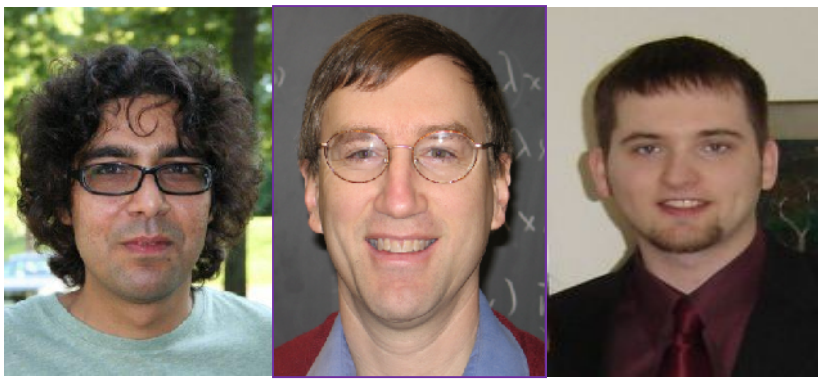
Applying Translucid Contracts for Modular Reasoning about Aspect and Object Oriented Events



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Question

How to reason about events and event handling code?

Results:

- In Ptolemy:
  - Greybox specifications, “translucid contracts” [Main conference]
- In other languages
  - This talk

Question for this talk:

How to extend translucid contracts to other languages?

Background + Our Previous Works

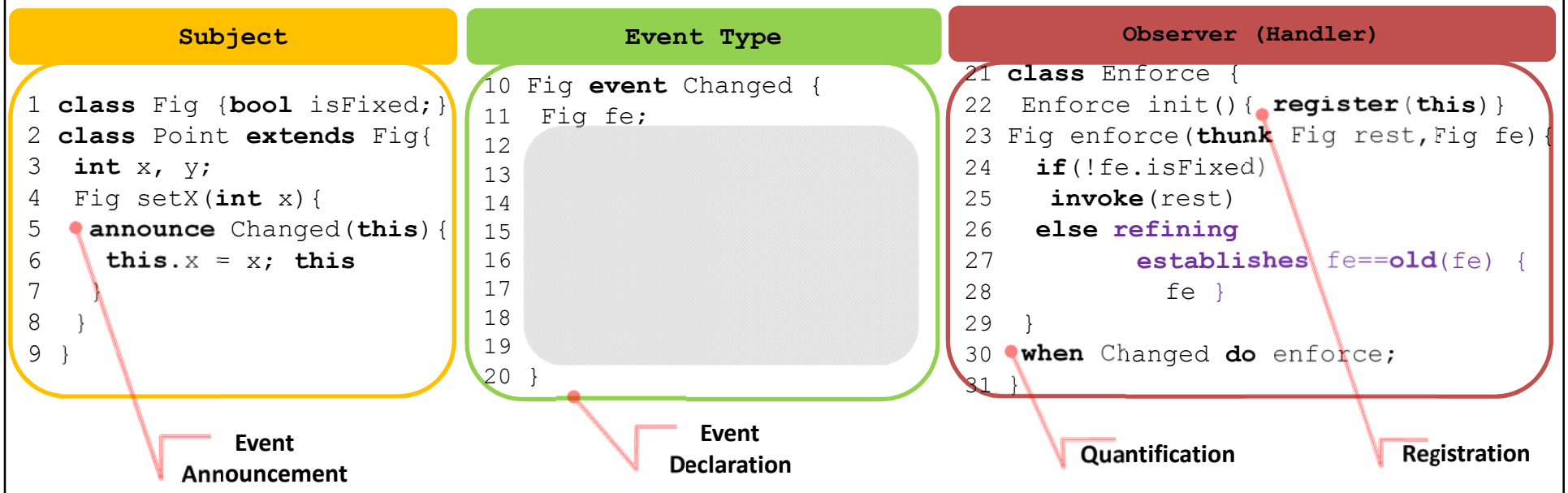
Problems for Modular Reasoning About control (with Advice)

1. Pervasive join point shadows:
   mySquare.setX (9);
2. Black-box specifications
   can't specify control effects of advice

Ptolemy Highlights

- Events:
  - Explicit Declaration
  - Explicit Announcement
  - Quantification for handlers
- Translucid Contracts

Ptolemy Example



- Skip execution of *setX()* when *isFixed* is true.
- Event-driven-programming:
  - **Subject** *Point* announces **event** *Changed* when *setX()* is called.
  - **Event handler** *enforce* registers for *Changed* and runs when the event is announced.
  - Handler *enforce* implements the above requirement.

