

Parallel programming

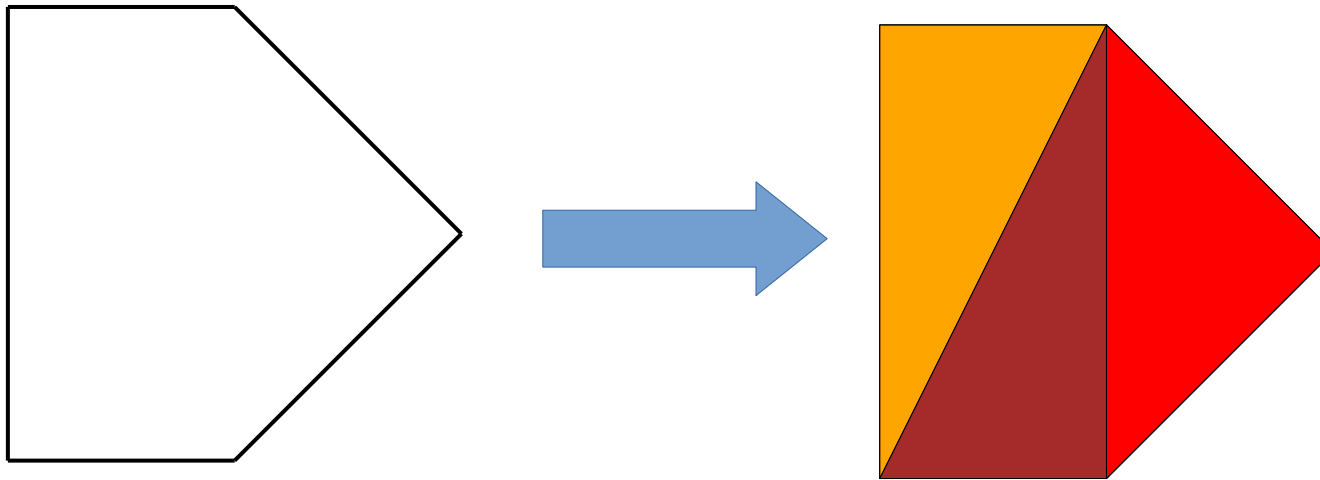
HW2 assignment





Triangulation of convex sets

- Problem: Find the triangulation of a convex set such that a *cost* (sum of triangle perimeters) is minimal.



