DIVISION OF COMPUTER SCIENCE

SEQUENTIAL ANIMATION OF A STRUCTURED ANALYSIS REQUIRED LOGICAL MODEL OF A VENDING MACHINE CONTROLLER

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1. Background

To give brief summary of research

This report summarises part of a research programme investigating prototyping methods for real-time systems. Previous work has examined Ada tasking as an animation tool for data flow models [Fensome 92], and the use of data flow to model real time system functional requirements [Fensome 93]. The present report describes work carried out in animating a Vending Machine case study using the sequential programming paradigm.

2. Structured Analysis (SA) requirement model

To summarise required logical model used for this reort

The vending machine controller is described in [Fensome 93], where the requirements and logical context diagrams are shown. Appendix 1 of the present report shows the first level decomposition of the requirement model, and includes the required logical model of data flow and control flow, and the control machine.

3. Structured Analysis Control Centred Animation

To summarise the design and to present pros and cons

The animation is a conventional control centred design, shown in Appendix 2 as a top level structure chart and Ada styled program units. Only sample parts of the design are given, which are sufficient to demonstrate the important features of the design transformation. The design is carried through to asking for an event input and producing a model output, and a procedural abstraction has been used throughout.

At the top level of the control machine design, the first decisions to be made concerned the data flow between program modules, and how atomic execution of input events could be emulated. These decisions involved dealing with polled inputs, and in particular how null inputs (null events) and time outs were to be handled. I decided that the control data flow p2cev and p3cev (in cfd0) would be a suitable coupling mechanism to the control module, if a 'null' event could be added to the design to signify no particular input event had occurred.

An automatic time-out event 'to' could be generated if time spent in, for example, the Input Control module was too long. Automatic time-out did assume an Ada environment with all the facilities of package Calendar (ie background real time clock which could be interrogated periodically). If this was not required or undesirable, then the time out could be generated by the animation user as just another input event.

The next problem was how to deal with the process activators pat3 and pat4 in cspec0. Should these be explicitly coded into the design or were these an unnecessary complication in the animation ? In fact since the control machine knows whether p3 or p4 are active, and will only call the appropriate process if it is active, there seems little point in having additional variables to represent the process activators. An example of this is when the event 'mp' (minimum payment) takes the control machine from S1 to S2 and activates P3 via pat3.

One control event 'cg' ("change given") also appears to be redundant in the design. In the requirement model it is necessary to signal this event to the control machine from

P4 (see cspec0), but again is unnecessary in the sequential implementation because control will return to the control machine automatically when P4 has executed.

Overall the animation design was not as easy as might be assumed, and took much longer than expected (is any design easy?). How this might be quantified I am not sure, but I am now aware of the difficult areas ie polling of inputs, atomic execution emulation, relevance of requirement model communication primitives.

However the design did show that the animation user I/O was not so much a problem as expected. The design would produce a scrolled screen on the animation computer which typically might be -

Return Coins? Y/N = N	New Stock? Y/N = N Customer selects = Cola	Customer Inserts = 10p
Product Available = Y	Product Given = Cola	Change = null

for each input event. This might seem crude, but would provide an adequate listing of event sequences and responses, in order to check for correct functionality.

4. Direct Animation with Visual Basic

To summarise design and to present pros and cons

The ability to quickly draw a user interface for the animation, and easily connect events into their related processing, was the reason why Visual Basic was used as an Animation Tool.

Visual Basic is a programming environment which provides a set of standard interface objects (eg boxes, buttons) on screen windows called forms, so that input events on the forms can be easily processed. The interface objects are connected into the programming environment by defined subprograms. For example the button labelled '10p' in the customer form shown in Appendix 3, is given a name Tenp_In and is connected via subprogram Tenp_In_Click, where 'Click' is the predefined name for the mouse click event on the button. Appendix 3 gives the complete Visual Basic listing for the CPVM animation, and shows Sub Tenp_In_Click ().

There are very few design decisions using Visual Basic as an animation tool because the programming paradigm is one of input event and subsequent processing. The atomic execution semantics of the data flow model are automatically provided by Visual Basic. This is an advantage because it makes the animation easy to implement from the data flow model ie the programmer just provides a connection into the Basic programming environment by coding 'Click' subprograms. The control machine cspec0 can easily be implemented as a subprogram which is called when each input event occurs. Also the process activators can be implemented as global variables which can be inspected by other subprograms which implement processes. For example see process 3 implemented as Sub validate_selection. Therefore there is an easy translation mechanism from a data flow model to the animation in Visual Basic.

