AOP with Metadata: Principles and patterns

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AOP and metadata: The need

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Signature-based pointcut

- **Utilize join point signatures**
  - Exploits inherent data associated with signature
  - Wildcards select a wide range of join points
- **Work well in many cases**
  - Logging and tracing
  - Profiling
  - Policy enforcement
  - Caching and pooling
  - Fault tolerance
  - Thread safety
  - Business rules

Metadata based pointcuts

- **Utilize join point metadata**
  - Often along with join point signature
- **Needed in certain cases**
  - Transaction management
  - Authentication
  - Authorization
  - Concurrency control
  - …

Conventional transaction management


```
public class Account {

    ...

    public void credit(float amount) {
        UserTransaction ut = ...;
        try {
            ut.begin();

            ... business logic ...

            ut.commit()
        } catch (Exception ex) {
            ut.rollback();
            // rethrow after logging and wrapping
        }
    }
```

Conventional transaction management


```
public void debit(float amount)
    throws InsufficientBalanceException {
    UserTransaction ut = ...;
    try {
        ut.begin();

        ... business logic ...

        ut.commit()
    } catch (Exception ex) {
        ut.rollback();
        // rethrow after logging and wrapping
    }
}
```

Conventional transaction management


```
public float getBalance() {
    ... business logic ...
}
```

AOP transaction management

```
public class Account {

    ...

    public void credit(float amount) {
        ... business logic ...
    }

    public void debit(float amount)
        throws InsufficientBalanceException {
        ... business logic ...
    }

    public float getBalance() {
        ... business logic ...
    }
}
```

System-specific aspect

```
public aspect BankingTransactionManagement {
    public pointcut transactedOps()
        : ???;

    Object around() : transactedOps()
                    && !cflowbelow(transactedOps()) {
        ...
        try {
            ut.begin();
            retValue = proceed();
            ut.commit();
        } catch (Exception ex) {
            ut.rollback();
        }
        return retValue;
    }
}
```

Reusable base aspect

```
public abstract aspect TransactionManagement {
    public abstract pointcut transactedOps();

    Object around()
       : transactedOps() && !cflowbelow(transactedOps()) {
        ...
        try {
            ut.begin();
            retValue = proceed();
            ut.commit();
        } catch (Exception ex) {
            ut.rollback();
        }
        return retValue;
    }
}
```

System-specific subaspect

```
public aspect BankingTransactionManagement
    extends TransactionManagement {

    public pointcut transactedOps()
        : ???;
}
```

System-specific subaspect

```
public aspect BankingTransactionManagement
    extends TransactionManagement {

    public pointcut transactedOps()
        : ???;
}
```

- Issue
  - Capturing operations with a transaction management need

System-specific subaspect

```
public aspect BankingTransactionManagement
    extends TransactionManagement {

    public pointcut transactedOps()
        : execution(* Account.credit(..))
          || execution(* Account.debit(..))
          || ...;
}
```

System-specific subaspect

```
public aspect BankingTransactionManagement
    extends TransactionManagement {

    public pointcut transactedOps()
        : execution(* Account.credit(..))
          || execution(* Account.debit(..))
          || ...;
}
```

- Issue
  - Maintaining the method list in the pointcut definition

System-specific subaspect: Metadata-based


```
public aspect BankingTransactionManagement
    extends TransactionManagement {

    public pointcut transactedOps()
        : @annotation(Transactional);
}
```

Account class with metadata

```
public class Account {
    ...

    @Transactional public void credit(float amount) {
        ... business logic ...
    }

    @Transactional public void debit(float amount)
        throws InsufficientBalanceException {
        ... business logic ...
    }

    public float getBalance() {
        ... business logic ...
    }
}
```

Multidimensional interfaces using metadata

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Tyranny of dominant signature

- **Simple signature**

```
void credit(float amount);
```

  - Business concern is dominating the signature
  - Other concerns aren't apparent

- **Tangled signature**

```
void transactional_authorized_credit(float amount);
```

