Remote Batch Invocation for Compositional Object Services

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Standard Approach to Distribution

- Step I: Design a language
  - Clean Interfaces, modules
  - C, C++, ML
- Step 2: Add library for distribution
  - Remote procedure calls
    - Stub that send calls remotely
  - Distributed objects
    - Proxies: pointer to remote object
    - Create proxies on demand
  - RMI
  - CORBA
  - DCOM
- End Result
  - Clean, elegant, orthogonal
  - Cons?
    - Performance
- Is it the case for Persistence too?
  - Example in later slides

Example: Music Jukebox in the Cloud

- Remote service which can play music on your home speakers
- Fine-grained interface
- OO design

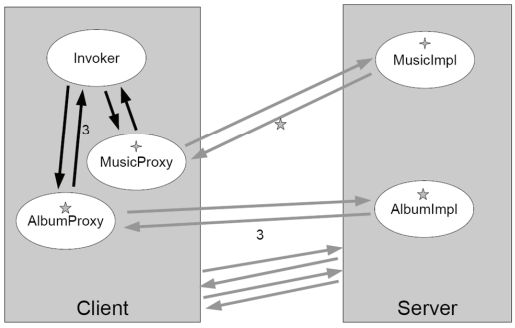
```
interface Music {
   Album[] getAlblums();
   …..
}

interface Alblum {
   String getTitle();
    void play();
    int rating();
    ….
}
```

Remote Procedure Calls (RPC)

```
int minimumRating = 4;
Music musicService = ... ;
for (Album album : musicService.getAlbums()) {
   if (album.rating() > minimumRating) {
        System.out.println("Played: " +
                           album.rating() + " " +
                           album.getTitle());
                           album.play();
   } else {
        System.out.println("Skipped: " +
                           album.getTitle());
   }
}
```

RPC behind the scenes



Result: Too many RPC calls

```
int minimumRating = 4;
Music musicService = ... ;
for (Album album : musicService.getAlbums()) {
   if (album.rating() > minimumRating) {
        System.out.println("Played: " +
                           album.rating() + " " +
                           album.getTitle());
                           album.play();
   } else {
        System.out.println("Skipped: " +
                           album.getTitle());
   }
}
```

n: number of albums
worst case: 4n + 1 remote calls

Current approaches

- Data Transfer Objects and Server Façade
  - Move data in bulk
  - Specialize to particular sequence of client calls
- Document-oriented Web Services
  - Stateless servers
- TCP-based command line interfaces
  - POP, IMAP, FTP, HTTP, etc...
- End result
  - Messy, non-compositional, rigid … *fast*

Data Transfer Object

```
class TitleAndRatingAndCond implements
  Serializable {
  public String getTitle() { ... }
  public int getRating() { ... }
  public boolean getCond() { ... }
}
```

Remote Facade

```
interface MusicFacade
{
  TitleAndRatingAndCond[]
            playHighRatedAlbums(int minRating);
  ...
}
```

Remote Façade and Data Transfer Objects

```
int minimumRating = 4;
MusicFacade musicService = ... ;
TitleAndRatingAndCond[] results =
  musicService.playHighRatedAlbums(minimumRating);
for (TitleAndRating result : results) {
if (result.getCond()) {
        System.out.println("Played: " +
                result.getRating() + " " +
                result.getTitle());
} else {
        System.out.println("Skipped: " + album.getTitle());
}}
```

What are the problem with DTO and Remote Façade?

- Tight coupling with objects/code
  - Not service-oriented
- Can result in
  - under-approximation
    - Multiple calls to server
      - Client needs to print title of two different albums
  - over approximation
    - Single call to server

Remote Batch Invocation (RBI) - Insight

- We have an *incorrect assumption:*
  - Distribution can be solved in existing languages without any changes
- Goals
  - Fine-grained interfaces
  - Execute many remote operations in bulk
  - Create Facades and Transfer objects automatically

Remote Batch Invocation (RBI)

```
int minimumRating = 4;
Service service = ... ;
batch (Music musicService : service) {
  for (Album album : musicService.getAlbums())
      final Artist = musicService.addArtist("John");
      if (album.rating() > minimumRating) {
          System.out.println("Played: " +
                  album.rating() + " " +
                  album.getTitle());
                  album.play();
      } else {
          System.out.println("Skipped: " + album.getTitle());
      }
}}
```

Generated Façade by Partitioning

```
int minimumRating = 4;
Service service = ... ; Music musicService = ...;

for (Album a : musicService.getAlbums())
    if (a.rating() > minimumRating) {
        // GET rating, title
        album.play();
    } else {
    }
```

Remote

```
for (????) {
    if (???) {
        System.out.println("Played: " +
                rating + " " +
                title);
    } else {
        System.out.println("Skipped: " + title);
    }
}
```

Local

Generated Code

```
int minimumRating = 4;
Service service = ... ; Music musicService = ...;
List<TitleAndRatingAndCond> results = new...;
for (Album a : musicService.getAlbums())
    if (a.rating() > minimumRating) {
        results.add(new TitleAndRatingAndCond(
        a.rating(), album.getTitle(), true));
        album.play();
    } else {
        results.add(new TitleAndRatingAndCond(0, null, false);
    }
```