The CPVM Visual Basic listing in Appendix 3 does not show any time-out events, but these could have been added as 'user generated' from the customer form. Visual Basic also provides a background idle loop facility which could be used to code automatic timeout events using the general timer facilities. The Timer function however was used to generate a delay function, which was then used to display a sequence of change coins in the 'Returned' box of the customer form.

However there are some disadvantages in using Visual Basic as an animation tool, mainly in the programming facilities offered by the language. Visual Basic has some

data typing facilities but these are somewhat crude, particularly for discrete types. For example there are no integer subtypes or enumerated types, each being implemented as a standard integer type (as Booleans are too).

The modularisation facilities in Visual Basic are also somewhat crude compared to the standard Ada facilities. Global modules, modules related to forms, and general purpose modules are provided, but there is no attempt to encapsulate data or provide anything which could remotely be called object oriented facilities. This is a very negative feature of Visual Basic, especially as part of my research objectives is to look for a prototyping method which allows carry over of prototype components into production software.

Finally the syntax for subprogram calls, whilst not difficult to use or learn, also caused problems. This is because procedure calls do not use brackets around the actual parameters, whereas function calls do have brackets. However if you call a procedure with brackets by mistake, it is misinterpreted as an array reference, a local array is set up (by default), and no error is reported. This is most unfortunate !

5. Conclusions

Emulation of the requirement model semantics with a sequential animation was certainly easier than the parallel equivalent (see technical report 131) where there was a significant tasking overhead. The programming tool used for the sequential animation did make a significant difference however.

Programming in an Ada environment was relatively difficult compared with the Visual Basic environment, because

- input polling had to be designed
- some of the requirement model communication primitives were redundant

In Visual Basic however, the animation was straight forward at the design level because processing is directly connected to input events, and the programming paradigm directly mirrors the requirement model semantics. However the language as a programming tool has some disadvantages in its abstraction and encapsulation facilities. Also the benefits of the graphical interface are questionable for prototyping event oriented systems, where a tabulated list of events and consequences are required.

For future work it is proposed that the prototype programming environment should provide

- only sequential programming
- input event scanning with easy facilities to connect into the required processing
- scrolled textual I/O
- good data typing including subtypes and ennumerated types
- good abstraction facilites; at least data abstraction, but preferrably object oriented (for ease of design transfer to production software).

References

[Fensome 92] *Prototyping Real Time Engineering Systems using Hatley & Pirbhai's Requirement Model* : April 92, School Information Sciences Technical Report No 131, University of Hertfordshire

[Fensome 93] *Modelling Real Time Systems Functional Requirements using Existing Data Flow Methods*: July 93, School Information Sciences Technical Report No 160, University of Hertfordshire

