

B.9 Structs

Solution to Exercise 126.

```

1 // Prog: create_rational_vector_3.cpp
2 // writes a function that can be used to initialize a
3 // rational_vector_3 from 6 int's
4 #include <cassert>
5
6 struct rational {
7     int n;
8     int d; // INV: d != 0
9 };
10
11 struct rational_vector_3 {
12     rational x;
13     rational y;
14     rational z;
15 };
16
17 // PRE: d != 0
18 // POST: the rational number n/d is returned
19 rational create_rational (const int n, const int d)
20 {
21     assert (d != 0);
22     rational result;
23     result.n = n;
24     result.d = d;
25     return result;
26 }
27
28 // PRE: d1 != 0, d2 != 0, d3 != 0
29 // POST: the rational_vector_3 (n1/d1, n2/d2, n3/d3) is returned
30 rational_vector_3 create_rational_vector_3
31 (const int n1, const int d1, const int n2,
32  const int d2, const int n3, const int d3)
33 {
34     rational_vector_3 result;
35     result.x = create_rational (n1, d1);
36     result.y = create_rational (n2, d2);
37     result.z = create_rational (n3, d3);
38     return result;
39 }
40
41 int main()
42 {
43     const rational_vector_3 v = create_rational_vector_3 (1,2,3,4,5,6);
44     return 0;
45 }

```

Solution to Exercise 127.

There are several possible representations for three-valued logic. A convenient one is based on the following observation: if we interpret *false* as 0, *unknown* as 1 and *true* as 2, then AND corresponds to the minimum of the two numbers, while OR corresponds to the maximum. The following program defines the type `Tribool` and the two operators, and it uses them to reproduce the truth tables.

```

1 // Prog: tribool.cpp

```

```

2 // implements three-valued logic
3
4 #include<iostream>
5 #include<cassert>
6
7 struct Tribool {
8     // INV : value in {0, 1, 2}
9     // 0 = false, 1 = unknown, 2 = true
10    unsigned int value;
11 };
12
13 // PRE: val in {0, 1, 2}
14 // POST: return value is a Tribool with the corresponding value
15 Tribool tribool (const unsigned int val)
16 {
17     assert (val <= 2);
18     Tribool result;
19     result.value = val;
20     return result;
21 }
22
23 // POST: returns x AND y
24 Tribool operator&& (const Tribool x, const Tribool y)
25 {
26     Tribool result;
27     if (x.value < y.value)
28         result.value = x.value;
29     else
30         result.value = y.value;
31     return result;
32 }
33
34 // POST: returns x OR y
35 Tribool operator|| (const Tribool x, const Tribool y)
36 {
37     Tribool result;
38     if (x.value > y.value)
39         result.value = x.value;
40     else
41         result.value = y.value;
42     return result;
43 }
44
45 // POST: Tribool value is written to std::cout
46 std::ostream& operator<< (std::ostream& o, const Tribool x)
47 {
48     if (x.value == 0) return o << "false ";
49     else if (x.value == 1) return o << "unknown ";
50     else return o << "true ";
51 }
52
53 int main()
54 {
55     // print 3 x 3 truth table for AND
56     for (int x_val = 0; x_val < 3; ++x_val) {
57         const Tribool x = tribool (x_val);
58         for (int y_val = 0; y_val < 3; ++y_val) {
59             const Tribool y = tribool (y_val);
60             std::cout << (x && y);
61         }
62         std::cout << "\n";
63     }
64     std::cout << "\n";
65
66     // print 3 x 3 truth table for OR

```

```

67   for (int x_val = 0; x_val < 3; ++x_val) {
68       const Tribool x = tribool (x_val);
69       for (int y_val = 0; y_val < 3; ++y_val) {
70           const Tribool y = tribool (y_val);
71           std::cout << (x || y);
72       }
73       std::cout << "\n";
74   }
75   std::cout << "\n";
76
77
78   return 0;
79 }

```

Solution to Exercise 128.