Translucid Contracts Example

```
10 Fig event Changed {
11  Fig fe;
12  requires fe != null
13  assumes{
14   if(!fe.isFixed)
15    invoke(next)
16   else
17    establishes fe==old(fe)
18  }
19  ensures  fe != null
20 }
```

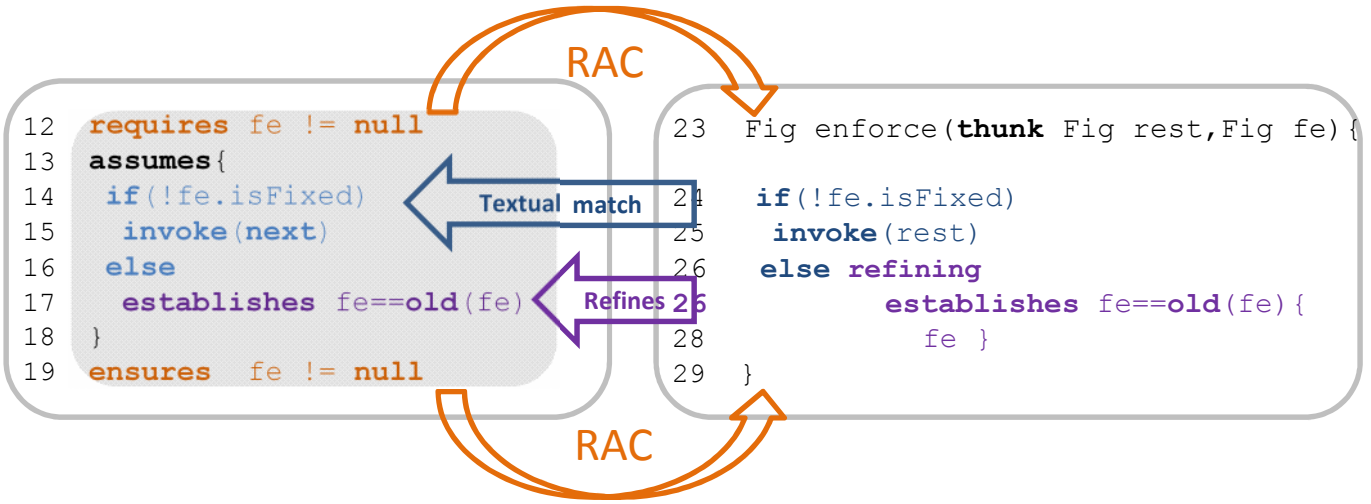
- Contract Limits the behavior of the handler
  - **requires/ensures** labels pre-/postconditions
- Greybox limits the handler's code
  - **assumes** block with program/spec. expressions

Assumes Block

```
10 Fig event Changed {
11  Fig fe;
12  requires fe != null
13  assumes{
14   if(!fe.isFixed)
15    invoke(next)
16   else
17    establishes fe==old(fe)
18  }
19  ensures  fe != null
20 }
```

- Assumes block is a mixture of
  - Specification exprs
    - Hide implementation details
  - Program exprs
    - Reveal code details
    - Must be present in code

TC Refinement



- A program expr. is refined by a **textually matching** prog. expr.
- A specification expr. is refined by a refining expression with the same specification.
- The pre-/postconditions are enforced using runtime assertion checks (RACs)
- Handler should **structurally match** the TC assumes block.

How Translucid Contracts rely on Ptolemy

```
21 class Enforce {
22  …
23  Fig enforce(thunk Fig rest,Fig fe){
24   if(!fe.isFixed)
25    invoke(rest)
26   else
27   refining establishes fe==old(fe){
28    fe }
29  }
30  when Changed do enforce;
31 }
```

Event Name

Handler Name

- Handlers statically know about types of event they handle.
- So can find contract for the handler, …
- Allows modular checking of handler's refinement.

