Case Study
Multi-Panel Interactive System

The Problem Domain

- Build a general type of interactive system
  - **Users interact with a set of panels**
    - **Web applications are an example**
- Each session goes through a number of states
    - **Finite state machine**
    - **Automatic Teller Machine**
  - **A state corresponds to a fill-in-the-blanks panel**
    - **User is adding to a database of information**
  - **Depending upon user choices transitions occur to other states**

Example Panel

– Enquiry on Flights –

Flight from Somewhere Flight to Anywhere

Departure on or after not soon enough

on or before too late

Preferred airline(s):

Special requirements: ______________________

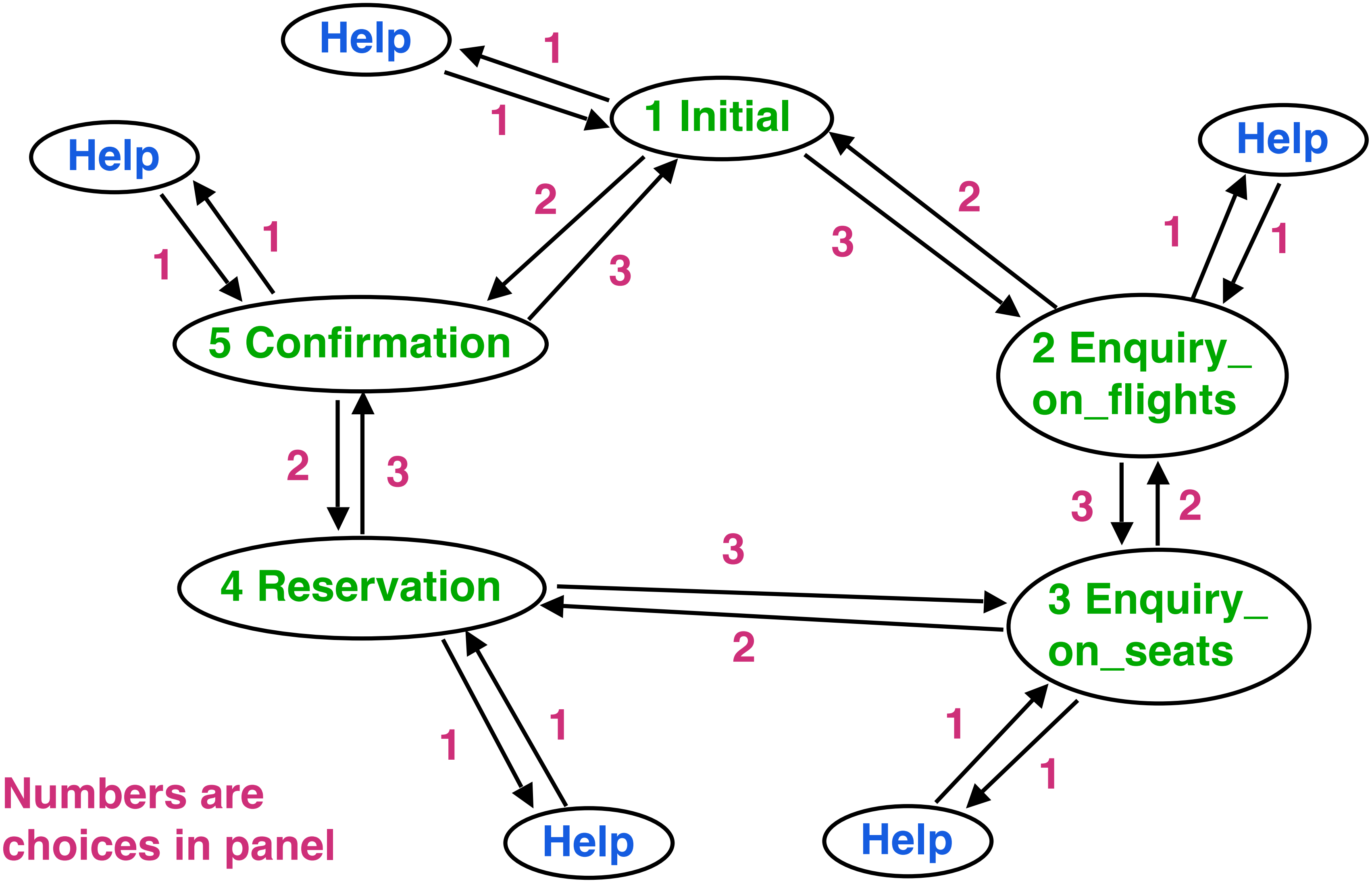
Available flights: 1

Flt# AA 42 Dep 8:25 Arr 7:45 Thru: Chicago

Choose next_action

0 Exit 1 Help 2 Further enquiry 3 Reserve seat

A State Transition Diagram



Numbers are choices in panel

The Problem

- Create a design and implementation for such applications
- General & flexible solution
- Things to think about
  - » **Finite state machine may be very large**
    - > **Applications can have hundreds of states and thousands of transitions**
  - » **Structure of the system is subject to change**
    - > **Cannot foresee all possible states & transitions**
  - » **No specific application is mentioned**
    - > **What if you need many variations**

The Problem – 2

- A general design – a set of reusable modules – would be a huge benefit
- Getting the problem to work is only a part of the solution and insufficient for the task
- Customer's requirements go **far beyond**