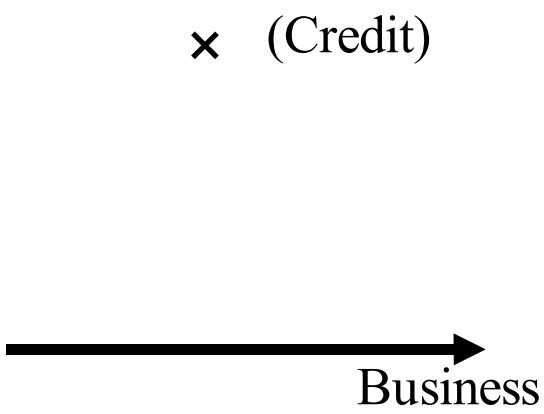
  - Ugh!
  - All clients aware of all concerns
  - Changes affect all clients
  - Expressing values in crosscutting dimension even harder
    - `transaction_required_authorized_accountModificatio n_credit()` ☹

Untangling using metadata

```
@Transactional(Required)
@Authorized("accountModification")
public void credit(float amount);
```

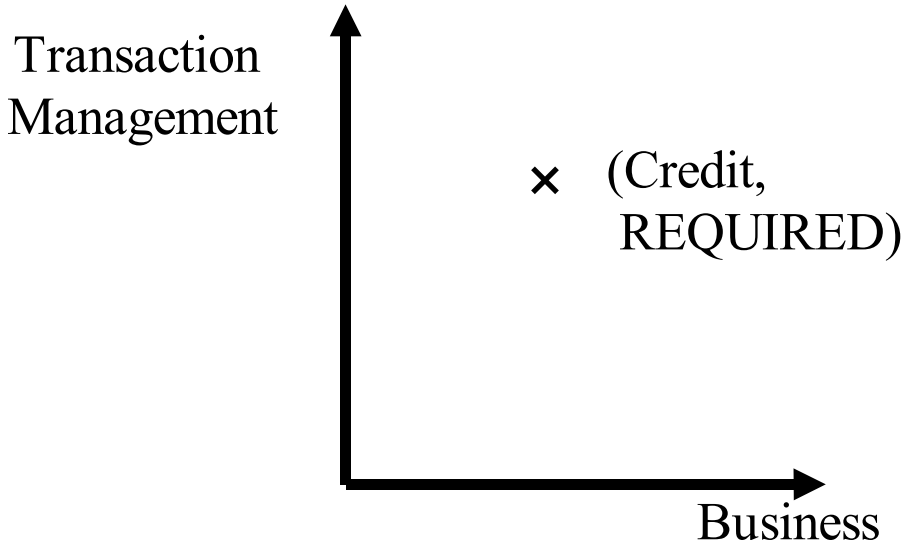
- Each dimension expressed nicely
- Implementation need to understand only relevant dimensions
- Changed affect only the relevant concern
- Expressing values in crosscutting dimension trivial

