Fun with Transactions

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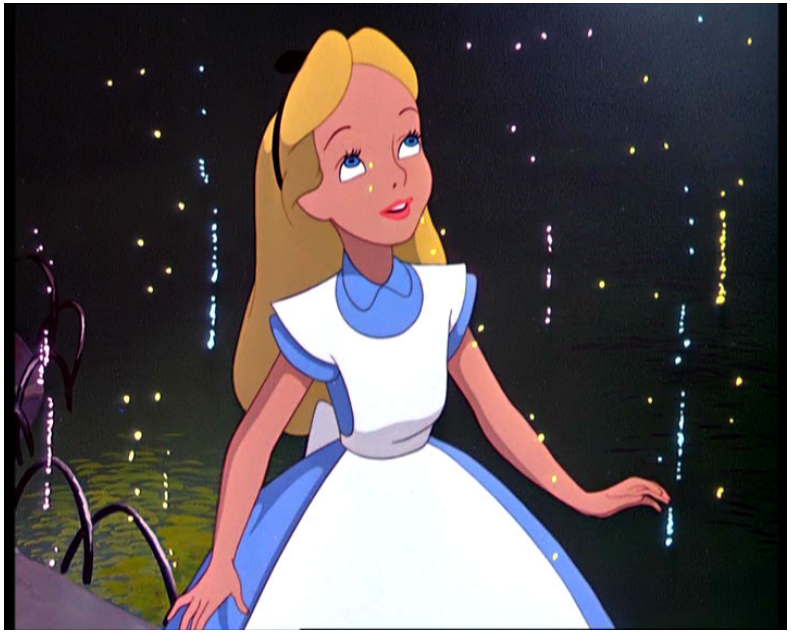
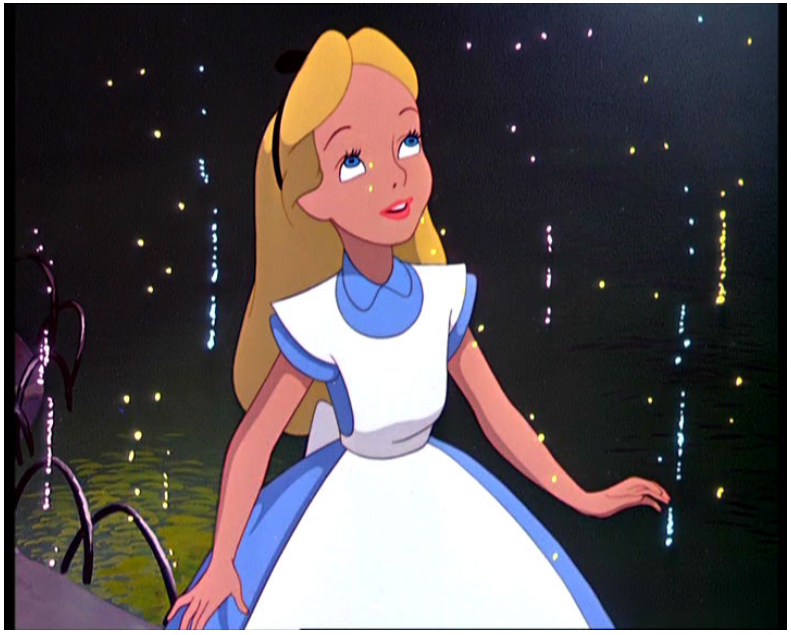
First, an illustration...

