccessors

- Declare a local variable if you need to change multiple MC parameters:

```
MMAccessor<LedMC> leds_acc(leds_id);
leds_acc->cycle(RobotInfo::FaceLEDMask,500,1.0);
leds_acc->cycle(RobotInfo::BackLEDMask,2000,2.0);
```

- Just call the constructor if you only need to change one:

```
MMAccessor<LedMC>(leds_id)->
   cycle(RobotInfo::FaceLEDMask,500,1.0);
```

Prunable Motions

- flash(LEDBitMask_t *bitmask*,
  float *value*,
  unsigned int *msec*)

  Sets the specified LEDs to *value* for so many msec, then sets them back.

- Once the action is complete, the motion command has no more work to do.

- If it's a persistent motion, it sits around waiting for its next assignment. If a prunable motion, the motion manager removes (prunes) it.

Flash the Back LEDs for 15 secs

```
virtual void DoStart() {

    BehaviorBase::DoStart();

    SharedObject<LedMC> leds_mc;
    leds_mc->flash(RobotInfo::BackLEDMask, 15000, 1.0);
    leds_id = motman->addPrunableMotion(leds_mc);
    cout << “Created LedMC, id = “ << leds_id << endl;

    BehaviorBase::DoStop();

  }
```

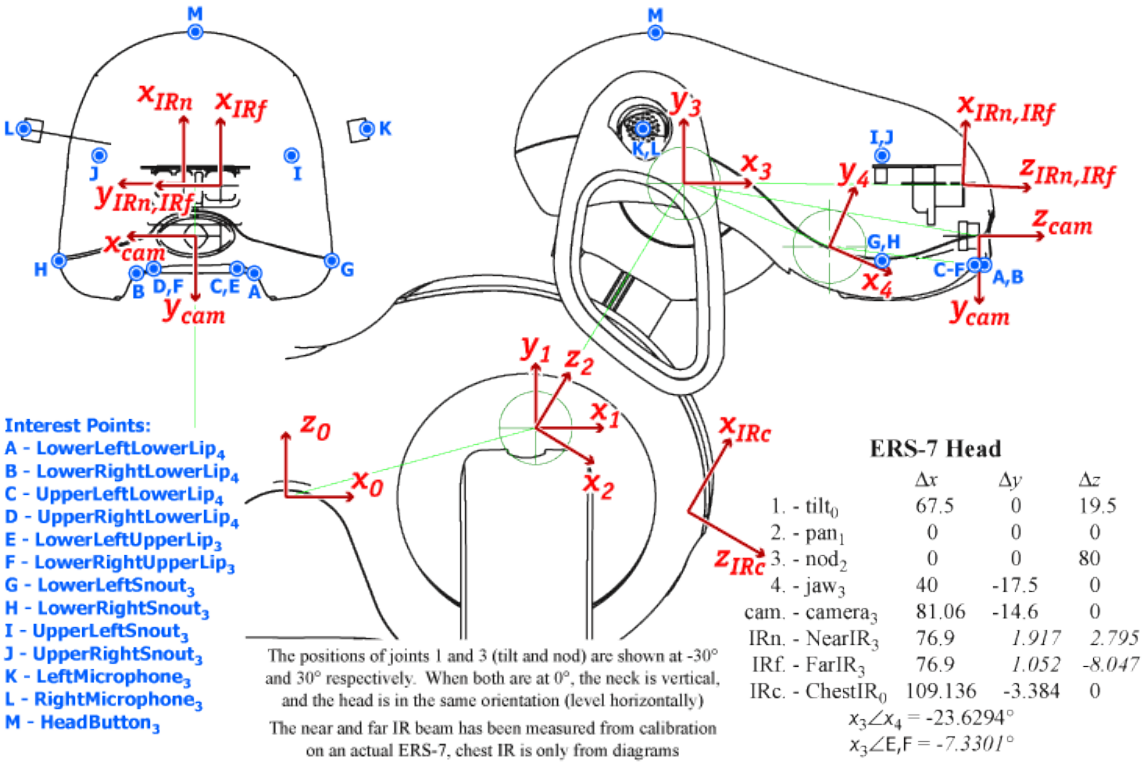
- What would happen if you started this behavior three times within a few seconds?