Multidimensional signature with metadata




```
public void credit()
```

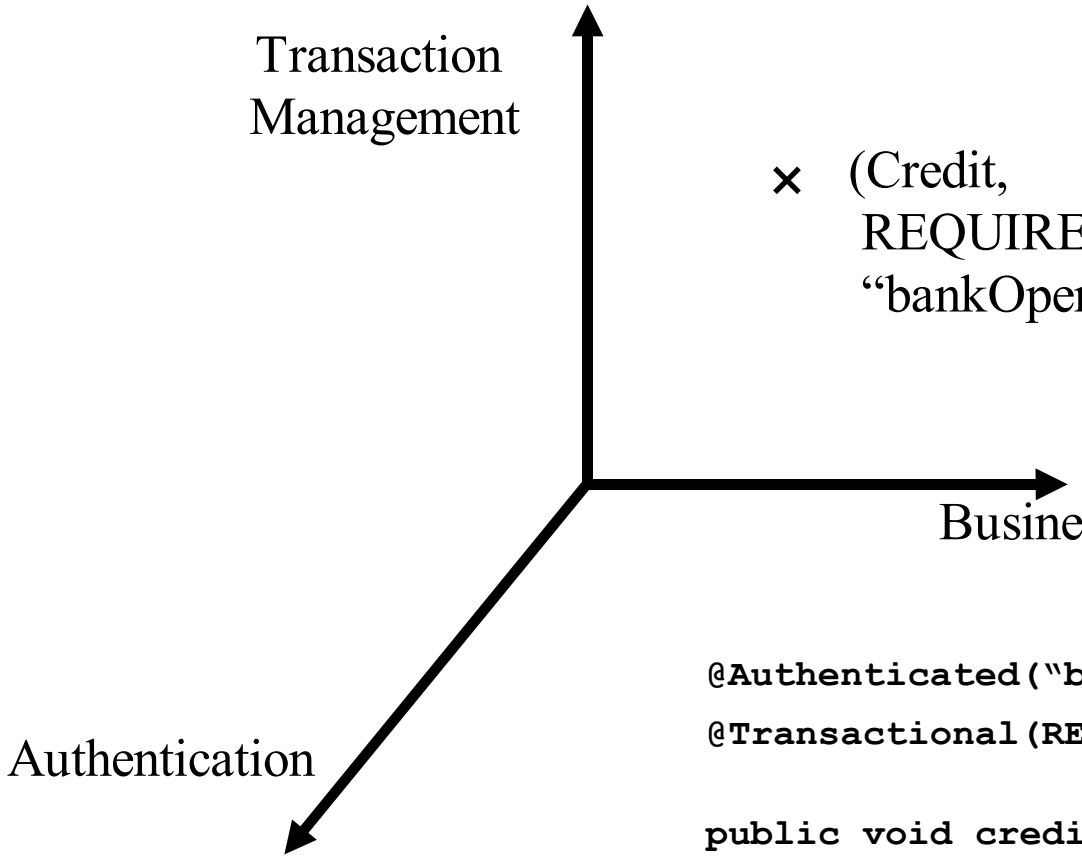
Multidimensional signature with metadata




```
@Transactional(REQUIRED)

public void credit()
```

Multidimensional signature with metadata



× (Credit, REQUIRED, "bankOperation")

```
@Authenticated("bankOperation")
@Transactional(REQUIRED)

public void credit()
```

Annotated Account class

```
public class Account {
    @Transactional(kind=Required)
    public void credit(float amount) {
        ...
    }

    @Transactional(kind=Required)
    public void debit(float amount) {
        ...
    }

    @Transactional(kind=None)
    public float getBalance() {
        ...
    }
}
```

Annotated Account class: Business client perspective


```
public class Account {

    public void credit(float amount) {
        ...
    }


    public void debit(float amount) {
        ...
    }


    public float getBalance() {
        ...
    }
}
```

Annotated Account class

```
public class Account {
    @Transactional(kind=Required)
    public void credit(float amount) {
        ...
    }

    @Transactional(kind=Required)
    public void debit(float amount) {
        ...
    }

    @Transactional(kind=None)
    public float getBalance() {
        ...
    }
}
```

Annotated Account class: Transaction management perspective


```
public class Account {
    @Transactional(kind=Required)
    * *.*(..) {
        ...
    }

    @Transactional(kind=Required)
    * *.*(..) {
        ...
    }

    @Transactional(kind=None)
    * *.*(..) {
        ...
    }
}
```

Metadata-fortified AOP

- **Concern interface**
  - Projection of a program element on a dimension
- **Each dimension**
  - Maps to a concern
  - Business concerns
    - Implemented by classes
  - Crosscutting concerns
    - Implemented by aspects
  - Coupling between classes and aspects limited to metadata

Metadata and AOP best practices

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Metadata to capture join points vs. current mechanism

- **The upside**
  - Easy way to capture certain crosscutting concerns
  - Limits collaboration between aspect and classes to just annotations
- **The downside**
  - Collaboration from classes is needed
  - Overuse may obscure AOP's obliviousness property
    - Especially when a little extra design effort may obviate the need for annotations