The most natural representation is by an unsigned int value in the range $\{0, \dots, 6\}$. Addition then simply adds the values and takes the result modulo 7. Subtraction could in principle be realized by subtracting the values and taking the result modulo 7, but the problem is that the intermediate subtraction result could be negative (and therefore not representable as unsigned int value). To overcome this problem, we simply add 7 to the first value before we subtract the second one; this is guaranteed to yield a positive value, and modulo 7, it makes no difference. The following program defines the type `Z_7` and the two operators, and it uses them to reproduce the addition and subtraction table.

```

1  // Prog: modulo7.cpp
2  // defines operations in the ring Z_7
3  #include<iostream>
4
5  struct Z_7 {
6      // INV : value in {0, 1, 2, 3, 4, 5, 6}
7      unsigned int value;
8  };
9
10 // POST: return value is the sum of a and b
11 Z_7 operator+ (const Z_7 a, const Z_7 b)
12 {
13     Z_7 result;
14     result.value = (a.value + b.value) % 7;
15     return result;
16 }
17
18 // POST: return value is the difference of a and b
19 Z_7 operator- (const Z_7 a, const Z_7 b)
20 {
21     Z_7 result;
22     result.value = (7 + a.value - b.value) % 7;
23     return result;
24 }
25
26 int main ()
27 {
28     Z_7 a;
29     Z_7 b;
30
31     // print table for addition
32     for (unsigned int a_val = 0; a_val < 7; ++a_val) {
33         for (unsigned int b_val = 0; b_val < 7; ++b_val) {

```

```

34     a.value = a_val;
35     b.value = b_val;
36     std::cout << (a + b).value << " ";
37 }
38     std::cout << "\n";
39 }
40     std::cout << "\n";
41
42     // print table for subtraction
43     for (unsigned int a_val = 0; a_val < 7; ++a_val) {
44         for (unsigned int b_val = 0; b_val < 7; ++b_val) {
45             a.value = a_val;
46             b.value = b_val;
47             std::cout << (a - b).value << " ";
48         }
49         std::cout << "\n";
50     }
51     std::cout << "\n";
52
53     return 0;
54 }

```

Solution to Exercise 129. The following program is at the same time the solution to the next Exercise 130.

```

1 // Program: rational.cpp
2 // Define and use operations on rational numbers.
3
4 #include <iostream>
5
6 // the new type Rational
7 struct Rational {
8     int n;
9     int d; // INV: d != 0
10 };
11
12 // POST: return value is the sum of a and b
13 Rational operator+ (const Rational a, const Rational b)
14 {
15     Rational result;
16     result.n = a.n * b.d + a.d * b.n;
17     result.d = a.d * b.d;
18     return result;
19 }
20
21 // POST: return value is the difference of a and b
22 Rational operator- (const Rational a, const Rational b)
23 {
24     Rational result;
25     result.n = a.n * b.d - a.d * b.n;
26     result.d = a.d * b.d;
27     return result;
28 }
29
30 // POST: return value is the product of a and b
31 Rational operator* (const Rational a, const Rational b)
32 {
33     Rational result;
34     result.n = a.n * b.n;
35     result.d = a.d * b.d;
36     return result;
37 }

```

```

38
39 // POST: return value is the quotient of a and b
40 // PRE: b != 0
41 Rational operator/ (const Rational a, const Rational b)
42 {
43     Rational result;
44     result.n = a.n * b.d;
45     result.d = a.d * b.n;
46     return result;
47 }
48
49 // POST: return value is true if and only if a == b
50 bool operator== (const Rational a, const Rational b)
51 {
52     return a.n * b.d == a.d * b.n;
53 }
54
55 // POST: return value is true if and only if a != b
56 bool operator!= (const Rational a, const Rational b)
57 {
58     return !(a == b);
59 }
60
61 // POST: return value is true if and only if a < b
62 bool operator< (const Rational a, const Rational b)
63 {
64     // here we have to watch out for signs
65     if (a.d > 0 && b.d > 0 || a.d < 0 && b.d < 0)
66         // no sign reversal in multiplying by a.d and b.d
67         return a.n * b.d < a.d * b.n;
68     else
69         // sign reversal
70         return a.n * b.d > a.d * b.n;
71 }
72
73 // POST: return value is true if and only if a <= b
74 bool operator<= (const Rational a, const Rational b)
75 {
76     return a < b || a == b;
77 }
78
79 // POST: return value is true if and only if a > b
80 bool operator> (const Rational a, const Rational b)
81 {
82     return b < a;
83 }
84
85 // POST: return value is true if and only if a >= b
86 bool operator>= (const Rational a, const Rational b)
87 {
88     return a > b || a == b;
89 }
90
91
92 // POST: a has been written to o
93 std::ostream& operator<< (std::ostream& o, const Rational a)
94 {
95     return o << a.n << "/" << a.d;
96 }
97
98 // POST: a has been read from i
99 // PRE: i starts with a rational number of the form "n/d"
100 std::istream& operator>> (std::istream& i, Rational& a)
101 {
102     char c; // separating character, e.g. '/'