Moving the Head

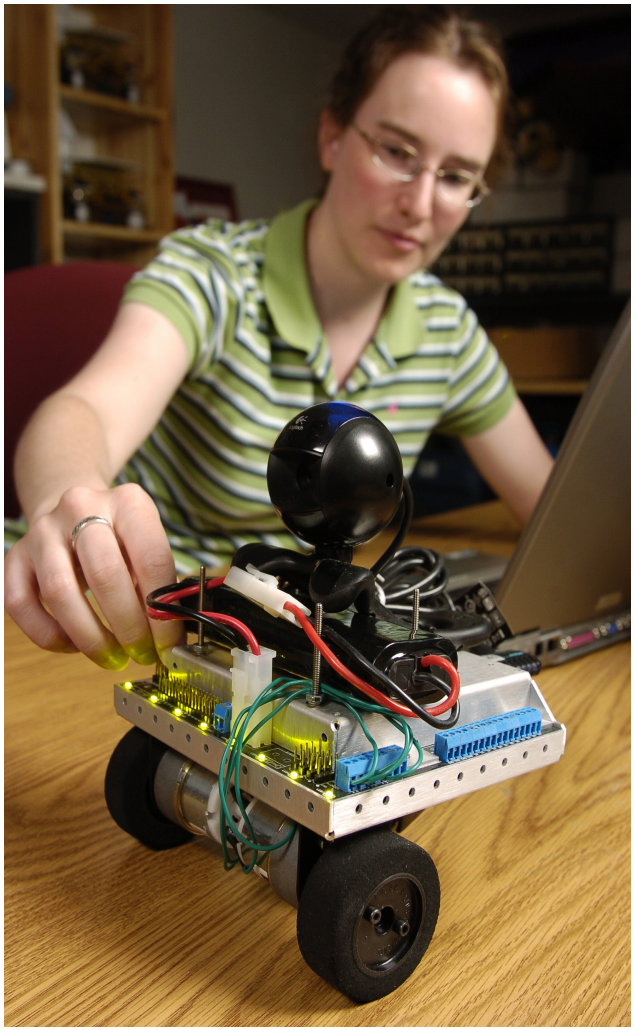
- Three head joints:
  tilt, pan, nod

- Head joints are named by their offsets into the joint array:

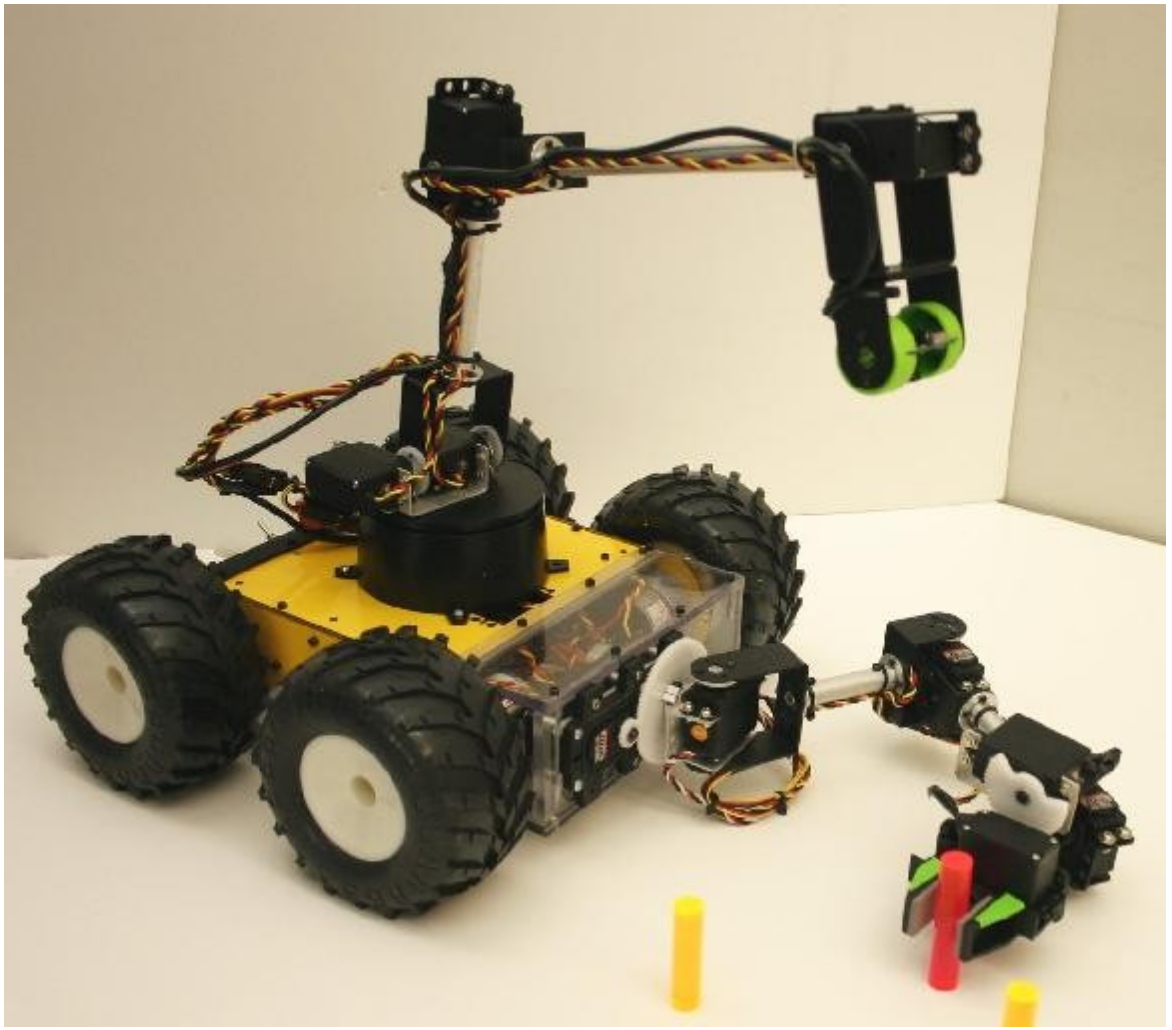
  TiltOffset
  PanOffset
  NodOffset



The Camera Defines the “Head”



Qwerkbot: 2DOF “head”
(pan and tilt)



Regis: 4DOF “goose neck”:
base (pan), shoulder/elbow/wrist (tilt)

HeadPointerMC

Defined in Motion/HeadPointerMC.h

- void setJointValue(unsigned int *joint*, float *value*)
  - setJointValue(TiltOffset, 0.5)
- float getJointValue(unsigned int *joint*) const
- void setMaxSpeed(unsigned int *joint*, float *x*)
- void setJoints(float *tilt*, float *pan*, float *nod*)

Detecting Motion Completion

- It takes time to move the head.
- Behaviors can't wait around: must relinquish control! (If they don't, sensor values can't be updated, since this happens in the same process, Main, where the behaviors run.)
- HeadPointerMC posts a status event when motion completes or times out. The generator is motmanEGID.

- To smoothly chain actions together, listen for status events. (Or use Tekkotsu's state machine formalism.)
- Example: moving the head and then blinking.

Move Head Then Blink

```
#include "Behaviors/BehaviorBase.h"
#include "Events/EventRouter.h"
#include "Motion/HeadPointerMC.h"
#include "Motion/LedMC.h"
#include "Motion/MMAccessor.h"
#include "Motion/MotionManager.h"
#include “Shared/WorldState.h”

class DstBehavior : public BehaviorBase {
protected:
  MotionManager::MC_ID leds_id, head_id;

public:
  DstBehavior() : BehaviorBase("DstBehavior"),
          leds_id(MotionManager::invalid_MC_ID),
          head_id(MotionManager::invalid_MC_ID) {}
```

Move Head Then Blink

```
virtual void DoStart() {
   BehaviorBase::DoStart();

   SharedObject<LedMC> leds_mc;
   leds_id = motman->addPersistentMotion(leds_mc);

   SharedObject<HeadPointerMC> head_mc;
   head_mc->setMaxSpeed(RobotInfo::TiltOffset,0.5);
   head_id = motman->addPersistentMotion(head_mc);

   erouter->addListener(this,EventBase::buttonEGID);

   erouter->addListener(this,
                        EventBase::motmanEGID,
                        head_id,
                        EventBase::statusETID);
 }
```