Remote

```
for (TitleAndRatingAndCond result : results) {
    if (result.getCond()) {
        System.out.println("Played: " +
                result.getRating() + " " +
                result.getTitle());
    } else {
        System.out.println("Skipped: " +
                result.getTitle();
    }
}
```

Local

Remote Batch Invocation

- Clean server interface, decoupled clients
  - Fine-grained interfaces
  - Automatic bulk data transfer and facades
- Only primitive values can be transferred between clients and server
  - ***No stubs, No proxies!***
- One round-trip per lexical batch block
- Two kinds of exceptions:
  - Remote exceptions
    - Does the paper handle them?
      - Not gracefully
    - Proposed solution: transactional memory on server
      - Does this violate service-oriented (stateless) principle?
  - Network exceptions (reduced!)

What can be executed remotely?

- Sequences and Composition
  - ***batch (r) { r.foo(); r.foo().bar().getName(); }***
- Loops and Conditions
  - ***batch (music) {***

```
    for (Album a : music.getAlbums() )
    if (a.rating() > 5)
        print( a.getName() + ": " + a.rating() ); }
```

What cannot be executed remotely?

- Constructor calls
- Casts
- While loops
- Assignments
- Exceptions
- Are these Java compiler specific?

- What is the main drawbacks?
  - Think of SQL
  - Aggregate over collections cannot be done remotely

RBI pros & cons – Memory model

- Only transfer primitive values
- No proxies (remote pointers)
  - Server can be stateless, "service oriented"
    - rbi.Service musicService = new rbi.Service("MusicCloud", Music.class);
    - What about iterative computation?
  - No distributed garbage collection
- Serialization through public interfaces

```
batch (remote) {
        RemoteSet r = remote.makeSet();
        for (int elem : localSet().items() )
        r.add( elem );
        ....
}
```

  - Is it legal to set RemoteSet r = localSet?
    - Use public setters and getters
    - Need reusable helper functions/coercions

RBI pros & cons – Execution model

- Client
  - Language support
  - How easy/hard is to add support to "batch" in PL?
    - final keyword
  - What about order of execution?
    - What is the output of the below code?

```
StringBuilder sb = new StringBuilder();
sb.append("My Album");
batch(Music music : musicService) {
m(sb);
music.createAlbum("1", sb);
}
...
void m(StringBuilder sb) { sb.append(": Blues"); }
```

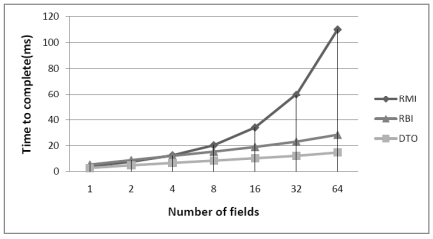
RBI pros & cons – Execution model

- Client
  - Language support
  - How easy/hard is to add support to "batch" in PL?
    - final keyword
  - What about order of execution?
  - Need library support too
- Server
  - Need to execute scripts
    - Can only call public methods
    - No constructors, static methods
  - Side effects?
    - Monoids (probably in ScalaQL class)
- Not completely transparent
  - Programmer controls batching
  - Is it good or bad?

RBI - Implementation

- Middleware library
  - Batch Execution Service and Translation (BEST)
- Source code transformation
  - Boilerplate code?
  - Conditions and loops require both remote and local execution
  - Very restrictive
    - Cannot transform arbitrary code
    - No while, assignment, casts, constructors
    - Cannot support multiple rounds trips within a batch block
- Does "batch" implementation too tied to Java?

Evaluation - Performance



Evaluation - Comparison

	RMI CORBA	Web Services	Remote Batch Invocation
Clean Interfaces	Good	Bad	Good
Latency	Bad	Good	Good
Memory model	Bad	Good	Good
Stateless	No	Yes	Yes
Partial Failure	Bad	Better	Better
Programming Model	Good	Bad	Good… but…

Can we generalize batches?

- Parameterize by batch handler
  - ***batch RMI (remoteObject) { … }*** ☑
  - ***batch WebService (service) { … }*** ☑
  - ***batch SQL (db) { … }*** ***?***
    - ***How does it compare to LINQ? (next class)***
    - ***OOPSLA paper: Static Analysis***
  - ***batch GPU (gpu) { …. }*** ***?***

Batching database access

```
batch SQL (Database db : dbService) {
  for (Album album : db.getAlbums())
      if (album.rating() > 50)
          System.out.println("Played: " +
              album.getTitle());
}
```

```
DbResults data = dbService.executeQuery(
          "select title from albums where rating > 4");
  for (item : data.items())
      System.out.println("Played: " + item.getTitle());
```

Related Work

- Microsoft LINQ
  - Batches vs. LINQ
- Mobile code / Remote evaluation
  - Does not manage returning values to client
- Implicit batching
  - Performance model is not transparent
- Asynchronous remote invocations
  - Asynchrony is orthogonal to batching
- Automatic program partitioning
  - binding time analysis, program slicing
- Transactions (batch/atomic)