  - » **mere correctness**
  - » **mere functionality**

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First Attempt

- Block/Module oriented – procedural
- System made of a number of blocks
    - **One for each state in the FSM**

First Attempt – 2

```
Enquiry_Block
    "Display Enquiry on Flight panel"
    repeat
        get user's answer and choice C for next step
        if error in answer then output error fi
    until not error in answer

    "Process answer"
    case C in
        C0 : goto Exit_Block
        C1 : goto Help_Block
        C2 : goto Reservation_Block
        ...
    esac
```

Similarly for all other states

Easy to devise, does the job

Terrible for meeting requirements

What are the Problems Block Design?

- Use **goto**'s (Dijkstra)
  - » **Usually symptomatic of deeper problem**
- Branch structure (**goto**'s) are an exact implementation of the graph
  - » **Vulnerable to change**
    - > **Add a new state**
      - – **add new block, change all other blocks**
    - > **Add a new transition**
      - – **Change all blocks that should use it**

What are the Problems – 2

- Forget **reusability** across applications
  - » **Specific to one application**
- Want not just a solution but a **quality solution**
  - » **Have to work harder**
- **What does quality mean for this system?**

Top Down – Functional Solution

- Problems seem to be due to the traversal (**goto**) structure
- Generalizing the transition diagram will gain generality
- Model the function transition as a transition table representation of a FSM
  - » **Designate one state as initial**
  - » **One or more states as final**