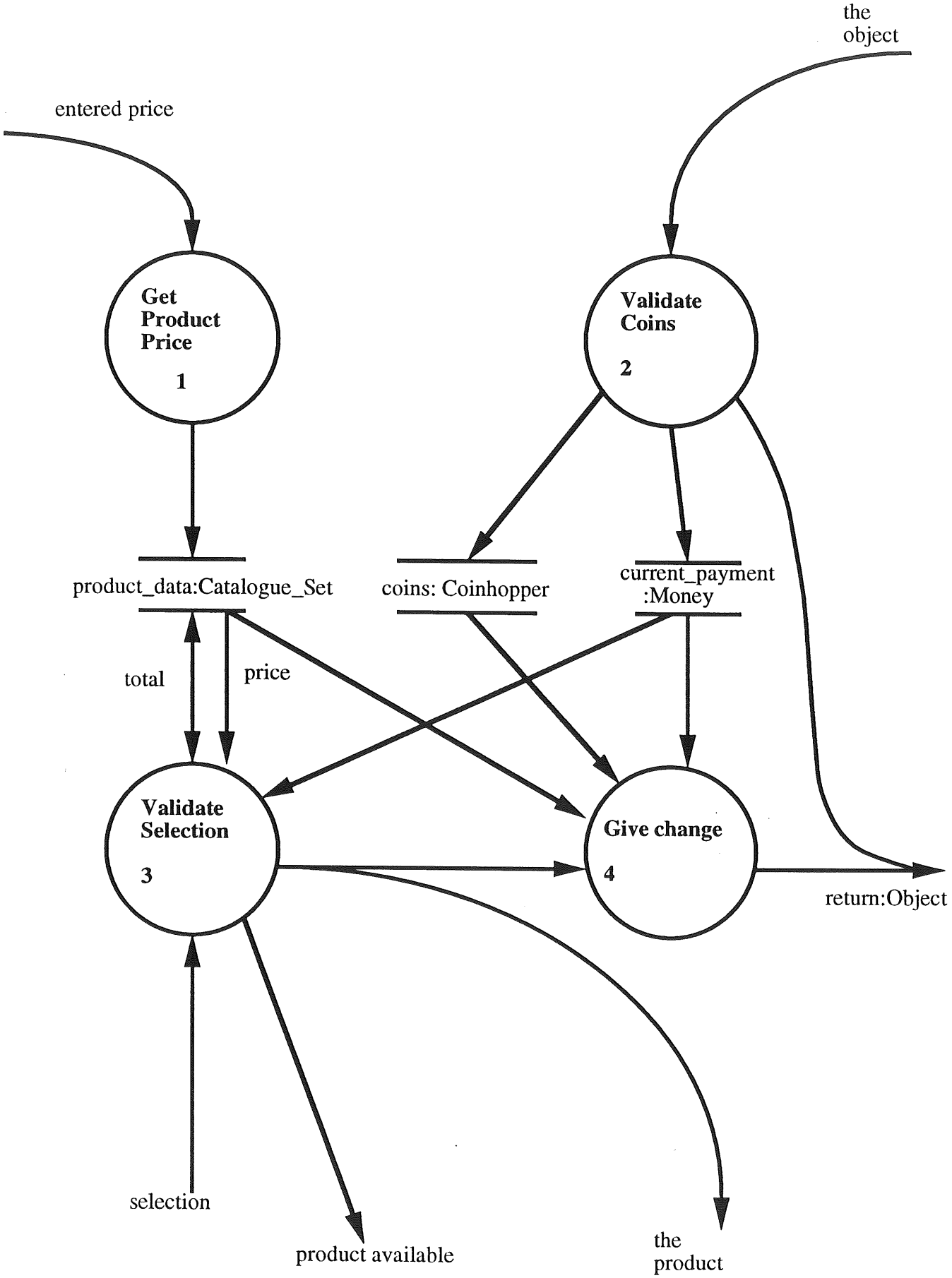
Appendix 1

Structured Analysis Required Logical Model

Level 1 DFD

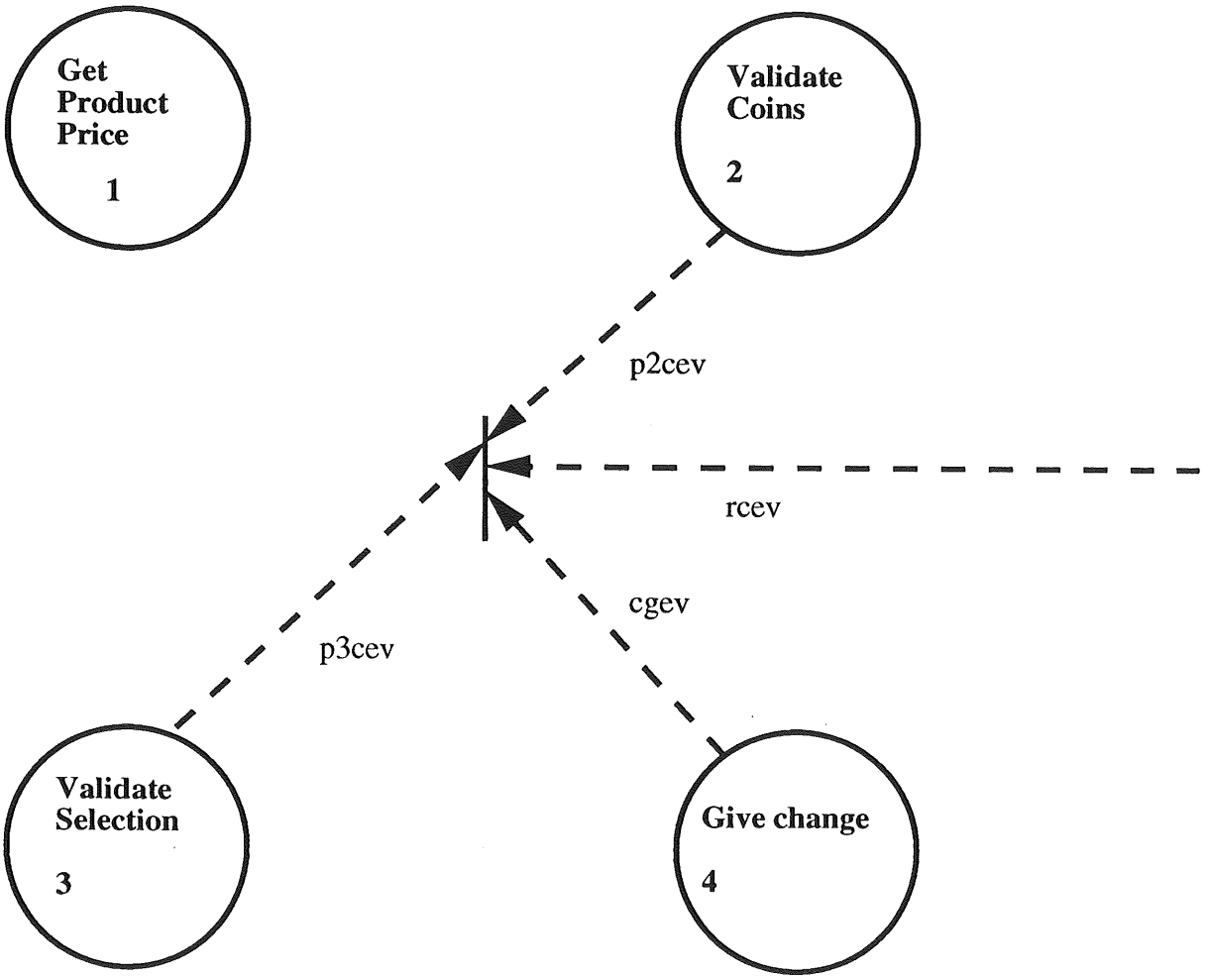
Level 1 CFD

Cspec0



CPVM DFD 0 Level 1