Guidelines in using metadata

- **Don't use when you can do without**
  - Implicit data available in join point signature often suffice
    - All RMI operations

```
execution(* Remote+.*(..) throws RemoteException);
```

    - All thread safe Swing calls

```
    call(void JComponent.revalidate())
 || call(void JComponent.repaint(..))
 || call(void add*Listener(EventListener))
 || call(void remove*Listener(EventListener));
```

  - Bad idea for certain cases
    - **@Trace**
    - **@Profile**

Guidelines in using metadata

- **Employ aspect inhertance**
  - Push down decision
  - Multiple subaspects combined with earlier guideline
- **Use annotation defined for other purposes**
  - EJB, EMF, Hibernate

Guidelines in using metadata

- **Use abstract annotation types**
  - do not dictate implementation
    - @ReadOnly, not @ReadLock
    - @Transactional, not @JTATransactional
    - @Timing, not @WaitCursor
    - @Idempotent, not @RetryOnFailure

Meta-guideline

- **Wisdom comes with experience!**
- **Start with something**
  - Refactoring is often your best friend

Metadata-fortified AOP: Effect on obliviousness

- **Metadata is in eye of beholder!**
  - Inherent data may be metadata
    - Is exception specification inherent data or metadata?
    - Public? Private? …
    - Type specification?
  - Metadata may be inherent data
    - @OrderProcessing?
    - @Persistent?
- **If guidelines are followed, obliviousness is preserved**