```

```

103     return i >> a.n >> c >> a.d;
104 }
105
106 int main ()
107 {
108     // input
109     std::cout << "Rational number r:\n";
110     Rational r;
111     std::cin >> r;
112
113     std::cout << "Rational number s:\n";
114     Rational s;
115     std::cin >> s;
116
117     // test the operations
118     std::cout << "Sum is          " << r + s      << ".\n";
119     std::cout << "Difference is " << r - s      << ".\n";
120     std::cout << "Product is   " << r * s      << ".\n";
121     std::cout << "Quotient is  " << r / s      << ".\n";
122     std::cout << "r == s?     " << (r == s) << ".\n";
123     std::cout << "r != s?     " << (r != s) << ".\n";
124     std::cout << "r < s?      " << (r < s)  << ".\n";
125     std::cout << "r <= s?     " << (r <= s) << ".\n";
126     std::cout << "r > s?      " << (r > s)  << ".\n";
127     std::cout << "r >= s?     " << (r >= s) << ".\n";
128
129     return 0;
130 }

```

Solution to Exercise 130. See solution to Exercise 129.

Solution to Exercise 131. It turns out that only operator+ requires real work; the following program evaluates it according to the case distinction in the small table that is given.

```

1  #include<iostream>
2
3  struct extended_int {
4      unsigned int u; // the absolute value
5      bool        n; // the sign (true means negative)
6  };
7
8  // POST: return value is the sum of a and b
9  //          || a > b      || a <= b
10 // =====
11 // (a,+)+(b,+) ||          (a+b,+)
12 // (a,+)+(b,-) || (a-b,+)   || (b-a,-)
13 // (a,-)+(b,+) || (a-b,-)   || (b-a,+)
14 // (a,-)+(b,-) ||          (a+b,-)
15 extended_int operator+ (const extended_int a, const extended_int b)
16 {
17     extended_int result;
18     if (a.n == b.n) {
19         result.u = a.u + b.u;
20         result.n = a.n;
21     }
22     else
23         if (a.u > b.u) {
24             result.u = a.u - b.u;
25             result.n = a.n;
26         }
27     else {

```

```

28     result.u = b.u - a.u;
29     result.n = b.n;
30 }
31 return result;
32 }
33
34 // POST: return value is -a
35 extended_int operator- (extended_int a)
36 {
37     a.n = !a.n;
38     return a;
39 }
40
41 // POST: return value is the difference of a and b
42 extended_int operator- (const extended_int a, const extended_int b)
43 {
44     return a + (-b);
45 }
46
47 // POST: return value is the product of a and b
48 extended_int operator* (const extended_int a, const extended_int b)
49 {
50     extended_int result;
51     result.u = a.u * b.u;
52     result.n = (a.n || b.n) && !(a.n && b.n); // XOR
53     return result;
54 }
55
56 // POST: a has been written to o
57 std::ostream& operator<< (std::ostream& o, const extended_int a)
58 {
59     if (a.n) o << "-";
60     return o << a.u;
61 }
62
63 // POST: a has been set to i
64 void set (extended_int& a, const int i)
65 {
66     if (i < 0) {
67         a.u = -i; a.n = true;
68     } else {
69         a.u = i; a.n = false;
70     }
71 }
72
73 // now test it
74 int main() {
75     extended_int x;
76     extended_int y;
77     for (int i = -1; i < 2; ++i)
78         for (int j = -1; j < 2; ++j) {
79             // set x to i
80             set (x, i);
81             set (y, j);
82             std::cout << "x = " << x << ", y = " << y << "\n";
83             std::cout << " x + y = " << x + y << "\n";
84             std::cout << " x - y = " << x - y << "\n";
85             std::cout << " x * y = " << x * y << "\n";
86         }
87     return 0;
88 }

```

Solution to Exercise 132. Let us use the following shortcuts:

E exact match
 P promotion
 S standard conversion

Here is the table of match qualities for the two parameters.

	A	B	C
a)	(S,S)	(S,E)	(S,S)
b)	(S,P)	(E,S)	(S,S)
c)	(E,S)	(S,E)	(S,S)
d)	(S,S)	(S,S)	(S,E)
e)	(S,P)	(S,S)	(S,S)
f)	(P,E)	(S,S)	(E,S)

A best match is indicated in bold. This implies that a) resolves to B; b),c) are ambiguous; d) resolves to C; e) resolves to A; f) is ambiguous.