Move Head Then Blink

```
virtual void DoStop() {

   motman->removeMotion(leds_id);
   leds_id = MotionManager::invalid_MC_ID;

   motman->removeMotion(head_id);
   head_id = MotionManager::invalid_MC_ID;

   BehaviorBase::DoStop();

 }
```

Move Head Then Blink

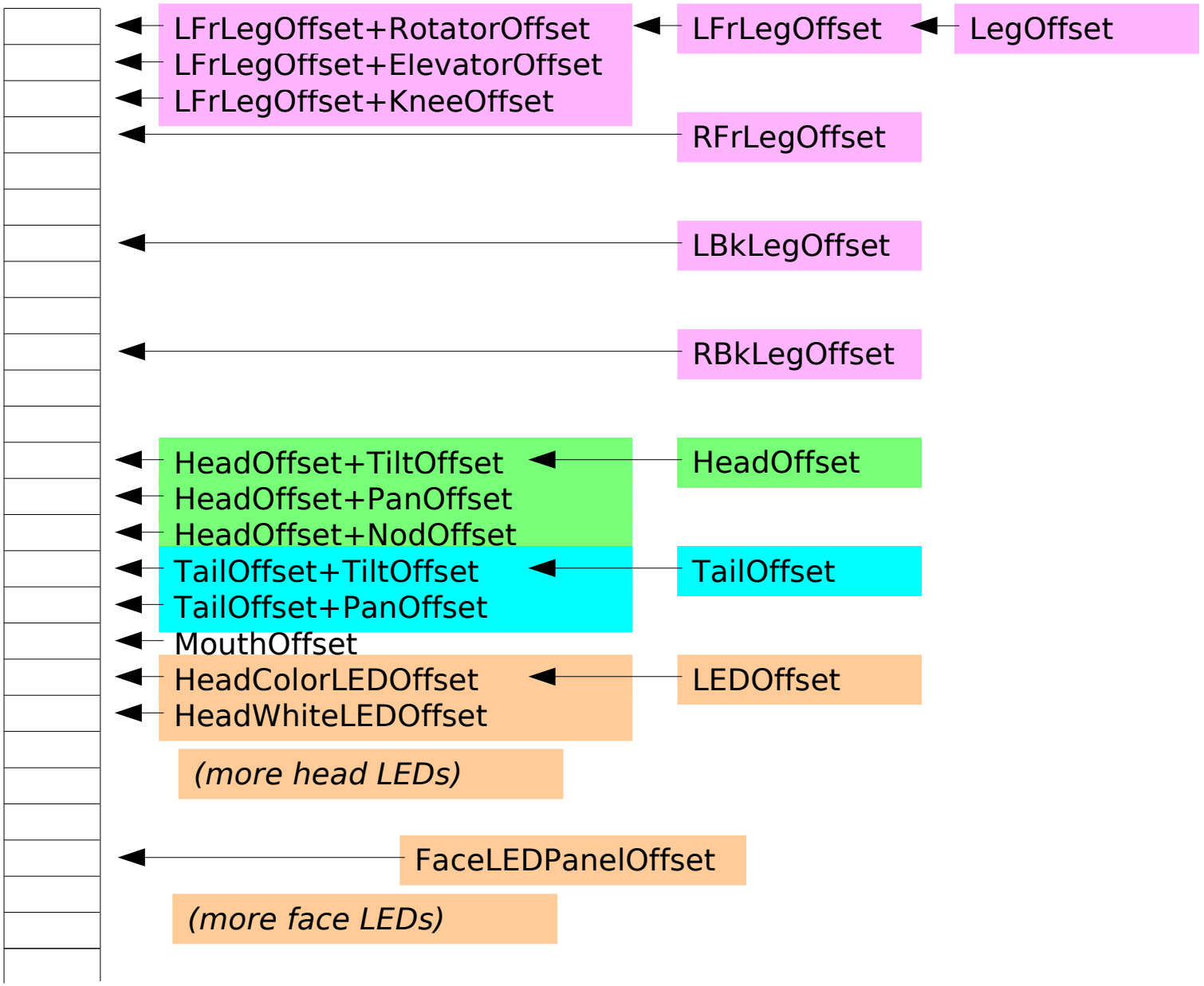
```
virtual void processEvent(const EventBase &event) {
    switch ( event.getGeneratorID() ) {

    case EventBase::buttonEGID:
      if ( event.getTypeID() == EventBase::activateETID )
        MMAccessor<HeadPointerMC>(head_id)->
          setJointValue(TiltOffset, calcNewHeadTarget());
      break;

    case EventBase::motmanEGID:
      MMAccessor<LedMC>(leds_id)->
        flash(RobotInfo::FaceLEDMask, 1000);
    }

}
```