Design Evolution with Metadata-fortified AOP

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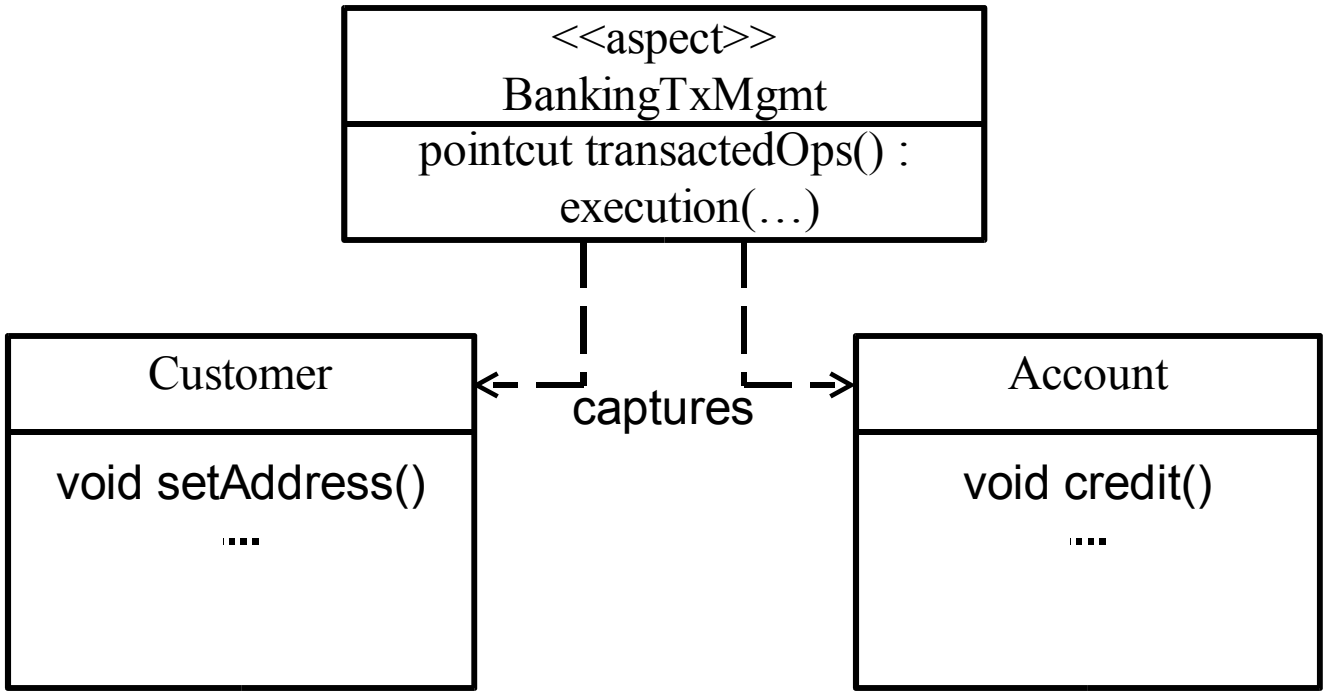
