The Affine Math Challenge and ***operator+*** for class Point

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The Challenge

Adi Shavit presented the Affine Math challenge in a past C++ meetup

The General Challenge:

f(A, B) => R1

f(A, 2*B) => R2

f(A, C) => R3

Strong Types - use the proper type!

```
Distance distance(Duration t, Speed s) {
    return t * s; // distance = time * speed
}

// usage:
Distance d = 1.5h * 100_kmh; // using literal types:
                            // 1.5h = 1.5 hours (std::chrono duration)
                            // 10_kmh = 10 km/h (with our own literal type)

// should be compilation error:
Distance d1 = 1h * 1h; // shouldn’t be able to multiple time units
Distance d2 = 10_km * 10_km; // multiplying distance units generates area units
```

Strong Types - not every operation is allowed!

```
// future / historical point in time
Time operator+(Time p, Duration t);
Time operator+(Duration t, Time t);

// Duration between points in time
Duration operator-(Time p1, Time p2);

// adding or subtracting durations
Duration operator+(Duration d1, Duration d2);
Duration operator-(Duration d1, Duration d2);

// But the following should NOT be allowed:
operator+(Time p1, Time p2); // 12:00pm + 9:00am = ??
```

Can we do that with Point?

```
Point p1 {3, 7};  // assume proper ctor
Point p2 {10, 10};
```

```
Point p3 = p1 + p2;
```

Should we do that with Point?

```
Point p1 {3, 7};   // assume proper ctor
Point p2 {10, 10};
```

```
Point p3 = p1 + p2;
```

But:

What does {13, 17} represent?

- there is no point in adding two points…

(Maybe there is a point in adding Point and “*PointDiff*” for moving a point)

Should we do that with Point?

```
Point p1 {3, 7};   // assume proper ctor
Point p2 {10, 10};
```

```
Point p3 = p1 + p2;
```

On the other hand maybe there is a need…

Should we do that with Point?

```
Point p1 {3, 7};   // assume proper ctor
Point p2 {10, 10};
```

```
Point p3 = p1 + p2;
```

On the other hand maybe there is a need…

Averaging:

```
Point middle = (p1 + p2) / 2;
```

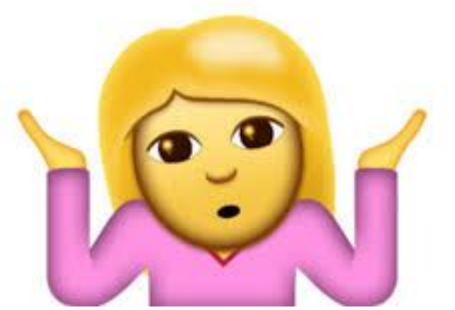
Adding two Points

```
auto twoPoints = p1 + p2;
```

Then, averaging:

```
Point middle = twoPoints / 2;
```

What should be the type of *`twoPoints`* **?**



Multiplying Points

```
auto twoPoints = p1 * 2;
```

Should we allow that **?**

Multiplying Points

```
// p3 should be closer to p2 (in ratio ⅓ <=> ⅔):
```

```
Point p3 = (p1 + p2 * 2) / 3;
```

```
// but p2 * 2 shouldn't be a point!
```

Dividing

```
// p3 should be closer to p2 (in ratio ⅓ <=> ⅔):
```

```
Point p3 = p1 / 3 + 2 * p2 / 3;
```

```
// but (p1 / 3) and (2 * p2 / 3) shouldn’t be points!
```

The Challenge

Allow:

- **Adding Points (2 points, 3 points, N points)**
- **Multiplying and Dividing by any number**

Result cannot be used as a Point, unless “getting it back” to a Single Unit Point

Rules:

- **We would rely only on compile time information**
- **Implementation shouldn’t be specific to Point**

Explaining the rules

```
auto twoPoints = p1 + p2; // twoPoints is NOT a Point

// middle is a Point, but only since 2 is known at compile time
Point middle = twoPoints / 2;

auto thirdOfP1 = p1 / 3; // is NOT a Point
auto twoThirdsOfP2 = p2 * 2 / 3; // is NOT a Point

Point closerToP2 = thirdOfP1 + twoThirdsOfP2; // is a Point!
```

Step 1

```
// that’s not a good approach… just let’s review it…
TwoPoints operator+(Point p1, Point p2) {
    return TwoPoints{p1, p2};
}

// for class TwoPoints
Point TwoPoints::operator/(int num) {
    // how can we tell if num == 2 and the operation is allowed?
}
```

Step 1 - before C++17 - Specialization

```
// “base template” for Divider - we do not allow dividing by any number rather than 2
template<class T, int num> struct Divider;

// specialized version for Divider
template<class T> struct Divider<T, 2> {
    static T divide() { return T{}; }
};
```

```
Point TwoPoints::operator/(int num) {
    return Divider<Point, num>::divide();
}
```

Oops...