To be defined shortly

Describing Effectors

- Tekkotsu maintains several arrays describing effectors:
  - the current value for each effector (i.e., each joint, LED, etc.)
  - min and max permissible value for each effector
  - PID settings for each joint-type effector
- Effectors are named by their offsets into these arrays, e.g., `MouthOffset` is the name of the mouth joint.
- See the file ERS7Info.h or QbotPlusInfo.h for definitions.

AIBO Effector Offsets



Move Head Then Blink

```
float calcNewHeadTarget() {
  const float lowpos =
       RobotInfo::outputRanges[HeadOffset+TiltOffset]
                              [MinRange];
  const float highpos =
       RobotInfo::outputRanges[HeadOffset+TiltOffset]
                              [MaxRange];
  const float midpos = (lowpos + highpos) / 2;

  const float curpos = state->outputs[HeadOffset+TiltOffset];

 if ( curpos < midpos )
    return highpos;
  else
    return lowpos;
}
```

Thought Questions

1) Suppose you push a button, the head starts to move, and you push the button again. What happens?

2) Suppose you activate the behavior, then turn on HeadPointerRemoteControl and try to move the head around while the behavior is still running. The result is jerky and the motion is attenuated. Why?

3) Suppose you don't want your active HeadPointerMC to start affecting the head until the user presses a button? What are some ways you could prevent this?

Motion Command Priority Level

- kIgnoredPriority = -1.0 won't be expressed
- kBackgroundPriority = 0.0 use if nothing else running
- kLowPriority = 5.0
- Default: kStdPriority = 10.0 what you get by default
- kHighPriority = 50.0
- kEmergencyPriority = 100.0 used by Emergency Stop

Move and Then Blink

- In DoStart()
  ```
  head_mc->setPriority(kIgnoredPriority);
  ```
- In processEvent(), before moving the head:
  ```
  head_acc->setPriority(kStdPriority);
  ```
- In processEvent(), after head motion completes:
  ```
  head_mc->setPriority(kIgnoredPriority);
  ```
- Note: setPriority() is inherited from MotionCommand, so it does not show up in the method list in the documentation for HeadPointerMC.

Motion Command Weight

- For each joint, the Motion Manager orders commands by priority and computes a weighted average as a function of both the priorities and the weights.

- Starting with the highest priority, if weights of active motion commands sum to < 1, the remaining weight is allocated to the next highest priority, and so on.

- Weights are adjustable. To set tilt/pan/nod weights:

```
head_mc->setWeight(0.5)
```

- Need to set individual joint weights? Use a PostureMC.

TailWagMC

- Wags tail back and forth (sine wave).
- User-specified period, magnitude.
- User can also adjust the tilt (but this doesn't change during wagging.)
- Stop/start with setActive(bool)

