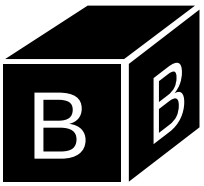


Chapter *24*

The State Design Pattern

```
DEFINITION PboxTreeSta;
    TYPE
        T = ARRAY 16 OF CHAR;
        Tree = RECORD
            (VAR tr: Tree) Clear, NEW;
            (IN tr: Tree) Contains (IN val: T): BOOLEAN, NEW;
            (VAR tr: Tree) Insert (IN val: T), NEW;
            (IN tr: Tree) NumItems (): INTEGER, NEW;
            (IN tr: Tree) PreOrder, NEW;
            (IN tr: Tree) InOrder, NEW;
            (IN tr: Tree) PostOrder, NEW
        END;
END PboxTreeSta.

DEFINITION PboxTreeObj;
    TYPE
        T = ARRAY 16 OF CHAR;
        Tree = RECORD
            (VAR tr: Tree) Clear, NEW;
            (IN tr: Tree) Contains (IN val: T): BOOLEAN, NEW;
            (VAR tr: Tree) Insert (IN val: T), NEW;
            (IN tr: Tree) NumItems (): INTEGER, NEW;
            (IN tr: Tree) PreOrder, NEW;
            (IN tr: Tree) InOrder, NEW;
            (IN tr: Tree) PostOrder, NEW
        END;
END PboxTreeObj.
```

Figure 24.1
The interfaces for a binary search tree implemented with the state design pattern and as it is implemented in Chapter 22.

The data structure for a binary tree using the state design pattern

```
TYPE
    T* = ARRAY 16 OF CHAR;
    Tree* = RECORD
        root: POINTER TO Node
    END;

    Node = ABSTRACT RECORD END;
    EmptyNode = RECORD (Node) END;
    NonEmptyNode = RECORD (Node)
        leftChild: Tree;
        value: T;
        rightChild: Tree
    END;
```