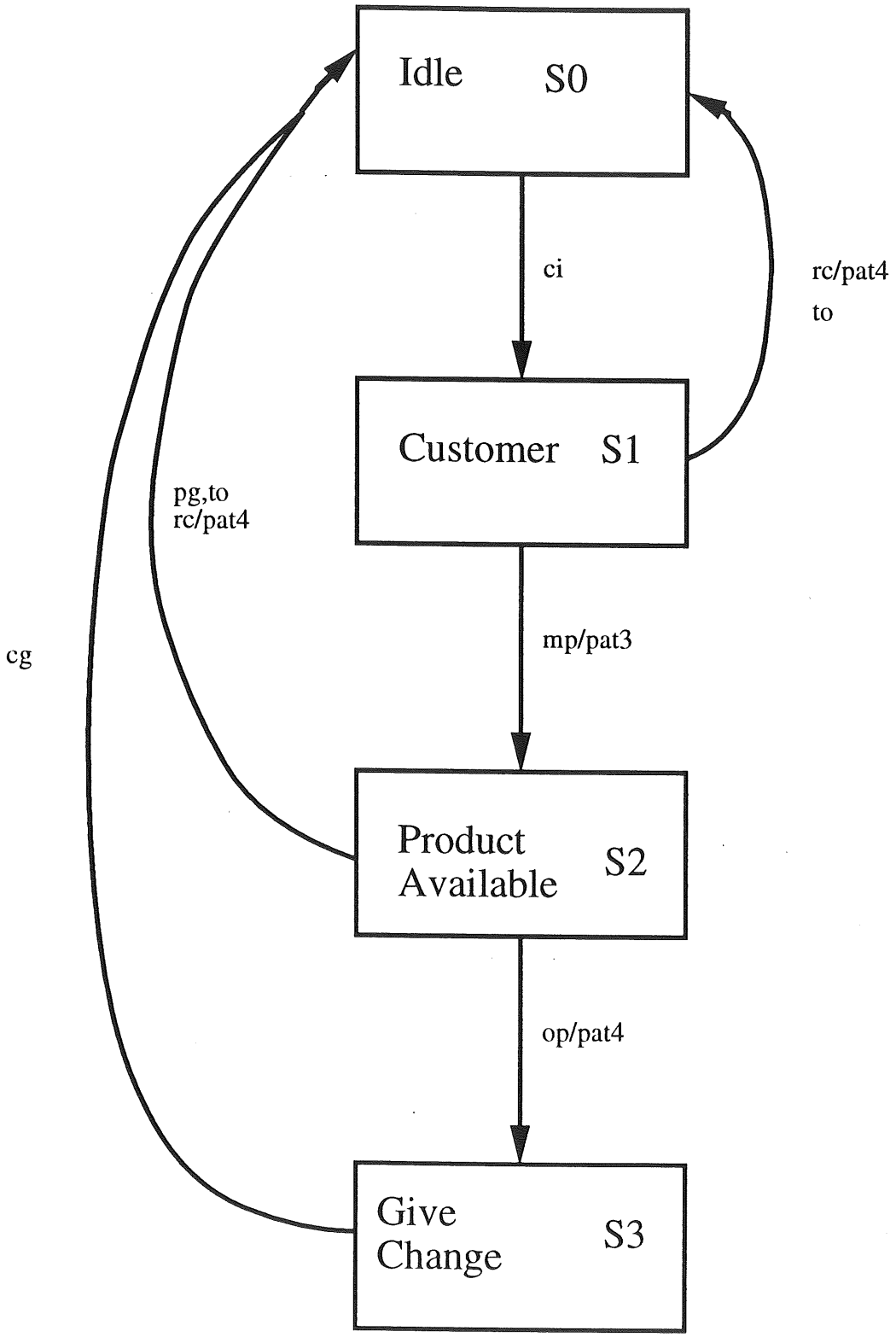
Required Logical Model



EVENT = {ci, mp, rc, pg, op, cg, to}

where
ci = coin inserted
mp = minimum payment
rc = return coins
pg = product given
op = over payment
cg = change given
to = time out

CPVM CFD 0 **Level 1**


Idle S0
ci
rc/pat4
to
Customer S1
pg,to
rc/pat4
cg
mp/pat3
Product
Available
S2
op/pat4
Give
Change
S3