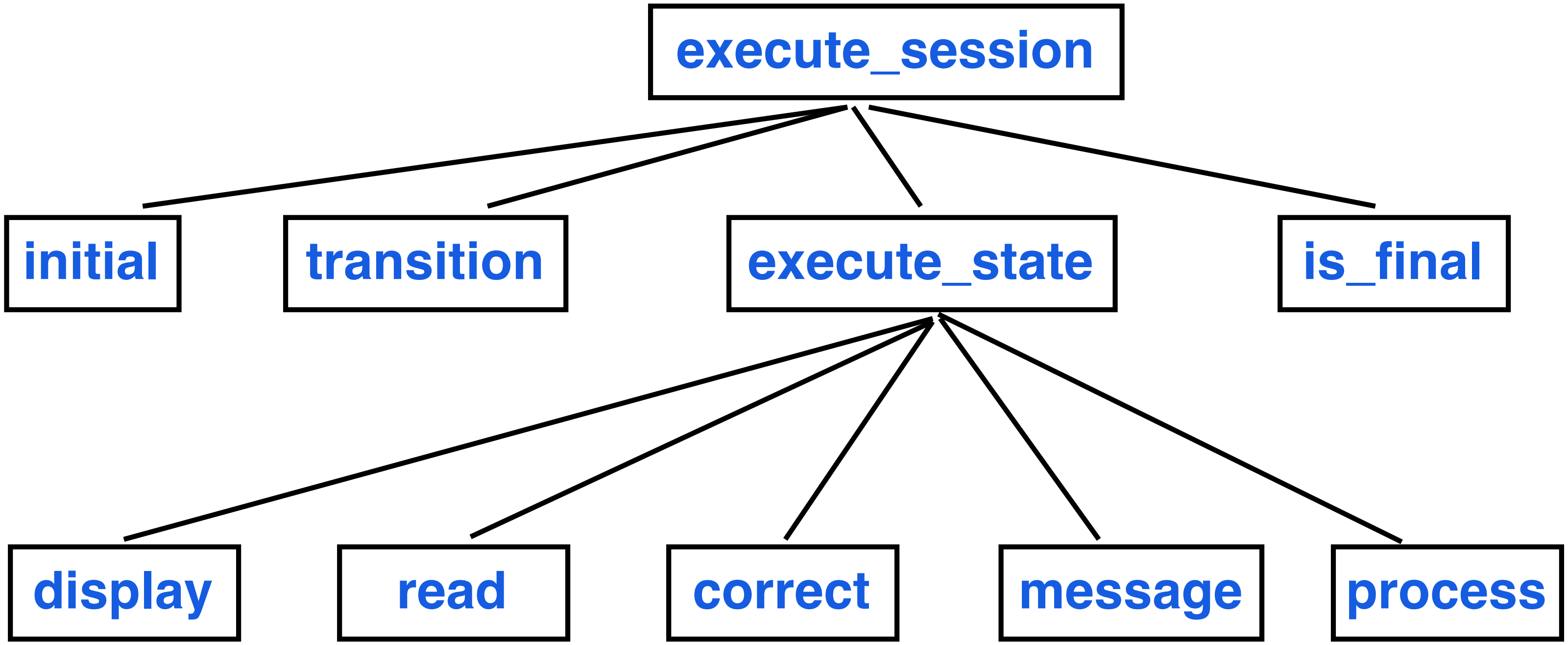
Transition Table

Choice

State

	0	1	2	3
1 Initial	-1	0	5	2
2 Flights		0	1	3
3 Seats		0	2	4
4 Reserv.		0	3	5
5 Confirm		0	4	1
0 Help		back		
-1 Final				

Top Down Decomposition



Implement execute_session

```
execute_session is
    -- Execute a complete session
    local state, next : INTEGER
    do
      state := initial  -- start in initial state
      repeat
                                          -- next is var parameter
         execute_state (state, next )
         state := transition ( state, next )
      until is_final ( state ) end
    end
```

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Implement execute_state

```
execute_state ( in s : INTEGER , out c : INTEGER ) is
    -- c contains the user's choice for next state
    local a : ANSWER  ;  ok :BOOLEAN
    do
      repeat
          display (s )    -- display panel for state s
          read ( s , a )   -- get user answer in a
          ok := correct ( s , a )
      until ok end
      process ( s , a )
      c := next_choice ( a )    -- get user choice for panel
    end
```

State s is argument for all functions!

What will be the structure/design of display?

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What are the Problems Top Down?

- Tight coupling
  - » **State is argument to every routine**
- Means long and complicate control structure
  - » **Case statements everywhere on state**
- Violates single choice principle
  - » **Too many locations need to know about all states**
    - > **difficult to modify as states added or removed**
- Not reusable/general –□except as a template
  - » **implicit argument in all functions is the application**
  - » **Generality □ know about all states in all applications**

An OO Solution

Routines exchange too much data ?
▯ put routines in your data

- Instead of building components around operations while distributing data
  - » **OO does reverse**
    - > **build around data and distribute operations**
- Use most important data types as basis for modules
  - » **Routines are attached to data to which it relates most closely**
- In our example **state should be a class**

State as Class

- What would be handed over to state?
  - » **All operations that characterize a state**
    - > **Displaying screen**
    - > **Analyzing answer**
    - > **Checking answer**
    - > **Producing error messages**
    - > **Processing correct answer**
  - » **Customize for each state**