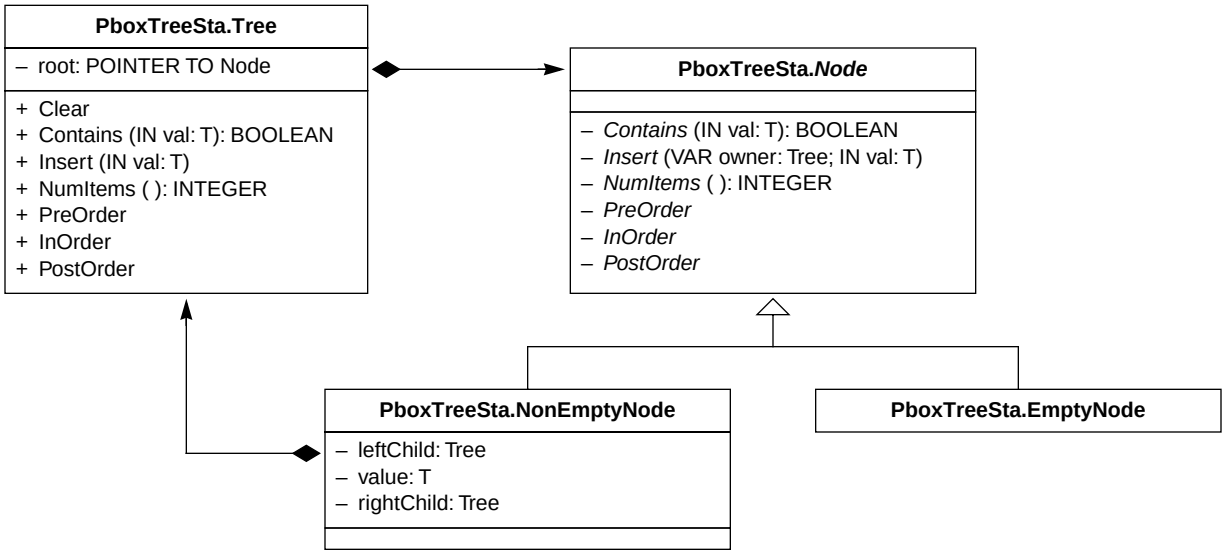
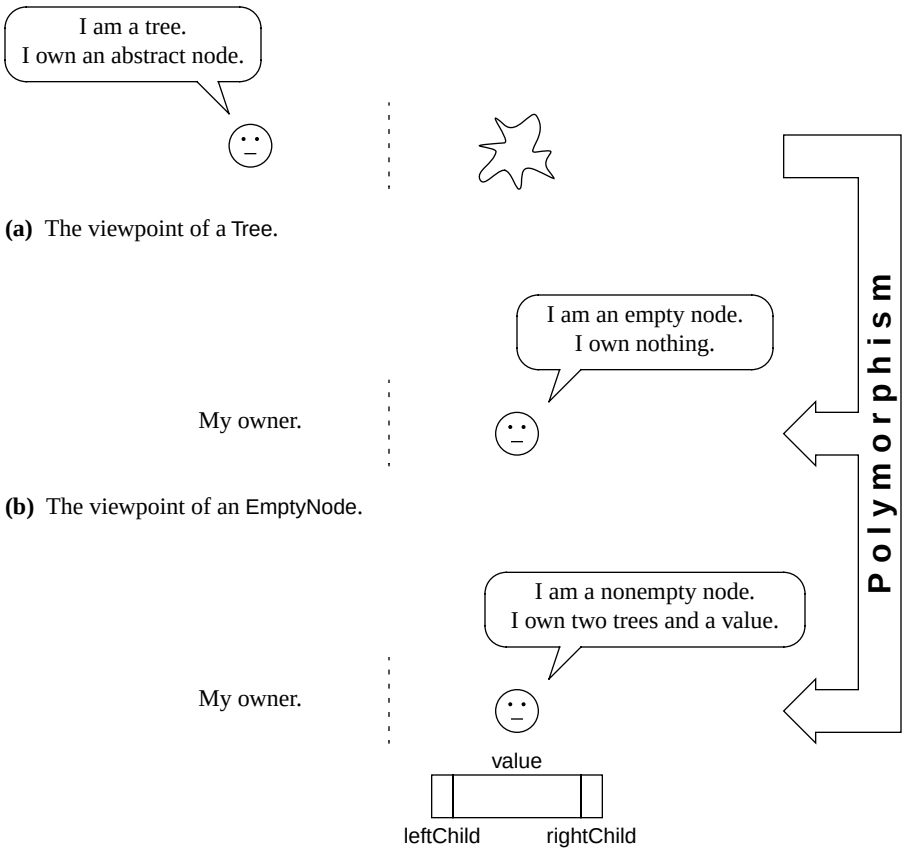


Figure 24.2
The UML diagram for a state design pattern implementation of a binary search tree.



(a) The viewpoint of a Tree.

(b) The viewpoint of an EmptyNode.

(c) The viewpoint of a NonEmptyNode.

Figure 24.3
The cooperating objects in the state design pattern for the binary search tree.

```
MODULE  PboxTreeSta;
   IMPORT StdLog;

   TYPE
      T* = ARRAY 16 OF CHAR;
      Tree* = RECORD
         root: POINTER TO Node
      END;

      Node = ABSTRACT RECORD END;
      EmptyNode = RECORD (Node) END;
      NonEmptyNode = RECORD (Node)
         leftChild: Tree;
         value: T;
         rightChild: Tree
      END;
```

Figure 24.4
The implementation of the binary search tree with the state design pattern.

```
(* ---------------------- *)
    PROCEDURE (VAR tr: Tree) Clear*, NEW;
        VAR
            p: POINTER TO EmptyNode;
    BEGIN
        NEW(p);
        tr.root := p
    END Clear;
```