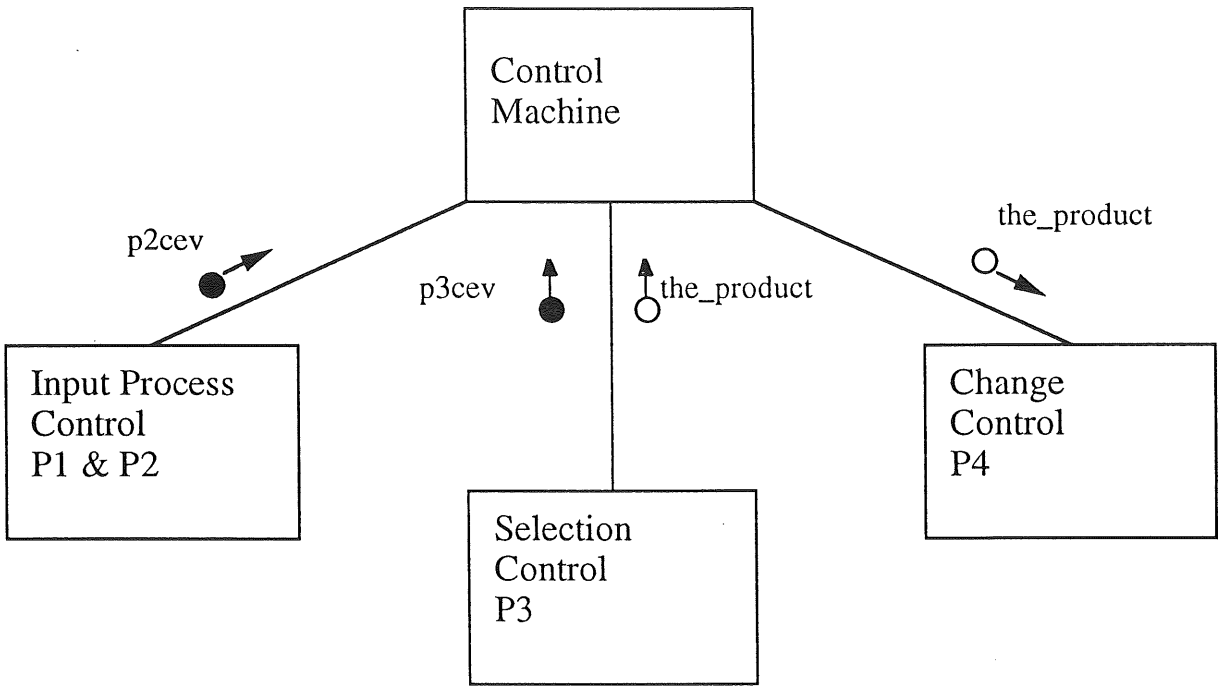
CPVM CSPEC 0

Appendix 2

Control Centred Structured Design

a) Top Level Structure Chart

b) Ada Style Control Centred Design



CPVM Animation
Top Level Control Centred Design

Fig 1

```
-- Ada Style CPVM Animation
-- Control Centred Design, module control machine
-- Oct 1993     D. A. Fensome

procedure main is

        p2cev, p3cev : EVENT;
        the_product : PRODUCT;
        vendmc : STATE;

        loop
                case venmc is
                        when S0 =>                              --Idle state
                                p2cev := Input_Control;
                                if p2cev = ci then              --coin inserted
                                        vendmc = S1;
                                end if;
                        when S1 =>                              --Serious Customer
                                p2cev := Input_Control;
                                if p2cev = rc then              --Return Coins
                                        vendmc = S0;
                                        Change_Control(null);--Give coins back!
                                els if p2cev = mp then          --Minimum payment
                                        vendmc = S2;
                                els if p2cev = to then
                                        vendmc = S0;            --timed out
                                end if;
                        when S2 =>
                                loop                            --poll all inputs
                                        p3cev := Selection_Control ( the_product);
                                        p2cev := Input_Control;
                                        if p3cev = op then      --overpaid, give change
                                                vendmc = S3;
                                                exit loop;
                                                                --time out, or return coins
                                        els if p3cev = to or p2cev = rc then
                                                Change_Control(null);
                                                vendmc = S0;
                                                exit loop;
                                                                --product given, no change
                                        els if p3cev = pg then
                                                vendmc = s0;
                                                exit loop;
                                        end if;
                                end loop;
                         when S3 =>
                                Change_Control(the_product);
                end case;
        end loop;

end main;
```

```
--Ada Style CPVM Sequential Animation
--Input Process Control P1 and P2
--D.A.Fensome          Oct 93

function Input_Control return  EVENT is

rcev : EVENT;
new_stock : CATALOGUE;
the_object : OBJECT;
the_money : MONEY;
entry_time : TIME;

begin
        entry_time :=  CLOCK;                       -- note the time
        loop
        get_return_coins (recev);                   --return coins demanded?
        if rcev /= null then
                return ( rcev);
        end if;

        get_new_stock (new_stock);                  --has stocker restocked/repriced?
        if new_stock /= null then
                put_new_stock(new_stock);
        end if;

        get_the_object (the_object);
        if the_object /= null then                  --anything input in coin chute?
                if the_object  = Slug then
                        P4.put_return (Slug)   -- return slug to user, not for us!
                else                                --convert to type money and store data
                        object_to_money (the_money, the_object);
                        add_to_current_payment (the_money);
                        add_to_coins(the_money);
                end if;
                return (is_mp);                 --has minimum payment been made?
        end if;

        until Is_Time_out (entry_time, timeout);
        return (to);

end Input_control;

-- Animation user I/O
-- Ada style

function get_return_coin return EVENT is

the_char : CHARACTER;

begin
        text_io.put ("Return coins ? Y/N = ");
        text_io.get (the_char);
        return (if the_char = 'Y' then rc else null; end;)
end get_return_coin;
```