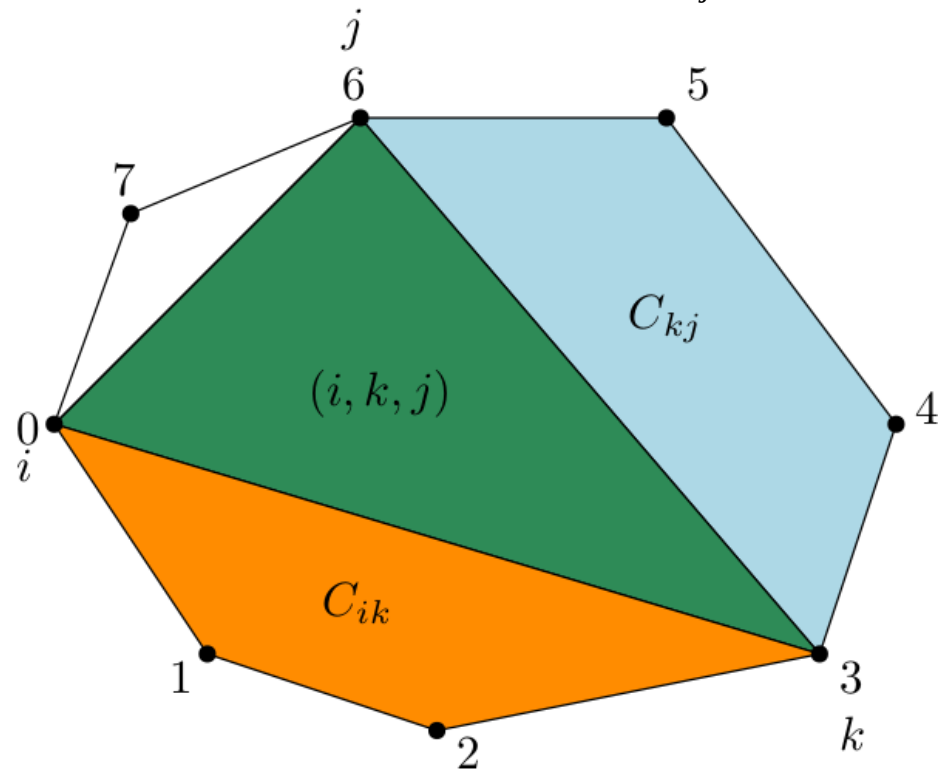
- **Applications:**

- Triangulation is useful in graphics to decompose a complex object into triangle mesh, which can be effectively processed by graphics cards.



Solving triangulation by using dynamic programming

- Number the points of a polygon by numbers in counter-clockwise order
- Let C_{ij} be a minimal cost of a sub-triangulation from point i to j .
- The following recursive formula minimizes the triangulation cost for C_{ij}

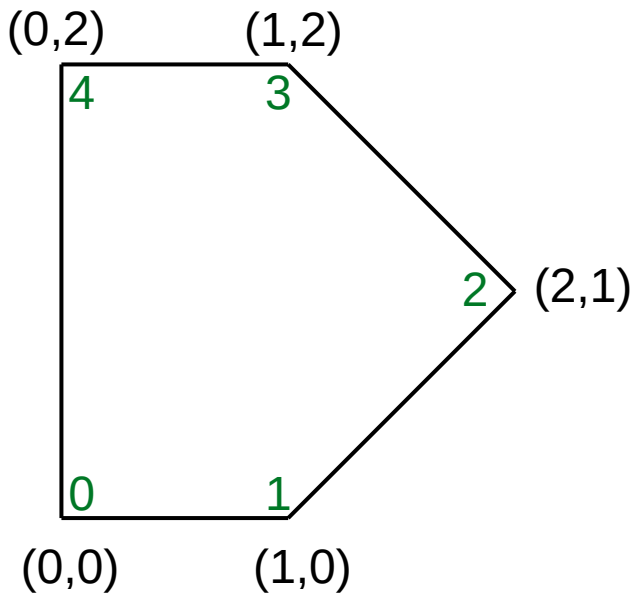


if $j < i+2$
 $C_{ij} = 0$

else

$$C_{ij} = \min_{k=i+1}^{j-1} (C_{ik} + C_{kj} + \|ik\| + \|kj\| + \|ji\|)$$

Solving triangulation by using dynamic programming



$$\begin{aligned}
 (0,1,2) &= 1 + \sqrt{2} + \sqrt{5} \approx 4.65 & (1,2,4) &= \sqrt{2} + \sqrt{5} + \sqrt{5} \approx 5.89 \\
 (1,2,3) &= \sqrt{2} + \sqrt{2} + 2 \approx 4.83 & (1,3,4) &= 2 + 1 + \sqrt{5} \approx 5.24 \\
 (2,3,4) &= \sqrt{2} + 1 + \sqrt{5} \approx 4.65 & (0,1,4) &= 1 + \sqrt{5} + 2 \approx 5.24 \\
 (0,1,3) &= 1 + 2 + \sqrt{5} \approx 5.24 & (0,2,4) &= \sqrt{5} + \sqrt{5} + 2 \approx 6.47 \\
 (0,2,3) &= \sqrt{5} + \sqrt{2} + \sqrt{5} \approx 5.89 & (0,3,4) &= \sqrt{5} + 1 + 2 \approx 5.24
 \end{aligned}$$

