References

Design Patterns: Elements of Reusable Object-Oriented Software, Gamma, Helm, Johnson, Vlissides, Addison-Wesley, 1995

States

Some Servers are stateful or have modes

Each connection has different states

Some commands are only legal in some states

How to deal with states?

If (case) statements
Table of function pointers
State Objects (State pattern)
Using Switch Statements

```java
int state = 0;
while (true) {
    command = input.read();
    switch (state) {
        case 0:
            if (command.isUser()) {
                username = command.argument();
                state = 1;
            }
            else if (command.isQuit())
                state = 4;
            else
                error("Illegal command: " + command);
            break;
        case 1:
            if (command.isPassword()) {
                if (valid(username, command.argument()))
                    state = 2;
                else {
                    error("Unauthorized User");
                    state = 3;
                }
            }
            else
                error("Unknown: " + command);
            break;
    }
}
```

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NoAuth</td>
</tr>
<tr>
<td>1</td>
<td>HaveUser</td>
</tr>
<tr>
<td>2</td>
<td>Process</td>
</tr>
<tr>
<td>3</td>
<td>Invalid</td>
</tr>
<tr>
<td>4</td>
<td>Quit</td>
</tr>
</tbody>
</table>
int state = NO_AUTH;
while (true) {
    command = input.read();
    switch (state) {
    case NO_AUTH:
        noAuthorizationStateHandle( command );
        break;
    case HAVE_USER:
        haveUserStateHandle( command );
        break;
    case PROCESS:
        processStateHandle( command );
        break;
    case INVALID:
        invalidStateHandle( command );
        break;
    case QUIT:
        quitStateHandle( command );
        break;
    }
}

void noAuthorizationStateHandle(PopCommand a Command) {
    if (command.isUser()) {
        username = command.argument();
        state = HAVE_USER;
    } else if (command.isQuit())
        state = QUIT;
    else
        error("Illegal command: " + command);
}
## Switch Method Analysis

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard to read for large or complex states</td>
<td>Everyone understands if statements</td>
</tr>
<tr>
<td>Hard to modify</td>
<td>Simple for small/simple situations</td>
</tr>
<tr>
<td>Hard to debug</td>
<td></td>
</tr>
<tr>
<td>The code will get very long very quickly</td>
<td></td>
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</tbody>
</table>
Special Case

command = input.nextCommand()

if command.isLogin()
    process login
else
    handle illegal command
end

while !command.quit?
    command = input.nextCommand()
    process command
end
### Implementing a State Machine with a Table

<table>
<thead>
<tr>
<th>Commands</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NoAuth</td>
</tr>
<tr>
<td>USER</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td></td>
</tr>
<tr>
<td>LIST</td>
<td></td>
</tr>
<tr>
<td>RETR</td>
<td></td>
</tr>
<tr>
<td>QUIT</td>
<td></td>
</tr>
</tbody>
</table>

Each cell needs:

- A function to process request
- Next state on success
- Next state on failure
## State Table Details

<table>
<thead>
<tr>
<th>Commands</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NoAuth</td>
</tr>
<tr>
<td>USER</td>
<td>actionUser</td>
</tr>
<tr>
<td></td>
<td>HaveUser</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
</tr>
<tr>
<td>PASS</td>
<td>actionNull</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
</tr>
<tr>
<td>LIST</td>
<td>actionNull</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
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<tr>
<td></td>
<td>Invalid</td>
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<tr>
<td>RETR</td>
<td>actionNull</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
</tr>
<tr>
<td></td>
<td>Invalid</td>
</tr>
<tr>
<td>QUIT</td>
<td>actionQuit</td>
</tr>
<tr>
<td></td>
<td>Quit</td>
</tr>
</tbody>
</table>

Function to process request

Next State on success

Next State on failure
Basic Operation

Get request from user

Use current state and new request to find in table operation to perform

Perform the operation

Change state based on table and result of operation
How to place Operation in a Table

**C/C++**
Use function pointers

**Smalltalk**
Use symbols and reflection
Use blocks

**Java**
Use reflection
Use Inner classes

**Ruby**
Use function references
Function Pointers in C/C++

void quickSort(int* array, int LowBound, int HighBound) {
    // source code to sort array from LowBound to HighBound
    // using quicksort has been removed to save room on page
}

void mergeSort(int* array, int LowBound, int HighBound) { // same here}

void insertionSort(int* array, int LowBound, int HighBound) { // ditto }

void main() {
    void (*sort)(int*, int, int);
    int size;
    int data[100];