Ptolemy and Modular Reasoning

- Reasoning about control effects of AO programs:
  1. Pervasive join point shadows
     1. Solution: Limit the application of advice:
        1. Ptolemy's explicit event announcement
  2. Black-box specifications can't handle control effects
     1. Solution: Use grey-box spec to specify control effects:
        1. Translucid contracts:
           1. Limit the behavior of advice

- Ptolemy +Translucid contracts enables modular reasoning about control effects

Observation

- Greybox specifications are not Ptolemy-specific
- We show applicability to:
  - Several AO interfaces
  - OO language, C#

Key Problem

- Statically find what types of events a handler can handle
- So can find specification for event handler

Applicability of Translucid Contracts to other AO interfaces

- AO interfaces make join points explicit
  - Mitigates problem of pervasive join point shadows.

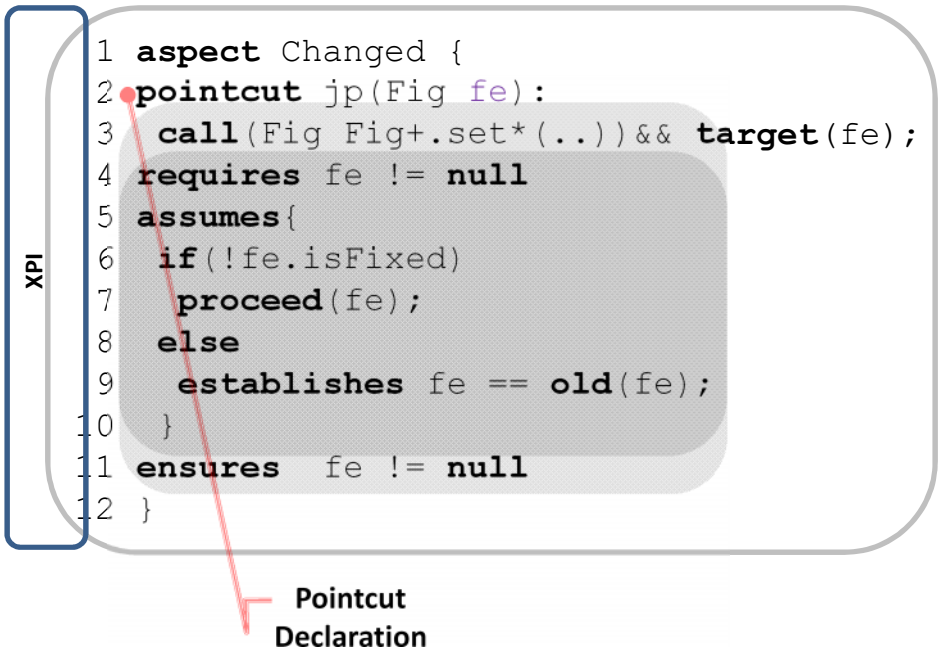
- Some AO interface proposals:
  - Crosscut programming interfaces (XPIs)
  - Aspect-aware interfaces (AAIs)
  - Open modules
  - Join point types
  - Explicit join points

Translucid Contracts for XPIs

- XPIs: a design-rule based interface; decouples the design of base and aspects

- XPI limits:
  - Exposure of join points
  - Behavior of base and aspect using black-box
    - No mechanism provided to check the refinement