Step 1 - before C++17 - Specialization

```
// “base template” for Divider - we do not allow dividing by any number rather than 2
template<class T, int num> struct Divider;

// specialized version for Divider
template<class T> struct Divider<T, 2> {
    static T divide() { return T{}; }
};
```

```
template<int num> Point TwoPoints::operator/(int) {
    return Divider<Point, num>::divide();
}
```

<= Now OK, but ugly

Step 1 - before C++17 - Specialization

```
// “base template” for Divider - we do not allow dividing by any number rather than 2
template<class T, int num> struct Divider;

// specialized version for Divider
template<class T> struct Divider<T, 2> {
    static T divide() { return T{}; }
};
```

```
template<int num>
Point TwoPoints::operator/(Number<num>) {
    return Divider<Point, num>::divide();
}
```

<= Now OK

Step 1 - before C++17 - class Number

```
template<int num> class Number {};
```

Step 1 - before C++17 - main

```
int main() {
    Point p = TwoPoints{} / Number<2>();
}
```

http://coliru.stacked-crooked.com/a/7fda5ead44c0eef5

Step 2 - replace Number<int> with...

```
std::ratio<N, D>
```

```
    Point p1 = TwoPoints{} / std::ratio<2>();

    auto twoThirdsOfaPoint = Point{} * std::ratio<2, 3>();
```

Step 3 - use a generic “*Aggregator*” (instead of “TwoPoints”...)

```
template<class T, long Numerator = 1, long Denominator = 1>
class Aggregator {
    T t;
public:
    …

};
```

operator+
operator/
operator*
return either T or Aggregator<T, …>

Step 3 - Point

```
class Point {
    double x, y;
public:
    Point(double x1, double y1): x(x1), y(y1) {}

    friend Aggregator<Point, 2> operator+(Point p1, Point p2) {
        return Aggregator<Point, 2>{Point{p1.x + p2.x, p1.y + p2.y}};
    }

    …
```

Step 4 - “*Aggregator*” using C++17 *if constexpr*

```
template<class T, long Numerator1, long Denominator1,
        long MultNum, long MultDenom>

friend auto constexpr operator*(Aggregator<T1, Numerator1, Denominator1> a,
                                std::ratio<MultNum, MultDenom> n) {

    if constexpr(Numerator1*MultNum != Denominator1*MultDenom) {
        return Aggregator<T1, Numerator1*MultNum, Denominator1*MultDenom>
                {a.getT()};
    } else {
        return a.getT().unsafe_multiply(n);
    }
}
```

Step 4 - "*Aggregator*" using C++17 *if constexpr*

```
template<class T, long Numerator1, long Denominator1,
        long MultNum, long MultDenom>

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Step 4 - "*Aggregator*" using C++17 *if constexpr*

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        return Aggregator<T1, Numerator1*MultNum, Denominator1*MultDenom>
                {a.getT()};
    } else {
        return a.getT().unsafe_multiply(n);
    }
}
```

and it works...

```
Point p1 { 5, 10 }, p2 { 25, 30 };

std::cout << "p1 + p2: " << p1 + p2 << std::endl;

    // prints: p1 + p2: [ Aggregate (2/1) ] : {30,40}

std::cout << "(p1 + p2)/2: " << (p1 + p2) / std::ratio<2>() << std::endl;

    // prints: (p1 + p2)/2: {15,20}
```

http://coliru.stacked-crooked.com/a/af3bcf51af8afca3

Is it useful?

Not sure this example is useful…

BUT:

- Type safety is important and useful
- if constexpr is useful

Thank you!

```
void conclude(auto greetings) {
    while(still_time() && have_questions()) {
        ask();
    }
    greetings();
}

conclude([]{ std::cout << "Thank you!"; });
```