An illustration

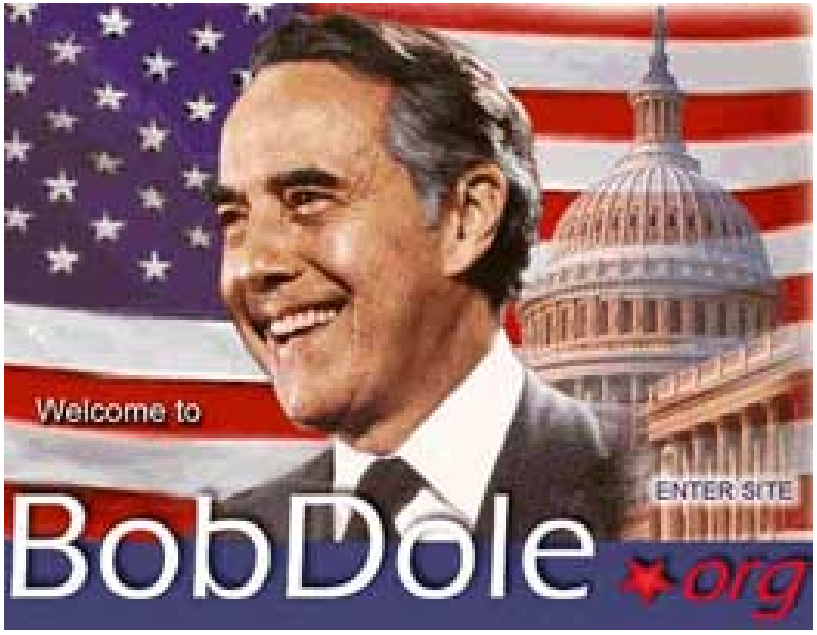


Alice

An illustration

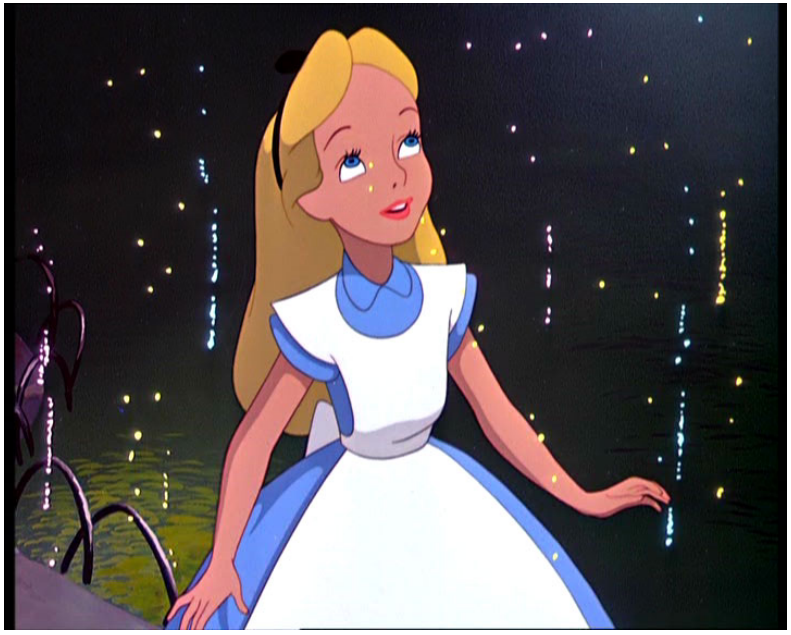


Alice

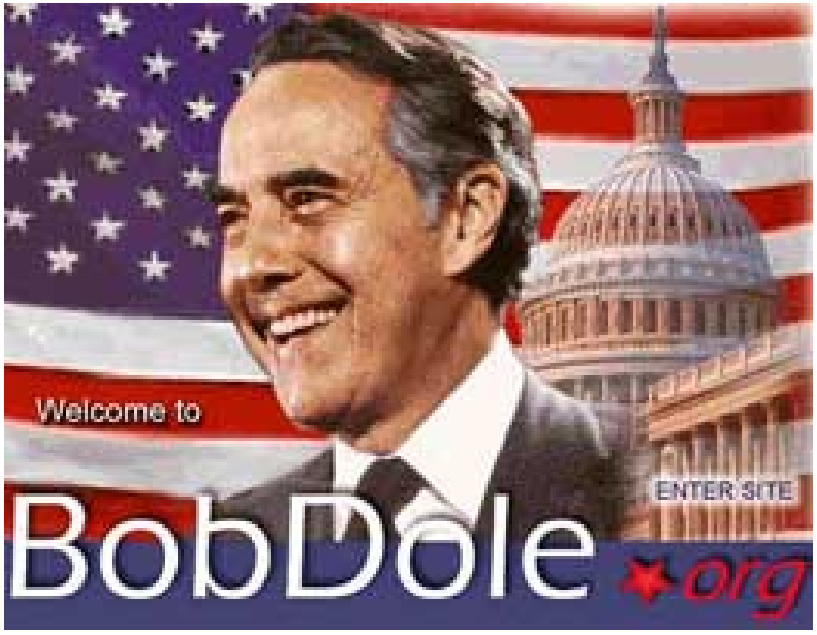


Bob

An illustration



Alice



Bob

Alice wants to donate $25 to Bob's campaign

An illustration

Alice gives Bob a check for $25 dollars from East Podunk Savings and Loan. Bob deposits the check.