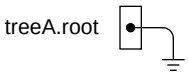
```
(* --------------------- *)
    PROCEDURE (IN tr: Tree) Contains* (IN val: T): BOOLEAN, NEW;
    BEGIN
        (* A problem for the student *)
        RETURN FALSE
    END Contains;
```

```
(* --------------------- *)
    PROCEDURE (IN node: Node) Insert (VAR owner: Tree; IN val: T), NEW, ABSTRACT;

    PROCEDURE (VAR tr: Tree) Insert* (IN val: T), NEW;
    BEGIN
        tr.root.Insert (tr, val)
    END Insert;

    PROCEDURE (IN node: NonEmptyNode) Insert (VAR owner: Tree; IN val: T);
    BEGIN
        ASSERT(node.value # val, 20);
        IF node.value < val THEN
            node.rightChild.Insert(val)
        ELSE
            node.leftChild.Insert(val)
        END
    END Insert;

    PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
        VAR
            p: POINTER TO NonEmptyNode;
    BEGIN
        NEW(p);
        p.leftChild.Clear;
        p.value := val;
        p.rightChild.Clear;
        owner.root := p (* Change the state of owner *)
    END Insert;
```

```
(* ---------------------- *)
    PROCEDURE (IN tr: Tree) NumItems* (): INTEGER, NEW;
    BEGIN
        (* A problem for the student *)
        RETURN 999
    END NumItems;
```

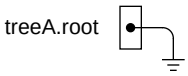
```
(* --------------------- *)
    PROCEDURE (IN node: Node) PreOrder, NEW, ABSTRACT;

    PROCEDURE (IN tr: Tree) PreOrder*, NEW;
    BEGIN
        tr.root.PreOrder
    END PreOrder;

    PROCEDURE (IN node: EmptyNode) PreOrder;
    BEGIN
        (* Do nothing *)
    END PreOrder;

    PROCEDURE (IN node: NonEmptyNode) PreOrder;
    BEGIN
        StdLog.String(node.value); StdLog.String("  ");
        node.leftChild.PreOrder;
        node.rightChild.PreOrder
    END PreOrder;
```

```
(* --------------------- *)
    PROCEDURE (IN tr: Tree) InOrder*, NEW;
    BEGIN
        (* A problem for the student *)
    END InOrder;

(* --------------------- *)
    PROCEDURE (IN tr: Tree) PostOrder*, NEW;
    BEGIN
        (* A problem for the student *)
    END PostOrder;

END PboxTreeSta.
```

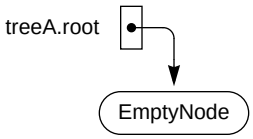


(a) The empty tree from PboxTreeObj in Figure 22.14.

Figure 24.5
The empty tree in PboxTreeObj and PboxTreeSta.



(a) The empty tree from PboxTreeObj in Figure 22.14.



(b) The empty tree from PboxTreeSta in Figure 24.4.

Figure 24.5
The empty tree in PboxTreeObj and PboxTreeSta.

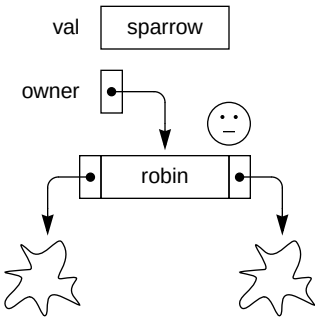
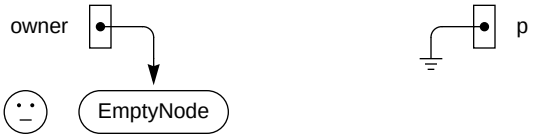


Figure 24.6
The viewpoint of a nonempty node in the environment of an Insert call.