Solution to Exercise 133.

```

1 // Prog: geometry.cpp
2 // defines basic 3d geometry operations on points (rotations,
3 // projections), and uses them to rotate a cube
4
5 #include <IFM/window>
6 #include <iostream>
7 #include <cmath>
8
9 // 2d points
10 // -----
11 struct point2 {
12     double x;
13     double y;
14 };
15
16 // 3d points
17 // -----
18 struct point3 {
19     double x;
20     double y;
21     double z;
22 };
23
24 // rotations
25 // -----
26 // POST: return value is p rotated around the x-axis by alpha (radians)
27 point3 rotate_x (const point3 p, const double alpha)
28 {
29     point3 r;
30     const double cosa = std::cos(alpha);
31     const double sina = std::sin(alpha);
32     r.x = p.x;
33     r.y = cosa * p.y - sina * p.z;
34     r.z = sina * p.y + cosa * p.z;
35     return r;
36 }
37
38 // POST: return value is p rotated around the y-axis by alpha (radians)
39 point3 rotate_y (const point3 p, const double alpha)
40 {
41     point3 r;
```



```

42     const double cosa = std::cos(alpha);
43     const double sina = std::sin(alpha);
44     r.x = sina * p.z + cosa * p.x;
45     r.y = p.y;
46     r.z = cosa * p.z - sina * p.x;
47     return r;
48 }
49
50 // POST: return value is p rotated around the z-axis by alpha (radians)
51 point3 rotate_z (const point3 p, const double alpha)
52 {
53     point3 r;
54     const double cosa = std::cos(alpha);
55     const double sina = std::sin(alpha);
56     r.x = cosa * p.x - sina * p.y;
57     r.y = sina * p.x + cosa * p.y;
58     r.z = p.z;
59     return r;
60 }
61
62 // projection
63 // -----
64 // PRE: v.z != p.z
65 // POST: return value is projection of p onto the plane z = 0,
66 //       with respect to view point v
67 point2 project (const point3 p, const point3 v)
68 {
69     const double t = p.z / (v.z - p.z);
70     point2 r;
71     r.x = p.x - t * (v.x - p.x);
72     r.y = p.y - t * (v.y - p.y);
73     return r;
74 }
75
76 // line drawing
77 // -----
78 // POST: draws a line from the projection of p to the projection
79 //       of q with respect to viewpoint v, and with offset o
80 void draw_line (ifm::Wstream w, const point3 p, const point3 q,
81                const point3 v, const point2 o)
82 {
83     const point2 p2 = project (p, v);
84     const point2 q2 = project (q, v);
85     w << ifm::Line
86         (int(p2.x+o.x), int(p2.y+o.y), int(q2.x+o.x), int(q2.y+o.y));
87 }
88
89 int main()
90 {
91     // construct a cube
92     point3 cube[8];
93     const int size = 200;
94     int i = 0;
95     for (double x=-size/2; x <= size/2; x += size)
96         for (double y=-size/2; y <= size/2; y += size)
97             for (double z=-size/2; z <= size/2; z += size) {
98                 cube[i].x = x;
99                 cube[i].y = y;
100                cube[i].z = z;
101                ++i;
102            }
103
104     // open window
105     ifm::Wstream w ("Rotate cube: press x, y, z or q to quit");
106

```

```
107 // drawing loop
108 const double alpha = 0.1; // rotation angle
109 point3 v; // viewpoint
110 v.x = 200;
111 v.y = 200;
112 v.z = 1000;
113 point2 o; // offset
114 o.x = 250;
115 o.y = 250;
116 for (;;) {
117 // draw all the 12 cube edges
118 w.clear();
119 draw_line (w, cube[0], cube[1], v, o);
120 draw_line (w, cube[0], cube[2], v, o);
121 draw_line (w, cube[0], cube[4], v, o);
122 draw_line (w, cube[1], cube[3], v, o);
123 draw_line (w, cube[1], cube[5], v, o);
124 draw_line (w, cube[2], cube[3], v, o);
125 draw_line (w, cube[2], cube[6], v, o);
126 draw_line (w, cube[3], cube[7], v, o);
127 draw_line (w, cube[4], cube[5], v, o);
128 draw_line (w, cube[4], cube[6], v, o);
129 draw_line (w, cube[5], cube[7], v, o);
130 draw_line (w, cube[6], cube[7], v, o);
131 w << ifm::flush;
132
133 // wait for keystroke
134 const int key = w.get_key();
135 // we assume ASCII encoding
136 switch (key) {
137 case 'x':
138 for (int i=0; i<8; ++i)
139 cube[i] = rotate_x (cube[i], alpha);
140 break;
141 case 'y':
142 for (int i=0; i<8; ++i)
143 cube[i] = rotate_y (cube[i], alpha);
144 break;
145 case 'z':
146 for (int i=0; i<8; ++i)
147 cube[i] = rotate_z (cube[i], alpha);
148 break;
149 case 'q':
150 return 0;
151 break;
152 default:
153 break; // do nothing
154 }
155 }
156
157 return 0;
158
159 }
```