East Podunk Savings and Loan

An illustration

East Podunk S & L now has a process they need to follow:

1. Take Alice's check from the pile of checks
2. Debit Alice $25
3. Credit Bob $25
4. Mark check as processed
5. Return check to Alice

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- *...the server crashes?*

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- *...the server crashes?*
- *...step #1 gets interrupted? (Race condition)*

An illustration

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What if...

- *...the server crashes?*
- *...step #1 gets interrupted? (Race condition)*
- *...a concurrent process overdraws Alice's account?*

Grouped operations

Operations are grouped, and succeed or fail as a group. Groups are called "transactions"

- **BEGIN** – Begin a group
- **COMMIT** – Complete a group
- **ROLLBACK** – Undo this group

ACID

Four characteristics of transactions ("**ACID**"):

- **Atomicity** – Transactions succeed or fail entirely, not partially
- **Consistency** – After each COMMIT or ROLLBACK, all database constraints are true
- **Isolation** – Sessions see only their own uncommitted data
- **Durability** – Once committed, data remain committed despite crashes

NoSQL?

In recent years, database users have begun to question the universal application of ACID, such as with the NoSQL movement.

- This is not a bad thing
- Many applications don't need transactions, ACID
- Many more applications still do require transactions and ACID

True or False: I'm not a bank. Therefore, I don't need transactions.

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False

When…

Transactions are important…

- When one logical operation requires multiple actual operations
- To ensure failures leave you in a known state
- If your server might possibly crash
- When you have special feelings toward this copy of your data

More examples

One End Point client manages call center data. Their application includes tasks like these:

- Update notes for a support case
- Modify employee performance statistics
- Update training databases
- Bill customers

Working without transactional guarantees will lead to orphaned records, missing information, and irritated customers.

Examples from End Point's clients

TriSano™(http://www.trisano.org) is a public health reporting application. For each new case, the application can record some or all of the following:

- Patient demographics
- Participating physicians
- Laboratory tests
- Reports to various agencies
- Contacts of different types
- Custom data collection forms

Data operations touch many tables. Changes need to be atomic to prevent orphaned data and ensure consistency.

ORMs

- Object-Relational Mappers (ORMs) often provide transaction APIs
- Users generally ignore those APIs, and use ORM defaults
- This behavior is generally wrong

Rules of thumb

1. Transactions group operations logically
2. Only the programmer knows what groupings are logical

Ergo, the programmer should control transactions (not the ORM, the database system, the database driver, or anything else)

Rules of thumb

You probably need transactions:

- Whether you're ready to admit it or not
- Whether you're ready to write your software to handle it or not
- If the application has units of work it needs to keep atomic
- If the servers might ever crash
- Even if your ORM disagrees

Neat Transaction Tricks

Savepoints

Transactions group operations. Within those groups, there may be nested subgroups, called subtransactions, implemented with **savepoints**.

Savepoint Example

```
BEGIN;
-- Do something useful
INSERT INTO actions VALUES
   ('IM IN YR AKSHUNZ DOIN YOOSFL STUFS');
SAVEPOINT try_something;
SELECT COUNT(*) FROM some_other_table;
UPDATE foo SET bar = baz WHERE qux = 42;
-- Perhaps a constraint causes a failure here
ROLLBACK TO SAVEPOINT try_something;
-- My outer transaction is still in-flight
```

Implementation note

In PostgreSQL, a statement that generates an error will cause continued errors until a rollback, either to a savepoint or of the transaction entirely. This makes savepoints quite common:

```
josh=# BEGIN;
BEGIN
josh=# SELECT syntax error;
ERROR: syntax error at or near "error"
LINE 1:  SELECT syntax error;
josh=# SELECT 1;
ERROR: current transaction is aborted, commands
ignored until end of transaction block
josh=# ROLLBACK;
```

Implementation note

MySQL, on the other hand, returns an error message for the syntax error, but still allows the transaction to commit:

```
mysql> start transaction;
mysql> insert into i values (1);
mysql> insert into i values (2);
mysql> insert into i values (1);
ERROR 1062 (23000):  Duplicate entry '1' for key 1
mysql> insert into i values (3);
mysql> commit;
Query OK, 0 rows affected (0.00 sec)
```

Perhaps this behavior irritates you as much as it does me.