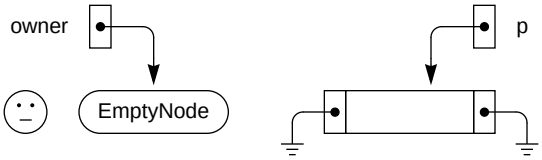
```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

val
sparrow



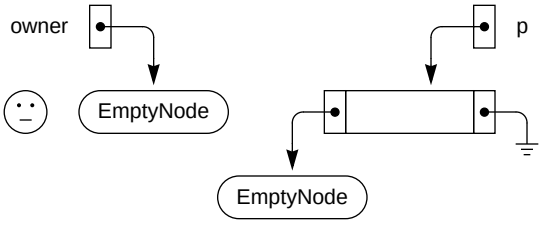
```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

val
sparrow



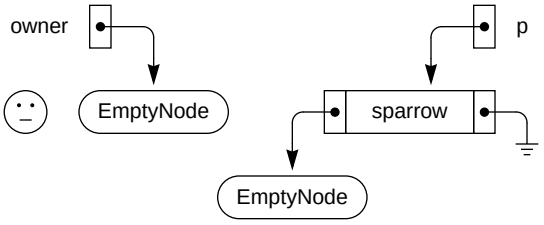
```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

val
sparrow



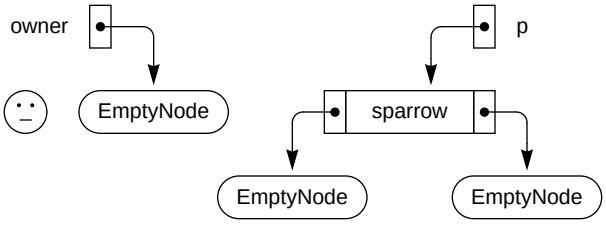
```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

val
sparrow



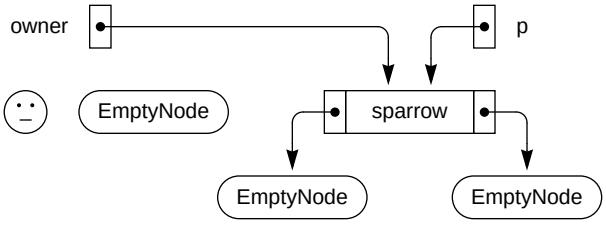
```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

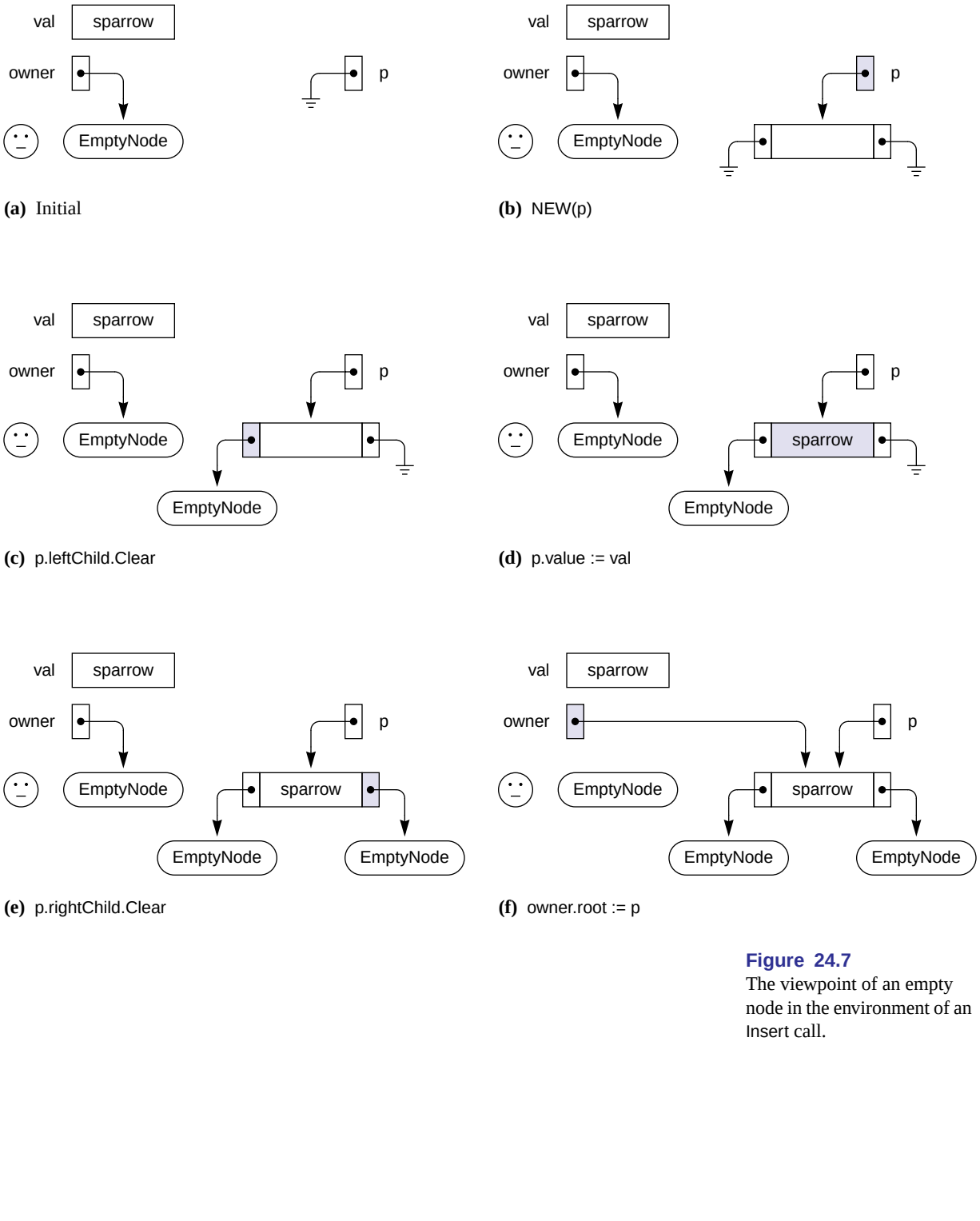
val
sparrow