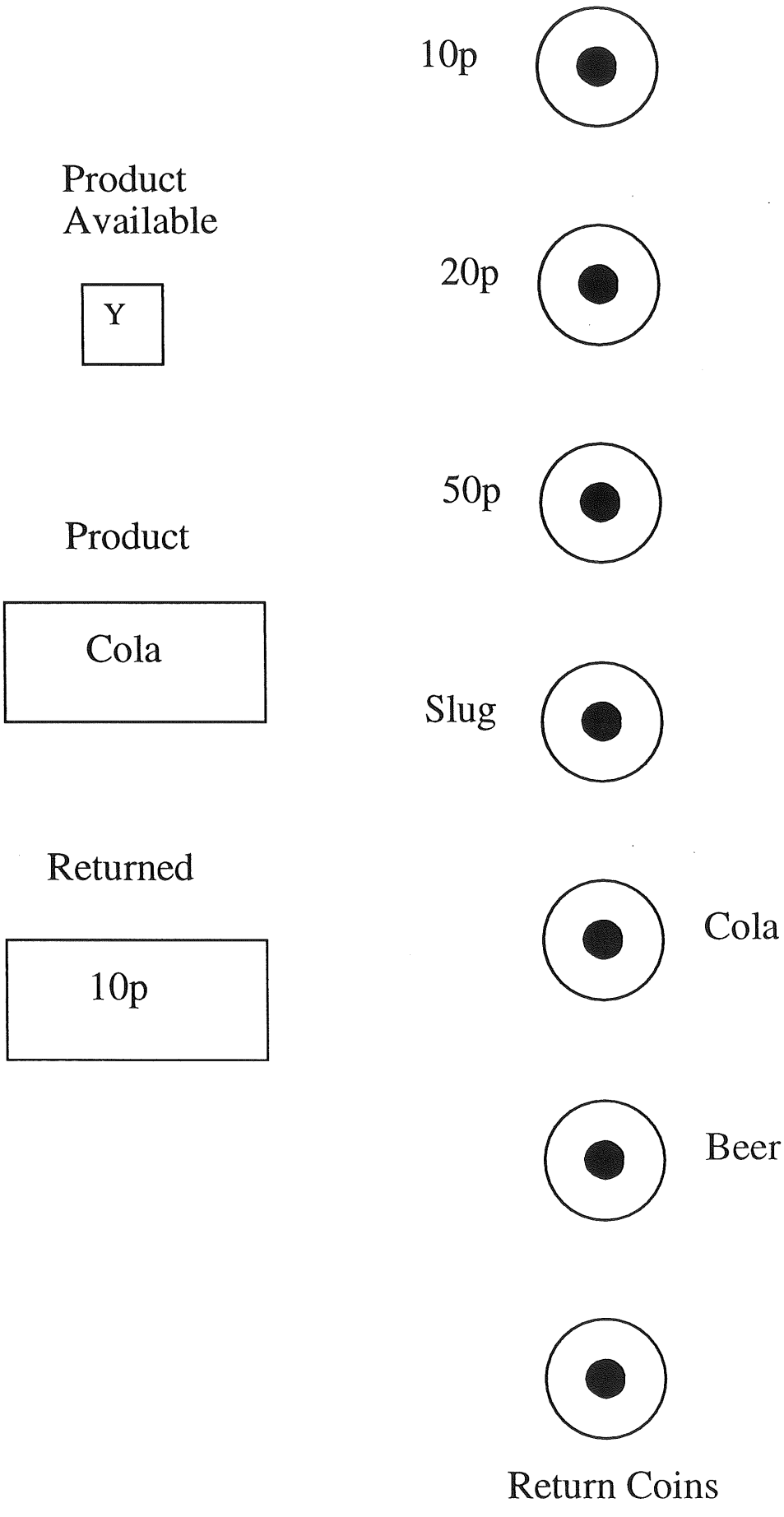
```
-- Part of P4 change control

procedure put_return (the_object : OBJECT);

begin
        object_io.put (the_object);
        text_io.putline ("Returned to Customer");
end put_return;
```