Implementation note

Your mileage may vary. Test, and pay attention to return results and error messages

Isolation levels

Isolation: No uncommitted data from other sessions is ever visible to my session

- **Dirty read**: A transaction reads data from a concurrent uncommitted transaction
- **Nonrepeatable read**: A transaction re-reads data and finds another transaction has changed them
- **Phantom read**: A transaction re-executes a query, and the set of rows satisfying that query has changed due to some other transaction.

Isolation levels

The SQL standard defines four isolation levels in terms of these phenomena:

Isolation Level	**Dirty**	**Non-repeat**	**Phantom**
Read uncommitted	Yes	Yes	Yes
Read committed	No	Yes	Yes
Repeatable read	No	No	Yes
Serializable	No	No	No

Applications can choose an isolation level appropriate for their needs. Stricter levels may entail poorer performance.

Beyond the database

The ideas of transactions and ACID are not limited to databases. Some other examples:

- Message queues
- Integration software
- Transactional memory systems

An operation could, conceivably, want to include multiple transaction-aware services in one transaction:

- Read messages from a queue, and do work in a database in response to those messages
- Use data from multiple separate databases
- Move messages from one messaging service to another
- Build documents using data in a database in a multi-step integration process

This is possible with **distributed transactions**

Two–phase commit

A *distributed transaction* is a transaction involving multiple services. It works as follows:

1. BEGIN the transaction in each service
2. Perform whatever operations are necessary
3. PREPARE each transaction for commit
   - Each service guarantees at this point that it can commit the transaction, even if something crashes, before returning
4. If any service reports it can't commit, ROLLBACK each transaction
5. If we haven't rolled back, COMMIT each transaction on each service

This is called **two-phase commit** (2PC) because commit happens in two steps

Two–phase commit

2PC is slower than single-phase commit

- Communicating with N services is slower than communicating with 1 service, where $N > 1$.
- On PREPARE, each transaction must store transaction state on disk, to ensure durability
- The application must also store its own state on disk, in case it crashes between PREPARE and COMMIT
  - Applications generally use *transaction managers* rather than handle these details on their own

Bitronix transaction manager example

```
#!/bin/jruby
require 'java'

BTM = Java::BitronixTm::bitronixTransactionManager
TxnSvc = Java::BitronixTm::TransactionManagerServices
PDS = Java::BitronixTmResourceJdbc::PoolingDataSource

# Do the stuff below for each data source
ds1 = PDS.new
ds1.set_class_name 'org.postgresql.xa.PGXADataSource'
...
ds1.init
# Get datasource connections, and start a transaction
c1 = ds1.get_connection
c2 = ds2.get_connection
btm = TxnSvc.get_transaction_manager
btm.begin
```

Bitronix transaction manager example

```
begin
        # Do something on each connection
        s2 = c2.prepare_statement
               "INSERT INTO ledger VALUES ('Bob', 100)"
        s2.execute_update
        s2.close
        ...
        btm.commit
        puts "Successfully committed"
rescue
        puts "Something bad happened:  " + $!
        btm.rollback
end
```

Transaction pitfalls

Stuff to watch out for

- Long transactions are typically bad
  - Locks remain held until transactions commit
  - Rollback space can't be released until commit
  - This may be particularly bad with 2PC
- More complex transactions are probably more likely to roll back
- Handle exceptions properly (you're doing this already, right?)
  - If you roll back and try again, you have to redo the entire operation

Transaction benefits

Miscellaneous. transaction benefits

- Performance
  - Several INSERTs with Auto–commit will generally be much slower than the same inserts in a single transaction
- Simpler code
  - Wrap one transaction in one exception handling block
- Data integrity
  - Orphaned records and other data anomalies are much less likely

Questions?

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