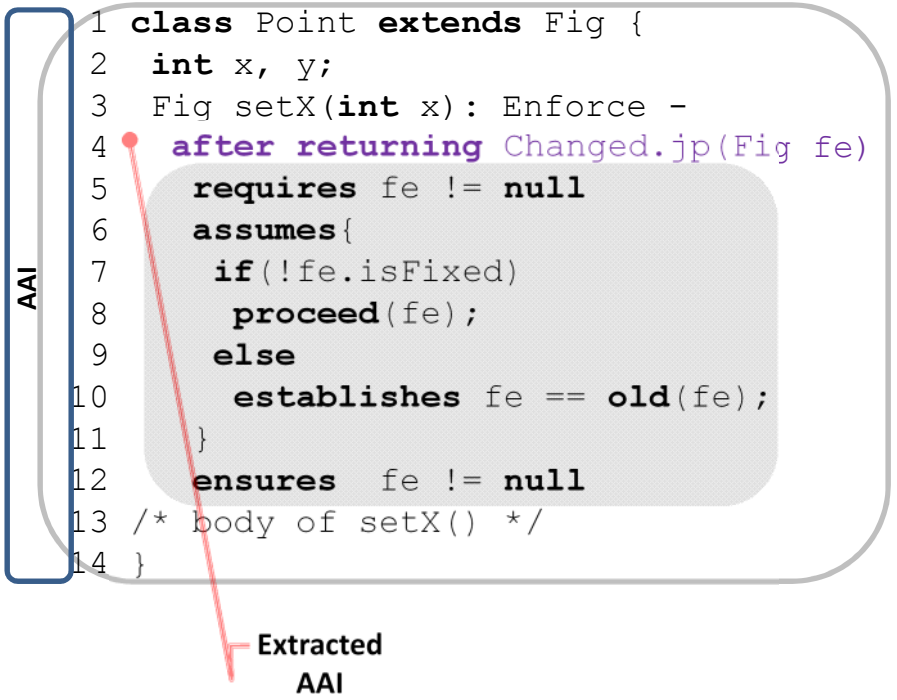
Translucid Contracts for XPIs




```
13 aspect Enforce {
14  Fig around(Fig fe): Changed.jp(fe){
15   if(!fe.isFixed)
16    proceed(fe);
17   else
18    refining establishes fe==old(fe){
19     return fe;
20   }
21  }
22 }
```

- Unlike Ptolemy, TC in XPI is attached to the pointcut rather than the event type
- Only variables in pointcut, *fe*, could be used in translucid contracts
- Refinement rules are added to AO type system in *Enforce* where it is reusing the pointcut *Changed.jp*

Translucid Contracts for AAIs



- Syntax/refinement rules are similar to XPI.

Translucid Contracts for Open Modules

- Open modules allow explicit exposure of pointcut for behavioral modifications , similar to signaling events in Ptolemy

Translucid Contracts for Open modules

Open Module

```
1  module Changed{
2   class Fig;
3   expose: XPI.jp(Fig)
4  }
5  aspect XPI {
6  pointcut jp(Fig fe):
7   call(Fig Fig+.set*(..))&& target(fe);
8  requires fe != null
9  assumes{
10  if(!fe.isFixed)
11   proceed(fe);
12  else
13   establishes fe == old(fe);
14  }
15 ensures  fe != null
16 }
```

Exposed Join Point

```
13 aspect Enforce {
14  Fig around(Fig fe): XPI.jp(fe)
15   if(!fe.isFixed)
16    proceed(fe);
17   else
18    refining establishes fe==old(fe){
19     return fe;
20   }
21  }
22 }
```

- Open module *changed* exposes a pointcut of class *Fig* to be advised by *Enforce.*
- Like XPIs and unlike Ptolemy, TCs are attached to pointcut decl.

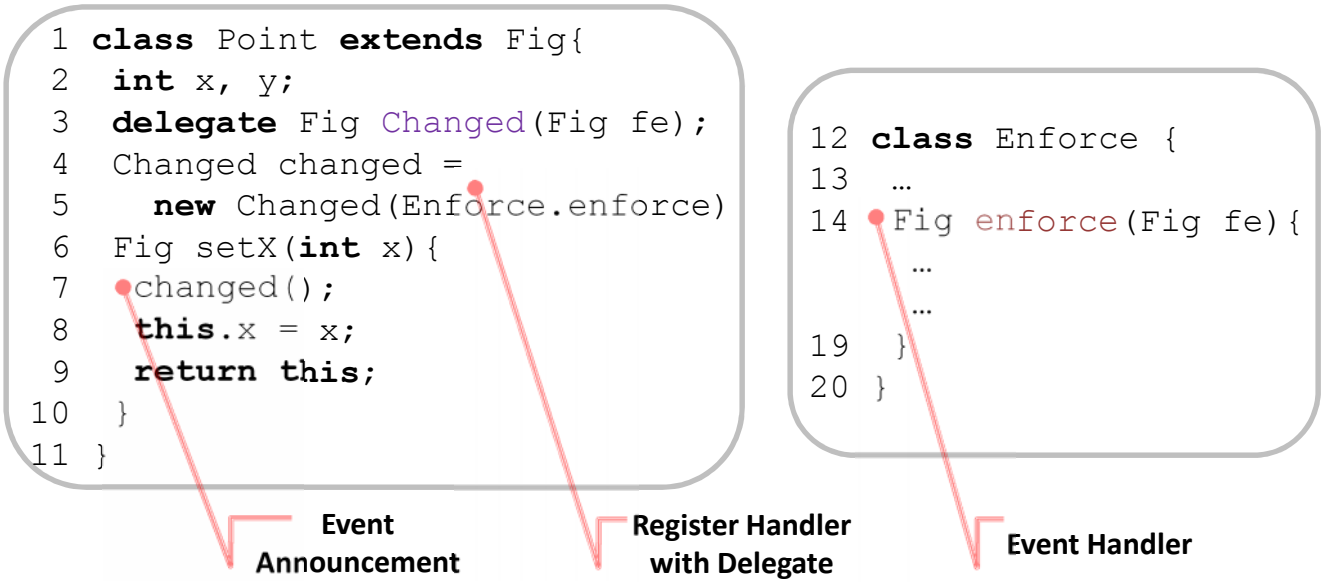
Translucid Contracts for Join Point Types & Explicit Join Points