Pseudocode:

```

for (diff = 0; diff < n; ++diff)
    for (i = 0, j = diff; j < n; ++i, ++j)
        if (j < i+2)
            Cij = 0.0
        else
            Cij = inf;
            for (int k = i+1; k < j; ++k)
                cost = Cik + Ckj + ||ik|| + ||kj|| + ||ji||
                if (Cij > cost)
                    Cij = cost

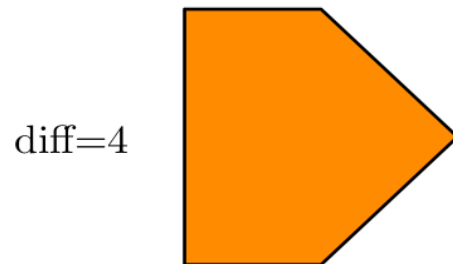
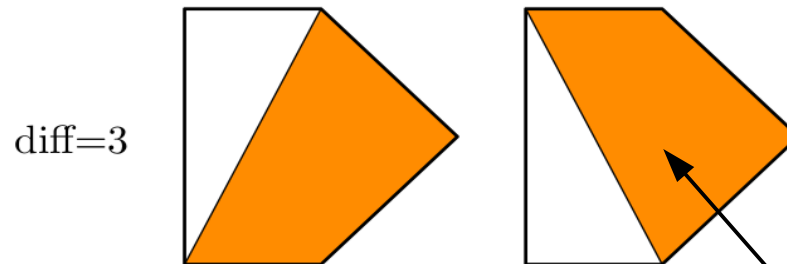
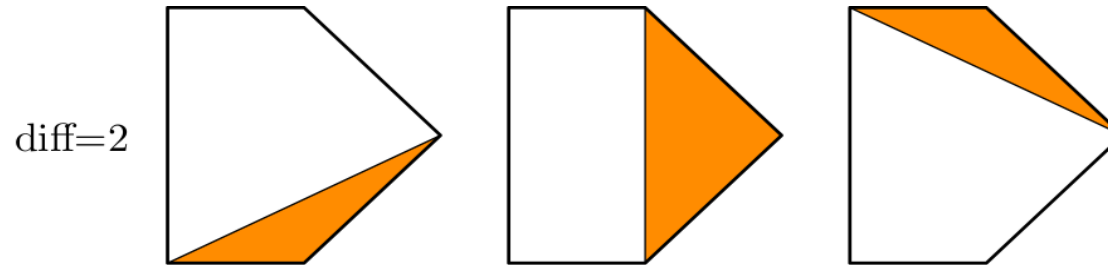
```

return C_{0n-1}

C		j →		
		0	1	2
i ↓	0	0	4.65	10.1
	-	0	0	4.83
	-	-	0	0
	-	-	-	0
	-	-	-	-



Solving triangulation by using dynamic programming



Found optimal triangulation for this parts



HW2 assignment

- Use the **code skeleton**
 - reads test problems, measures runtime, generates SVG files to show the triangulation
 - try '--help' to see the supported program arguments
- **Assignment:**
 - implement a parallel min-cost triangulation
 - use OpenMP 4.0 or higher
 - upload your solution to UploadSystem
- **Flags for g++ (used by UploadSystem)**
 - `-fopt-info-vec-missed -fopt-info-vec -Ofast -std=c++17 -march=native -fopenmp`



Tricky issues

- Do not forget to optimize the sequential code (memory access, vectorization, ...).
- You should carefully think about which OpenMP schedule to use and what part of code is parallelizable.
- Make you sure that your code is vectorized, e.g. use ‘-fopt-info-vec’ option with GCC. See the compiler output after uploading to UploadSystem, it should inform you whether the vectorization is successful.
- Floats are enough for computing the cost.
- Square root can be vectorized if you use:
 - GCC 4.9 and newer, glibc 2.22 and newer
 - Intel compiler 15 and newer
- If you use Clang it may be beneficial to tune your code without the square root. Afterwards, you can add the square root and verify the vectorization in the output of UploadSystem.
- Compile your code with ‘-march=native -Ofast -fopenmp’ to maximize the probability of the vectorization.