```
PROCEDURE (IN node: EmptyNode) Insert (VAR owner: Tree; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    NEW(p);
    p.leftChild.Clear;
    p.value := val;
    p.rightChild.Clear;
    owner.root := p (* Change the state of owner *)
END Insert;
```

val
sparrow





(a) Initial

(b) NEW(p)

(c) p.leftChild.Clear

(d) p.value := val

(e) p.rightChild.Clear

(f) owner.root := p

Figure 24.7
The viewpoint of an empty node in the environment of an Insert call.

```
DEFINITION PboxLListSta;
    TYPE
        T = ARRAY 16 OF CHAR;
        List = RECORD
            (VAR lst: List) Clear, NEW;
            (IN lst: List) Display, NEW;
            (IN lst: List) GetElementN (n: INTEGER; OUT val: T), NEW;
            (VAR lst: List) InsertAtN (n: INTEGER; IN val: T), NEW;
            (IN lst: List) Length (): INTEGER, NEW;
            (VAR lst: List) RemoveN (n: INTEGER), NEW;
            (IN lst: List) Search (IN srchVal: T; OUT n: INTEGER; OUT fnd: BOOLEAN), NEW
        END;
END PboxLListSta.

DEFINITION PboxLListObj;
    TYPE
        T = ARRAY 16 OF CHAR;
        List = RECORD
            (VAR lst: List) Clear, NEW;
            (IN lst: List) Display, NEW;
            (IN lst: List) GetElementN (n: INTEGER; OUT val: T), NEW;
            (VAR lst: List) InsertAtN (n: INTEGER; IN val: T), NEW;
            (IN lst: List) Length (): INTEGER, NEW;
            (VAR lst: List) RemoveN (n: INTEGER), NEW;
            (IN lst: List) Search (IN srchVal: T; OUT n: INTEGER; OUT fnd: BOOLEAN), NEW
        END;
END PboxLListObj.
```

Figure 24.8
The interfaces for a linked list implemented with the state design pattern and as it is implemented in Chapter 21.

The data structure for a linked list using the state design pattern