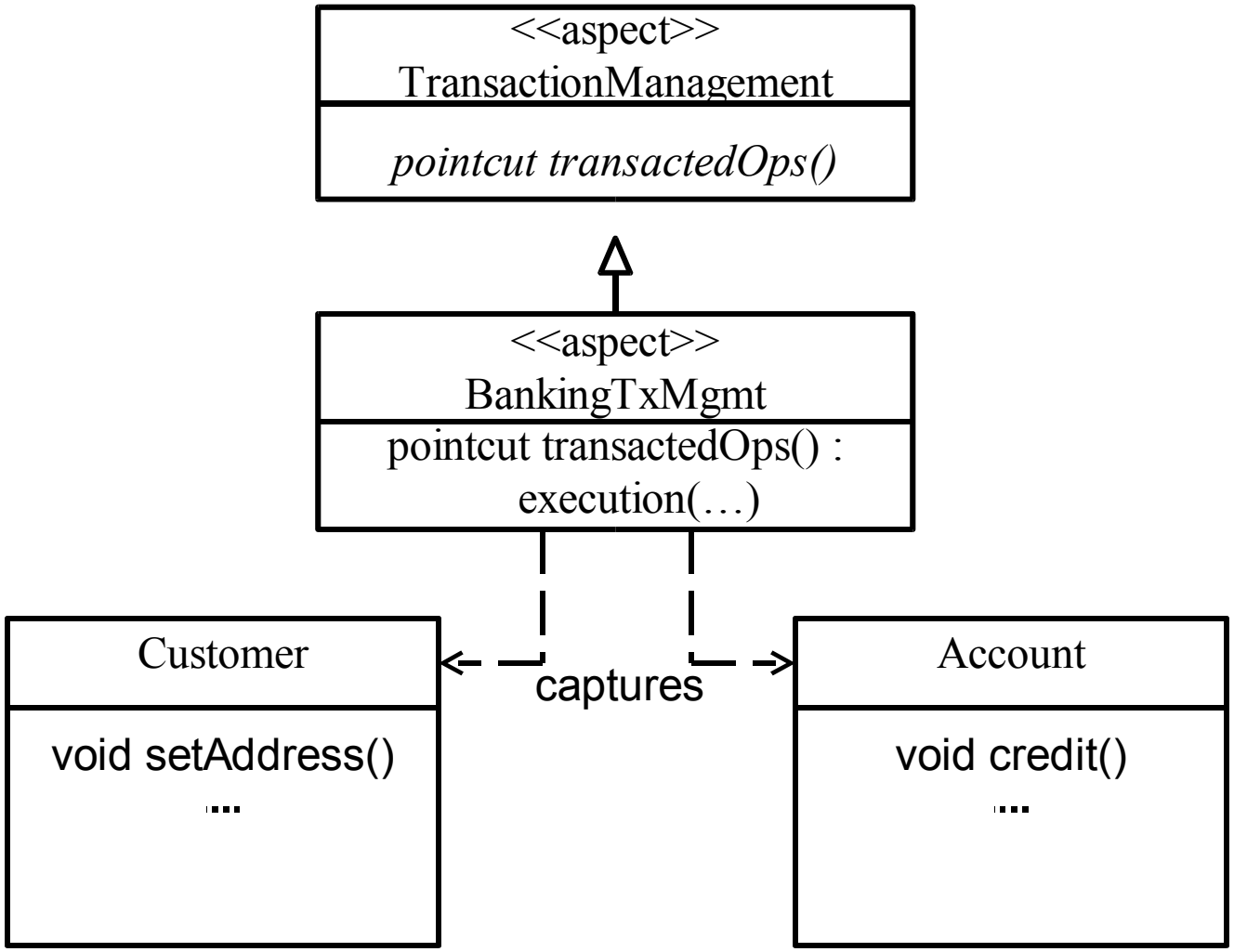
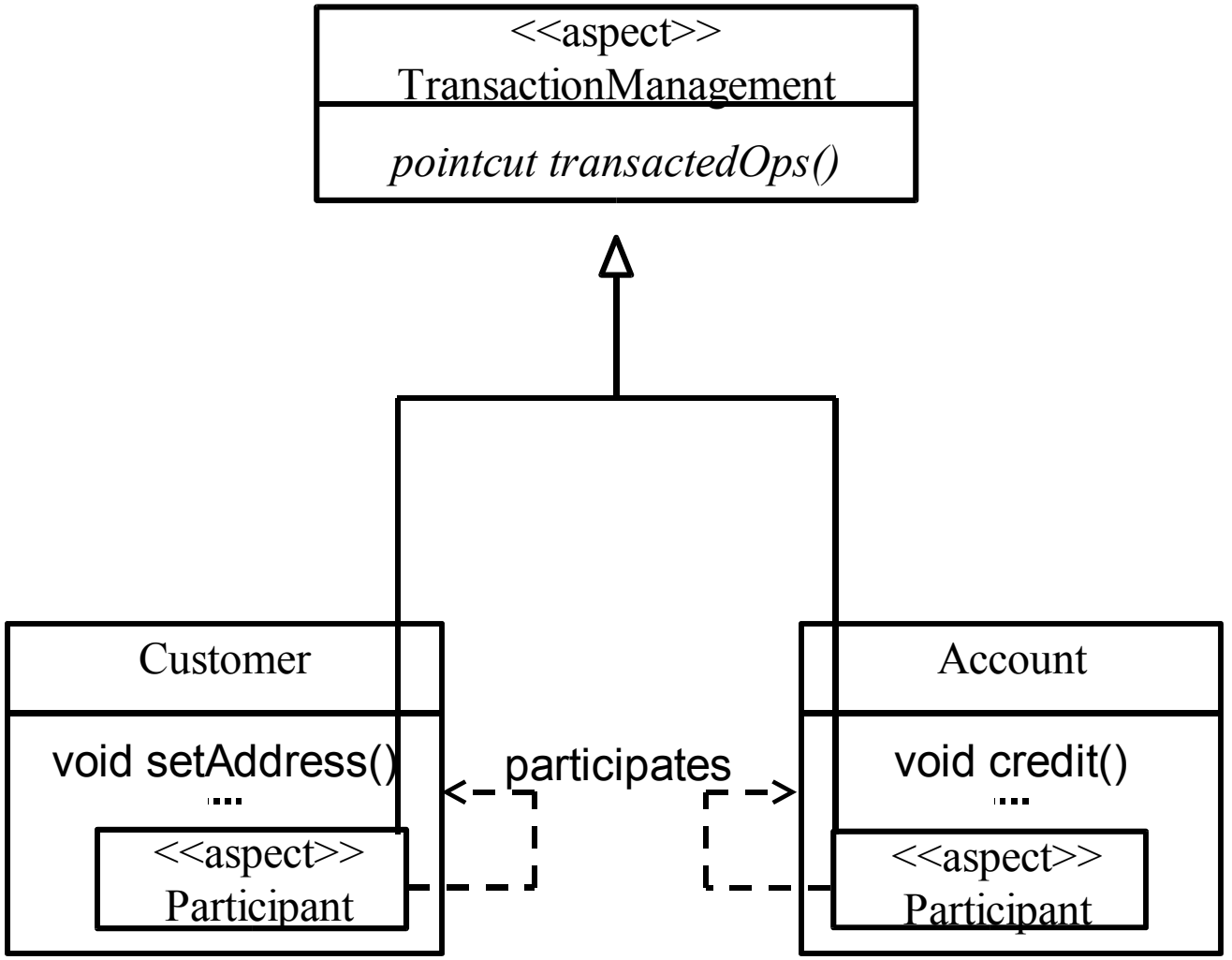
Naïve aspect implemenation