Class State

STATE*

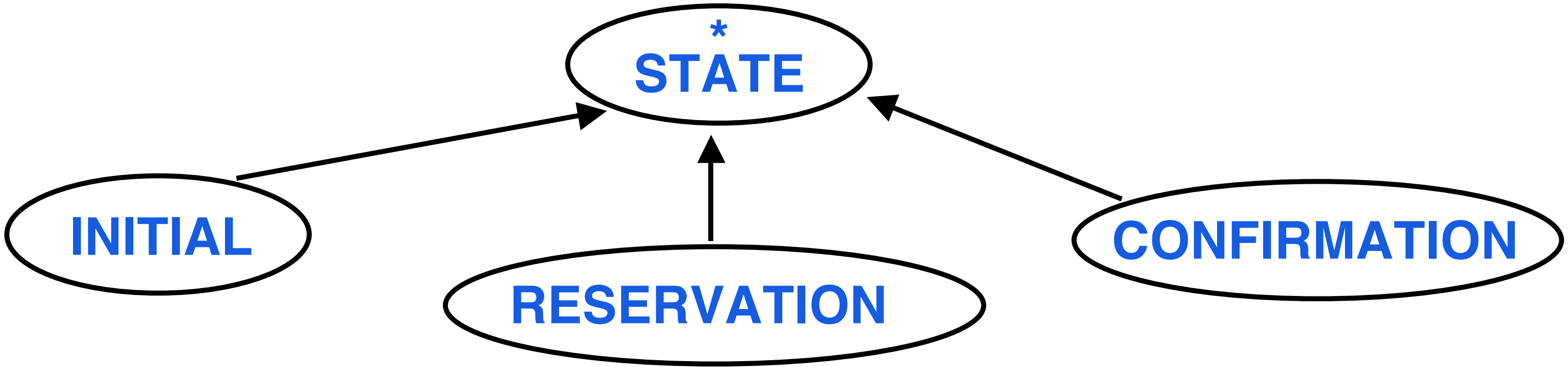
input : ANSWER
choice : INTEGER
execute
correct : BOOLEAN
display*
read*
message*
process*

- Deferred class
- Deferred features
- Execute is effective because we know its behaviour

```
execute is
local ok : BOOLEAN
do
   from ok := false until ok loop
   display  ;  read  ;  ok := correct
   if not ok then message end
   end
ensure ok
end
```

Inheritance & Implementation

- **STATE** describes the general notion of state
  - **execute is the same for all states**
  - **other routines must be customized**
- Use deferred classes to specify general situation and provide for extension
- Use inheritance to specify particular states
  - **Implement deferred routines**



Architecture of System

- Separates elements common to all states and elements specific to individual states
- Common elements do not need to be redeclared in descendants
- Satisfies **open-closed principle**
  - » **STATE is closed**
  - » **Inheritance opens it**
- State is typical of **behaviour classes**
  - » **deferred classes capture common behaviour**
- Inheritance & Deferral are key for reusable components

Completing the System Design

- How do we represent transitions and an actual application?
- Have to take care of managing a session
  - » **What execute_session did in top down**
- What is missing?
  - » **The notion of the specific application**

Application Class

- Features
  - **execute**
    - **how to execute the application**
  - **initial & is_final**
    - **special states – properties of application**
  - **transition**
    - **mapping from state to state**
- May want to add more features
  - **Add new state or transition**
  - **Store in a data base**
  - **...**

Application Class – 2

notes in
next slide

```
class application feature
   initial : INTEGER
   execute is
      local st : STATE  ;  st_number : INTEGER
      do
      from st_number : initial
      until st_number = 0 loop
         st := associated_state.item ( st_number )
         st.execute
         st_number := transition.item (st.number, st.choice )
      end
   put_state ( st : STATE; sn : INTEGER) is …
   choose_initial (sn : INTEGER ) is …
   put_transition (source, target, label : INTEGER ) is …
feature { NONE }
   transition : ARRAY2 [ STATE ]
   associated_state : ARRAY [ STATE ]
end
```

Implementing the Design

- Number states from 1..N for the application
  - » **Array associated_state of APPLICATION gives the STATE associated with a number**
  - » **It is polymorphic**
- Represent transition as an P (states) x Q(choices) array **transition**
- Attribute **initial** represents the initial state
- Creation procedure of APPLICATION uses creation procedures of ARRAY and ARRAY2
  - – **see p691 & 692 of Meyer 1997**
- Building an application is relatively easy due separation of parts

Points to Think About

- Forget about a main program
- Focus on data abstraction
  - » **Leads to structures that can more easily change and are more easily reused**
- Don't ask
  - » **What does the system do?**
    - > **It is not a function**
- Big win from OO
  - » **clear, general, manageable, change-ready abstractions**

Points to Think About – 2

- Don't worry too much about modelling the **real world**
  - » **Goto version is a close model but poor design**
- Heuristic to find the classes
  - » **Look for data transmissions and concepts that appear in communication between numerous components of a system**

What counts in OO design is how good are your abstractions for structuring your software.

Above all else, worry about finding the right abstractions