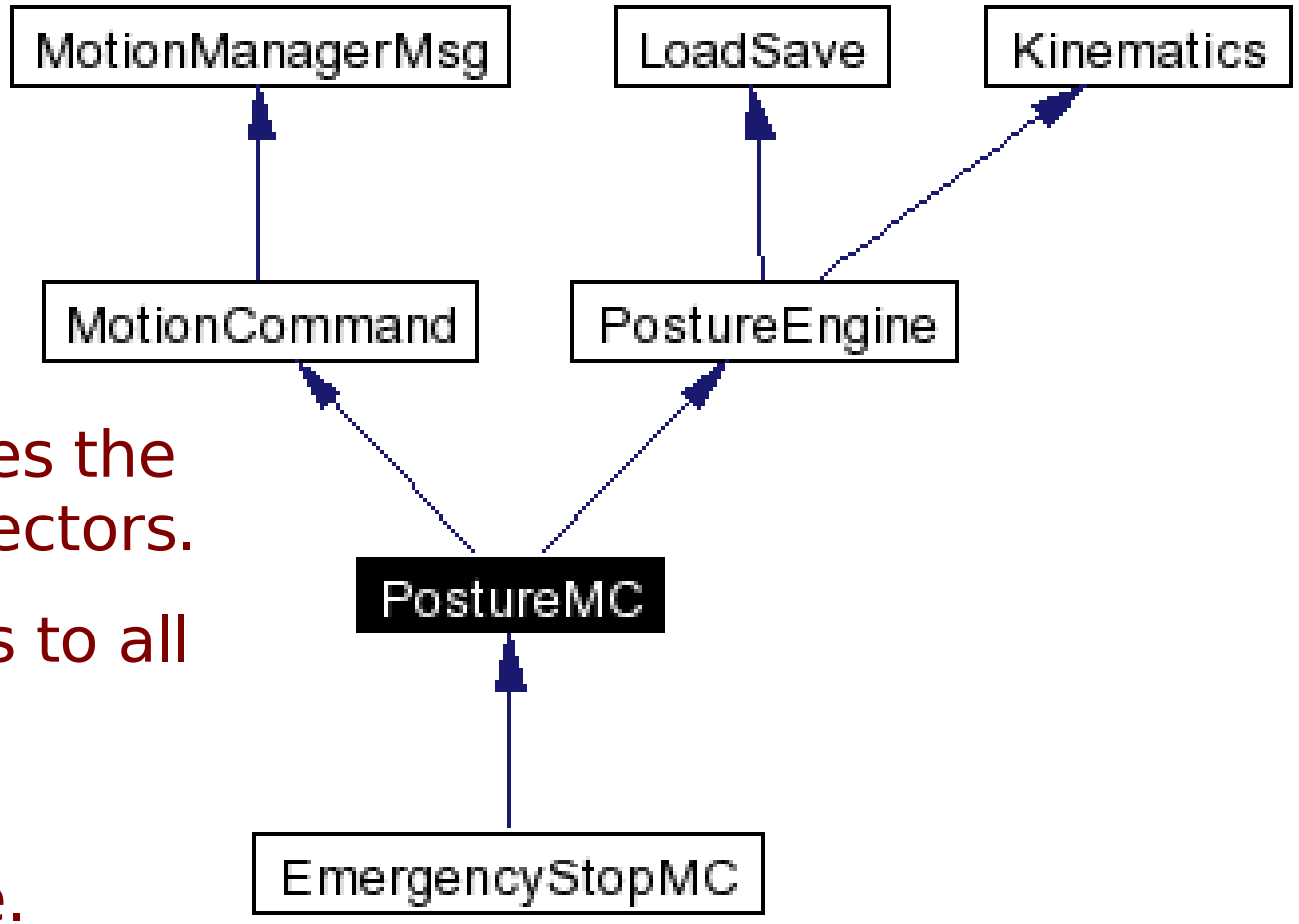
- Can “unset” the tilt to allow some other motion command to control it while this one handles the wag.
- “Unset” = set tail tilt weight to zero.

How MCs Really Work

- LEDs, head joints, tail joints, etc. are all effectors.
- OutputCmd specifies a value and weight for one effector.

- Aperios wants new effector values every 8 msec. But it buffers them 4 frames at a time.
- So LedMC, HeadPointerMC, and TailWagMC's updateOutput() methods are called every 32 msec and need to return 4 frames' worth of output.
- HeadPointerMC uses 3 OutputCmds, one per joint. LedMC uses 4*27 OutputCmds (there are 27 LEDs). TailWagMC uses 5 (1 for tilt and 4*1 for pan).

PostureMC



- A “posture” specifies the states of all the effectors.
- Offers direct access to all OutputCmds.
- Can load/save postures from a file.
- Interface to kinematics engine.