Appendix 3

Visual Basic Animation

Customer Form

Visual Basic code



Visual Basic - Customer Form

```
'Visual Basic sequential implementation of CPVM
'D.A.Fensome August 93

'H & P's finite state control machine '
'
Sub cspec0 (ByVal cev As Integer)

'*************************

Select Case state
      Case s0
            If cev = ci Then            'coin inserted
                  state = s1
            End If
            Pat3 = False
            Pat4 = False
      Case s1
            If cev = mp Then            'minimum payment
                  state = s2
                  Pat3 = True
            ElseIf cev = rc Then        'return coins
                  state = s0
                  Pat4 = True
            ElseIf cev = to Then
                  state = s0
            End If
      Case s2
            If cev = op Then            'over paid
                  state = s3
                  Pat4 = True
            ElseIf cev = pg             'product given
                    state = s0
                    Pat3 = False
            ElseIf cev = rc Then
                  state = s0
                  Pat4 = True
            End If
      Case s3
            If cev = cg Then            'change given
                  state = so
            End If

      End Select


End Sub

Sub Return_coins_Click ()
'*******************
      cspec0 rc
      Give_change null

End Sub
```

```
'process 2
'
'
Sub get_coins (ByVal the_object)

'************************

Select Case the_object
        Case Tenp
                current_payment = current_payment + 10
                Coins.TenpCount = Coins.TenpCount + 1
        Case Twentyp
                current_payment = current_payment + 20
                Coins.TwentypCount = Coins.TwentypCount + 1
        Case FiftypCount
                current_payment = current_payment + 50
                Coins.FiftypCount = Coins.FiftypCount + 1
        Case slug
                returned.text = "SLUG...urghh"
End Select

If current_payment >= Min_payment Then
        cspec0 mp
End If

End Sub


Sub Tenp_In_Click ()
'*****************
        cspec0 ci
        get_coins Tenp
        Tenp_In.Value = False

End Sub

Sub Twentyp_In_Click ()
'*******************
        cspec0 ci
        get_coins Twentyp
        Twentyp_In.Value = False

End Sub
```

```
Sub Fiftyp_In_Click ()
'********************

        cspec0 ci
        get_coins Fiftyp
        Fiftyp_In.Value = False
End Sub

Sub Slug_In_Click ()
'*****************
        get_coins slug
End Sub

Sub Beer_button_Click ()
'********************
        validate_selection Beer

End Sub

Sub validate_selection (ByVal the_selection%)
'       ******************

'process 3

        Dim enough_paid%, some_there%


        If Pat3 Then
                enough_paid = Check_enough(the_selection)          'process 3.1
                some_there = Is_Product_Available(the_selection)   'process 3.2
                put_product the_selection, enough_paid, some_there 'process 3.3
        End If

End Sub

Function Check_enough% (ByVal the_selection%)
'*************************************
'process 3.1

Dim the_cost%

        the_cost = Product_data(the_selection).CostPart
        If current_payment > the_cost Then
                cspec0 op
                Check_enough = True
          ElseIf current_payment = the_cost Then
                  Check_enough = True
          Else
                  Check_enough = False
          End If

End Function
```

```
Function Is_Product_Available% (ByVal the_selection)
'****************************************
'Process 3.2

        If Product_data(the_selection).GoodsPart > 0 Then
            product_available.text = "YES"
            Is_Product_Available = True
        Else
            product_available.text = "NO"
            Is_Product_Available = False
        End If

End Function

Sub put_product (ByVal the_selection%, ByVal enough_paid%, ByVal product_available%)
'*************************************************************************
'Process 3.3
        If (enough_paid And product_available) Then
            the_product.text = Product_data(the_selection).ProductPart
            Give_change (the_selection)
        End If

End Sub

Sub Give_change (ByVal the_product%)
'******************************
'Process 4
Dim payment%
        If Pat4 Then
            payment = Calc_change(the_product)  'process 4.1

            Convert_to_Coins payment          'process 4.2

        End If

End Sub


Function Calc_change% (ByVal this_product)
'************************************
'Process 4.1
        If this_product = null Then
            Calc_change = current_payment
        Else
            Calc_change = current_payment - Product_data(this_product).CostPart

        End If

End Function
```

```
Sub Convert_to_Coins (ByVal the_payment%)
'**********************************

'Process 4.2
'Return change for 10/20/30p depending on coins available

        Select Case the_payment
                Case 0
                        Exit Sub
                Case 10
                        If Coins.TenpCount > 0 Then
                                returned.text = "10p"
                                Coins.TenpCount = Coins.TenpCount - 1
                        End If
                Case 20
                        If Coins.TwentypCount > 0 Then
                                returned.text = "20p"
                                Coins.TwentypCount = Coins.TwentypCount - 1
                        ElseIf Coins.TenpCount > 1 Then
                                 Convert_to_Coins 10
                                 Blank_return
                                 Convert_to_Coins 10
                        End If
                Case 30
                        Convert_to_Coins 20
                        Blank_return
                        Convert_to_Coins 10
          End Select

          cspec0 cg

End Sub

Sub Blank_return ()
'***************
        delay 5
        returned.text = ""
        delay 5
End Sub


Sub delay (ByVal secs%)
'********************
        start! = Timer      'gets the current time since midnight
        Do
                timenow! = Timer

        Loop While timenow - start < secs

End Sub
```

```
Sub Cola_button_Click ()
'********************
        validate_selection Cola
End Sub

Sub Form_Click ()
'***************

'set up globals

        current_payment = 0

        Product_data(Cola).ProductPart = "Cola"

        Product_data(Cola).CostPart = 20

        Product_data(Cola).GoodsPart = 5

        Product_data(Beer).ProductPart = "Beer"

        Product_data(Beer).CostPart = 30

        Product_data(Beer).GoodsPart = 5

        Coins.FiftypCount = 5

        Coins.TwentypCount = 5

        Coins.TenpCount = 5

        state = 0

        Pat3 = False
        Pat4 = False


 End Sub
```