    // pretend data and Size are initialized

    if (size < 25)
        sort = insertionSort;

    else if (size > 100)
        sort = quickSort;

    else
        sort = mergeSort;

    sort(data, 0, 99);
}
SPOP State table in C/C++

struct
{
    int   currentState;
    char  *command;
    int   stateIfSucceed;
    int   stateIfFailed;
    int   (*action)(char **);
} actionTable[] =
{
    {0, "USER", 1, 3, actionUser},
    {0, "QUIT", 4, 4, actionQuit},
    {1, "PASS", 2, 3, actionPass},
    {1, "QUIT", 4, 4, actionQuit},
    {2, "LIST", 2, 2, actionList},
    {2, "RETR", 2, 2, actionList},
    {2, "QUIT", 4, 4, actionList},
    {0, 0, 0, 0, 0}
};

Easy to see what is going on.

Easy to add new commands.
def cat()
    puts 'dog'
end

def increase(aNumber)
    puts aNumber + 1
end

x  = method(:cat)
x.call

y = method(:increase)
y.call(4)
Ruby State Table

noAuth = {
    #Command Success Fail State action
    :user => [:HaveUser, :Invalid, method(:actionUser)]
    :quit => [:Quit, :Quit, method(:actionQuit)]
    etc.
}

haveUser = {
    :pass => [:Process, :Invalid, method(:actionPass)]
    :quit => [:Quit, :Quit, method(:actionQuit)]
    etc
}

stateTable = {
    :NoAuth => noAuth
    :HaveUser => haveUser
    etc
}

currentState = :NoAuth

while currentState != :Quit
    command = input.readCommand()
    stateOperations = stateTable[currentState][command.symbol]
    operationSucceeded? = stateOperations[3].call(command.data)
    if operationSucceeded?
        currentState = stateOperations[0]
    else
        currentState = stateOperations[1]
    end

def actionUser
    blah
end

def actionQuit
    blah
end
State Table Analysis

Advantages

- Compact view of states and transitions
- Easy to add remove states
- Easy to modify transitions

Disadvantages

- Language support varies
- Compile time checks are replaced by runtime check
Implementing a State Machine: Objects

Each method (pass, user, etc.) performs the proper action for the given state and returns the next state.

SPopState is abstract state with the default behavior for each method.
class SPopServer
{
    public void processRequest(InputStream in, OutputStream out, InetAddress clientAddress) throws IOException
    {
        SPopState currentState = new NoAuth();
        do
        {
            ProtocolParser requestData = new ProtocolParser( in );
            String request = requestData.getCommand();
            if ( request.isPassword() )
                currentState = currentState.pass( request, this);
            else if ( request.isUser())
                currentState = currentState.user(this);
            etc.
            send response to client
        } while ( ! currentState instanceof Quit );
    }
}
public class SPopState {
    public SPopState quit( SPopServer parent) {
        return new Quit();
    }

    public SPopState pass( PopCommand clientRequest, SPopServer parent)
        throws IllegalCommand {
        throw new IllegalCommand();
    }

    public SPopState user( PopCommand clientRequest, SPopServer parent)
        throws IllegalCommand {
        throw new IllegalCommand();
    }

    public SPopState list( PopCommand clientRequest, SPopServer parent)
        throws IllegalCommand {
        throw new IllegalCommand();
    }
}
Subclasses Implement Correct behavior for that State

```java
public class NoAuth extends SPopState {
    public SPopState user( PopCommand clientRequest, SPopServer parent) {
        parent.setUser( clientRequest.getArgument() );
        parent.sendOKResponse();
        return new HaveUser();
    }
}

public class HaveUser extends SPopState {
    public SPopState pass( PopCommand clientRequest, SPopServer parent) {
        parent.setPassword( clientRequest.getArgument() );
        if ( parent.user&PasswordValid() ) {
            parent.sendOKResponse();
            return new Process();
        }
        else {
            parent.sendErrorResponse();
            return new NoAuth();
        }
    }
}
```
State Object Analysis

Problems

Lots of little parts

Algorithm distributed among different classes

Advantages

Easy to add new states

Easy to change state transitions

Each State class deals with one state