- Join point types and Explicit join points are similar to Ptolemy's event types.

Applicability to OO languages

- For each handler, need to statically know about the type of events it can handle.
- C# has built-in:
  - events (EventType interface)
  - delegates (method pointers)

Problem Determining Handled Event Type of a Handler



- Any method with the same signature as delegate *Changed* could be registered as its handler.
- Handler *enforce* has no way to tell which event it is handling.

Solution:
A Simple Convention

- Every handler,
  takes as first argument an
  instance of the event type
  it handles

C# Library

- A C# library, emulating Ptolemy's functionality, using C# events and delegates developed

Event Declaration

C#

```
10 class Changed:EventType <Fig, Changed.Context>{
11  class Context{
12   Fig fe;
13   Context (Fig fe){ this.fe = fe;}
14   Fig contract() {
15    Contract.Requires(fe != null);
16    Contract.Ensures(fe != null);
17    if (!fe.isFixed)
18     return new Changed().Invoke();
19    else {
20     Contract.Assert(true);
21     Contract.Assert(fe==Contract.OldValue(fe));
22    }
23  }}}
```

Translucid Contract

Ptolemy

```
10 Fig event Changed {
11  Fig fe;
12  requires fe != null
13  assumes{
14   if(!fe.isFixed)
15    invoke(next)
16   else
17    establishes fe==old(fe)
18  }
19  ensures  fe != null
20 }
```

- Event *Changed* extends the built-in *EventType* with return type *Fig* and context variable *fe.*
- Translucid contract is attached to the event type *Changed*
- Method ***contract()*** documents the translucid contract.
- Pre/postconditions are written using **Code Contracts**
- Specification exprs are documented using assert exprs.

Event Announcement

C#

```
1  class Fig { int isFixed; }
2  class Point:Fig {
3   int x, y;
4   void setX(int x) {
5    Changed.Announce(
6       new Changed.Context(this),()=>{
7     this.x = x;
8     return this;});
9   }
10 }
```

Ptolemy

```
1 class Fig {int isFixed;}
2 class Point extends Fig{
3  int x, y;
4  Fig setX(int x){
5   announce Changed(this){
6    this.x = x; this
7   }
8  }
9 }
```

- Event body is provided as an anonymous closure.

Event Handler

C#

```
26 class Enforce {
27  Fig enforce(ChangedEvent next) {
28    if (!next.fe.isFixed)
29     return next.Invoke();
30    else {
31     return next.fe;
32    }
33  }
34 }
```

Refining Expression

Quantification

Ptolemy

```
21 class Enforce {
22  Enforce init(){ register(this)}
23  Fig enforce(thunk Fig rest,Fig fe){
24   if(!fe.isFixed)
25    invoke(rest)
26   else
27   refining establishes fe==old(fe){
28    fe }
29  }
30  when Changed do enforce;
31 }
```

- Passing the event type to the handler, emulates Ptolemy's quantification.
- Can statically determine which events a handler is handling.
- Then the event type contract could be pulled out and the handler refinement of the contract could be checked statically for structural refinement and dynamically by runtime assertion checking.

Conclusion

- Previous work: Translucid Contracts enable modular reasoning of control effects in AO programs. Implemented in Ptolemy
- This work: Translucid contracts are not Ptolemy-specific , can be used to reason about:
  - Other AO interfaces
  - OO languages such as C#

Questions