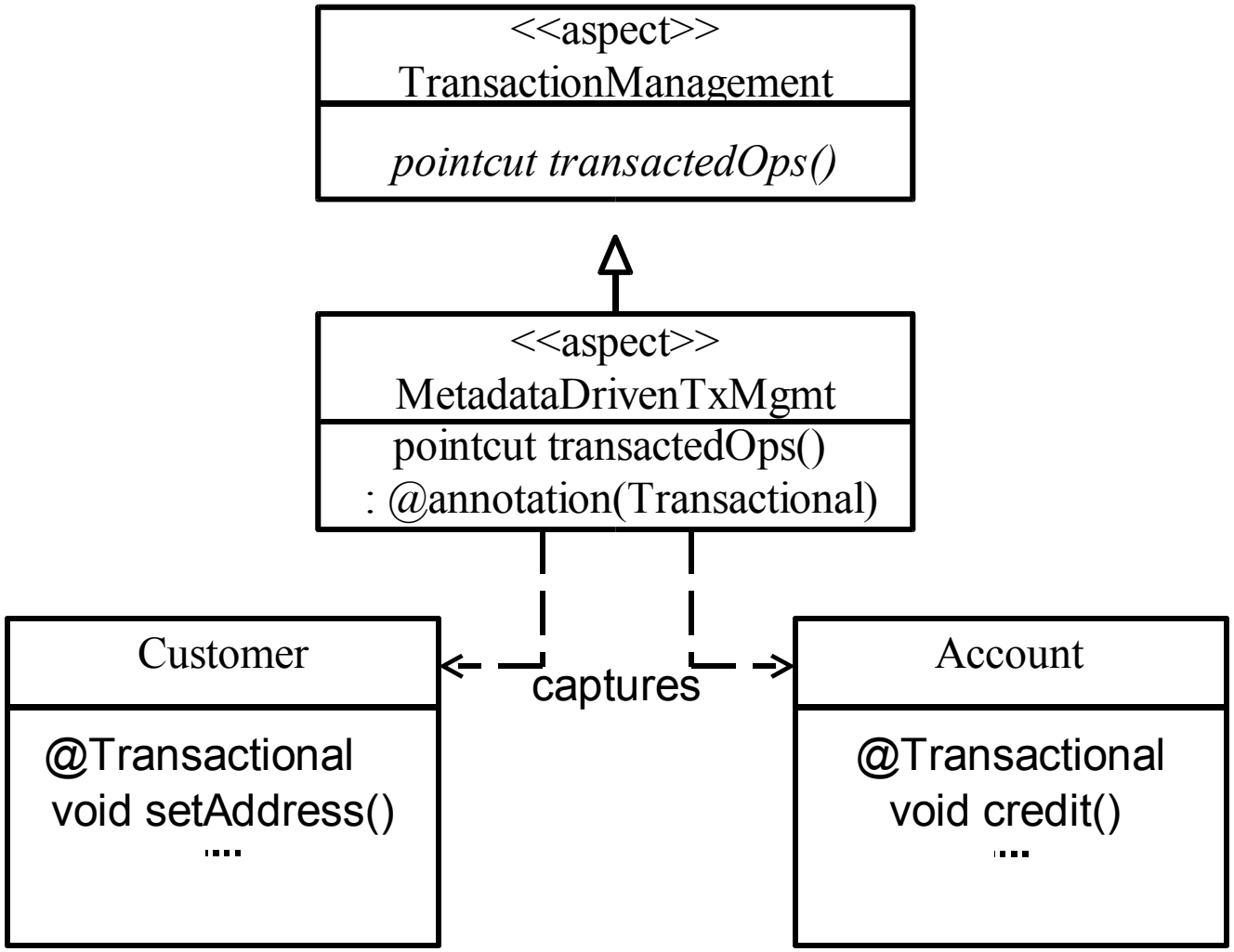
Extracting the base aspect



Using participant pattern: direct participation



Metadata-driven crosscutting

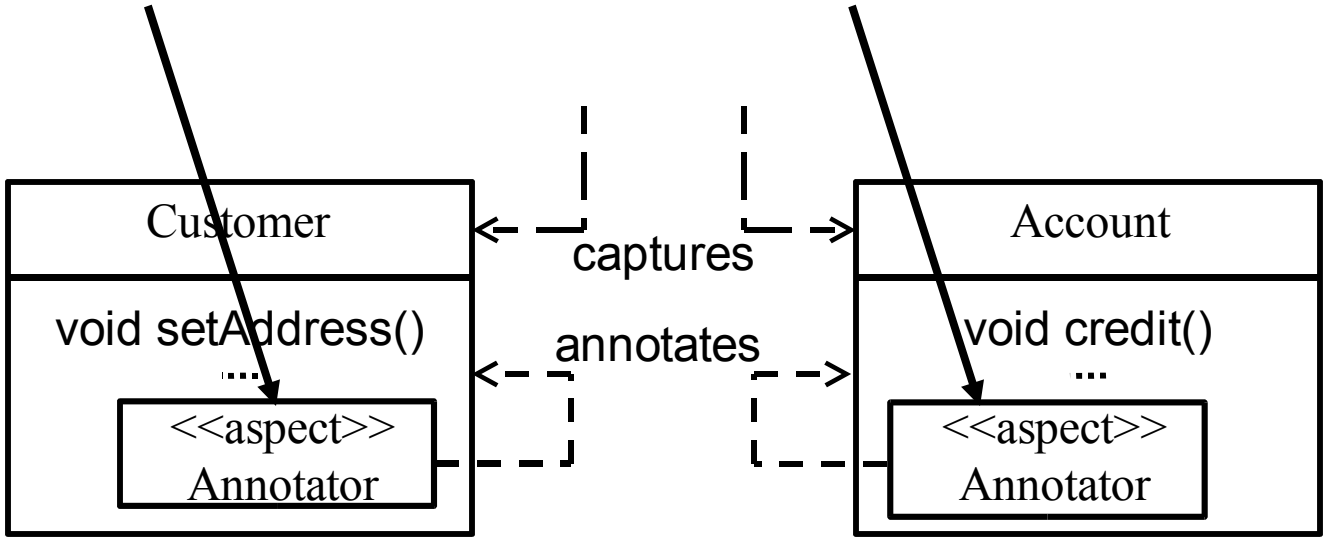


Using participant pattern: indirect participations


```
declare @annotation : * Account.credit(..)
                      || * Account.debit(..)
                     : @Transactional(Required);
```

Or

```
declare @annotation : * @PurchaseActivity Customer.*(..)
                     : @Transactional(Required);
```



Summary

- **AOP is a powerful programming methodology**
  - Fortifying it with metadata makes it more powerful
- **Metadata and AOP combinations is synergistic**
  - AOP can crosscut based metadata
  - Metadata get a principled consumer and supplier
- **Projection onto multidimensional concern space is a systematic approach to view metadata**
- **Watch out for overuse of metadata undermining AOP principles**

For More Information

- **Ramnivas Laddad, Metadata and AOP: A Perfect Match**
  - Part of AOP@Work series on IBM developerWorks
  - http://www.ibm.com/developerworks/java/library/j-aopwork3
  - http://www.ibm.com/developerworks/java/library/j-aopwork4 (To be published in April)
- **AOP@Work series**
  - http://www.ibm.com/developerworks/views/java/libraryview.jsp?search_by=AOP@work:

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