```
TYPE
   T* = ARRAY 16 OF CHAR;
   List* = RECORD
      head: POINTER TO Node
   END;

   Node = ABSTRACT RECORD END;
   EmptyNode = RECORD (Node) END;
   NonEmptyNode = RECORD (Node)
      value: T;
      next: List
   END;
```

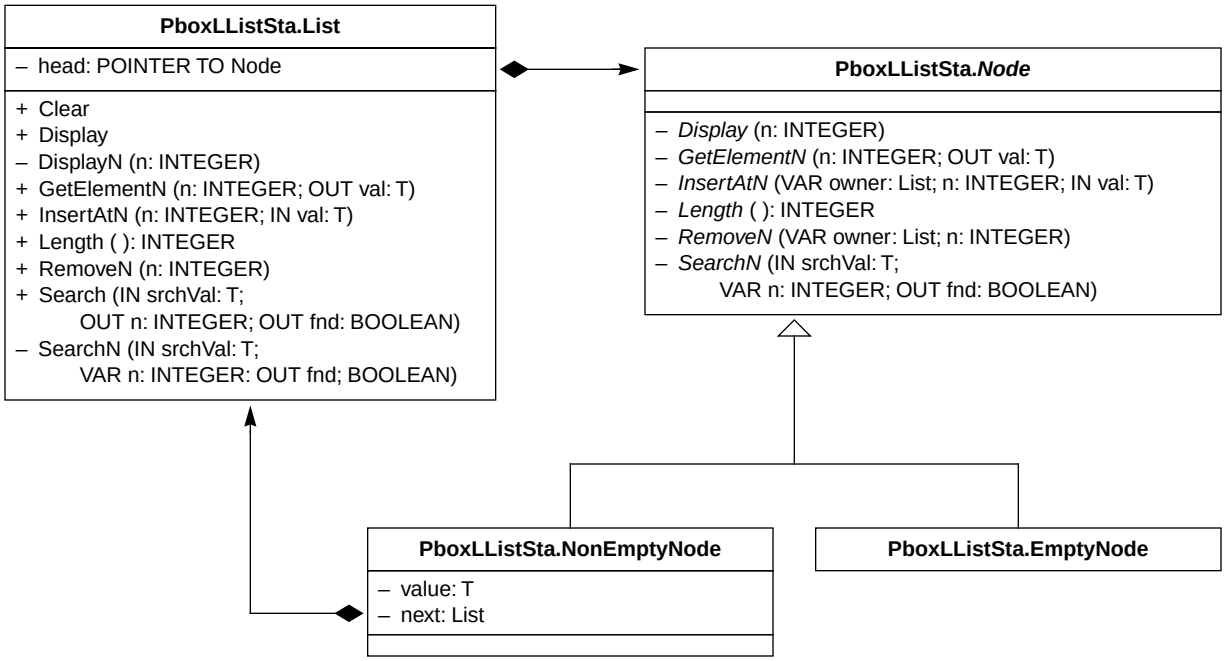


Figure 24.9
The UML diagram for a state design implementation of a linked list.

```
MODULE  PboxLListSta;
   IMPORT StdLog;

   TYPE
      T* = ARRAY 16 OF CHAR;
      List* = RECORD
         head: POINTER TO Node
      END;

      Node = ABSTRACT RECORD END;
      EmptyNode = RECORD (Node) END;
      NonEmptyNode = RECORD (Node)
         value: T;
         next: List
      END;
```

Figure 24.10
The implementation of the linked list with the state design pattern.

```
(* ---------------------- *)
    PROCEDURE (VAR lst: List) Clear*, NEW;
        VAR
            p: POINTER TO EmptyNode;
    BEGIN
        NEW(p);
        lst.head := p
    END Clear;
```

```
(* ---------------------- *)
    PROCEDURE (IN node: Node) DisplayN (n: INTEGER), NEW, ABSTRACT;

    PROCEDURE (IN lst: List) DisplayN (n: INTEGER), NEW;
    BEGIN
        lst.head.DisplayN(n)
    END DisplayN;

    PROCEDURE (IN lst: List) Display*, NEW;
    BEGIN
        lst.DisplayN (0)
    END Display;

    PROCEDURE (IN node: EmptyNode) DisplayN (n: INTEGER);
    BEGIN
        (* Do nothing *)
    END DisplayN;

    PROCEDURE (IN node: NonEmptyNode) DisplayN (n: INTEGER);
    BEGIN
        StdLog.Int(n); StdLog.String(" "); StdLog.String(node.value); StdLog.Ln;
        node.next.DisplayN(n+1)
    END DisplayN;
```

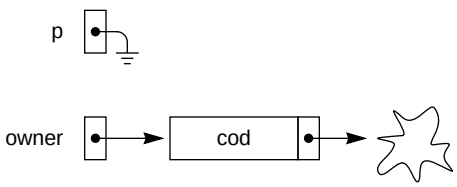
```
(* --------------------- *)
    PROCEDURE (IN node: Node) GetElementN (n: INTEGER; OUT val: T), NEW, ABSTRACT;

    PROCEDURE (IN lst: List) GetElementN* (n: INTEGER; OUT val: T), NEW;
    BEGIN
        ASSERT(0 <= n, 20);
        lst.head.GetElementN(n, val)
    END GetElementN;

    PROCEDURE (IN node: EmptyNode) GetElementN (n: INTEGER; OUT val: T);
    BEGIN
        HALT(21)
    END GetElementN;

    PROCEDURE (IN node: NonEmptyNode) GetElementN (n: INTEGER; OUT val: T);
    BEGIN
        IF n = 0 THEN
            val := node.value
        ELSE
            node.next.GetElementN(n - 1, val)
        END
    END GetElementN;
```

```
(* --------------------- *)
    PROCEDURE (VAR node: Node) InsertAtN (VAR owner: List; n: INTEGER; IN val: T), NEW, ABSTRACT;

    PROCEDURE (VAR lst: List) InsertAtN* (n: INTEGER; IN val: T), NEW;
    BEGIN
        ASSERT(n >= 0, 20);
        lst.head.InsertAtN(lst, n, val)
    END InsertAtN;

    PROCEDURE (VAR node: EmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
        VAR
            p: POINTER TO NonEmptyNode;
    BEGIN
        NEW(p);
        p.value := val;
        p.next.Clear;
        owner.head := p (* Change the state of owner *)
    END InsertAtN;

    PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
        VAR
            p: POINTER TO NonEmptyNode;
    BEGIN
        IF n > 0 THEN
            node.next.InsertAtN(n - 1, val)
        ELSE
            NEW(p);
            p.value := val;
            p.next := owner; (* Change the state of p.next *)
            owner.head := p (* Change the state of owner *)
        END
    END InsertAtN;
```

```
(* --------------------- *)
    PROCEDURE (IN lst: List) Length* (): INTEGER, NEW;
    BEGIN
        (* A problem for the student *)
        RETURN 999
    END Length;

(* --------------------- *)
    PROCEDURE (VAR lst: List) RemoveN* (n: INTEGER), NEW;
    BEGIN
        (* A problem for the student *)
    END RemoveN;

(* --------------------- *)
    PROCEDURE (IN lst: List) Search* (IN srchVal: T; OUT n: INTEGER; OUT fnd: BOOLEAN), NEW;
    BEGIN
        (* A problem for the student *)
        fnd := FALSE
    END Search;

END PboxLListSta.
```

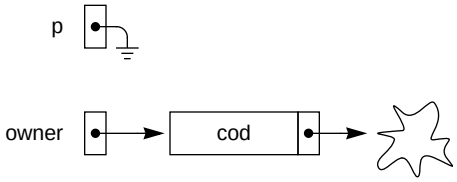
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

n	**val**
0	tuna



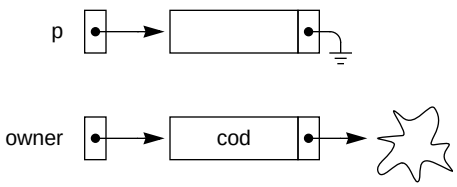
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

n	**val**
0	tuna



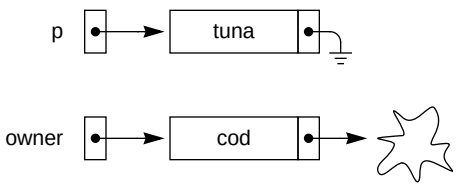
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

n	**val**
0	tuna



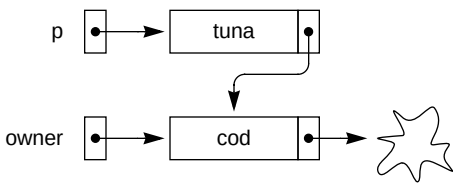
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

n	**val**
0	tuna



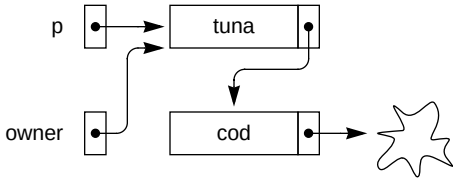
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

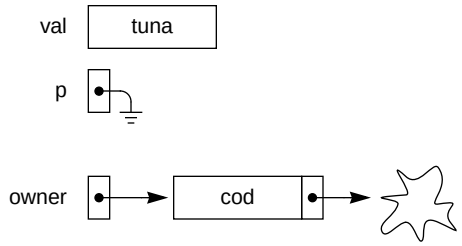
n	**val**
0	tuna



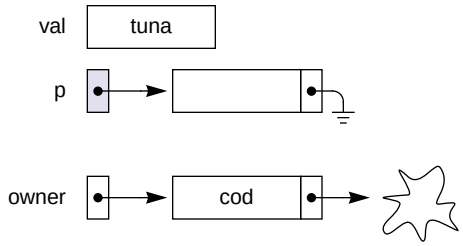
```
PROCEDURE (VAR node: NonEmptyNode) InsertAtN (VAR owner: List; n: INTEGER; IN val: T);
    VAR
        p: POINTER TO NonEmptyNode;
BEGIN
    IF n > 0 THEN
        node.next.InsertAtN(n - 1, val)
    ELSE
        NEW(p);
        p.value := val;
        p.next := owner; (* Change the state of p.next *)
        owner.head := p (* Change the state of owner *)
    END
END InsertAtN;
```

n	**val**
0	tuna

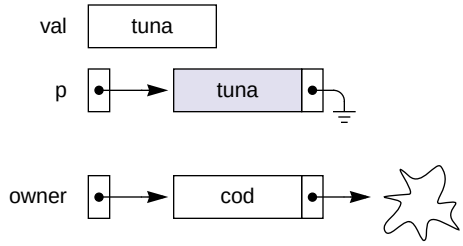




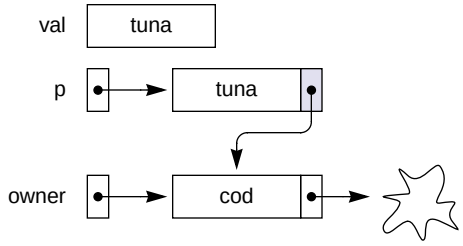
(a) Initial



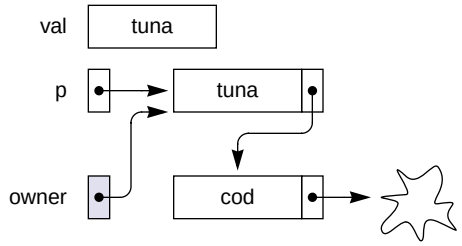
(b) NEW(p)



(c) p.value := val



(d) p.next := owner



(e) owner.head := p

Figure 24.11
Method InsertAtN for a nonempty node.