Parallel programming

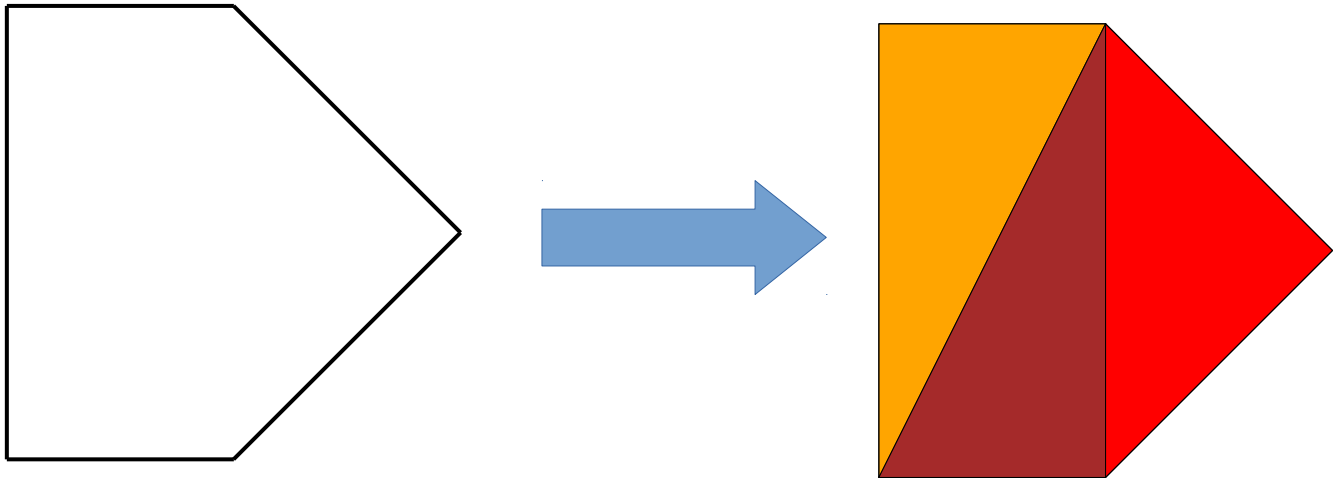
OpenMP – assignment

Libor Bukata a Jan Dvořák

FAKULTA ELEKTROTECHNICKÁ
ČVUT V PRAZE

Triangulation of convex sets

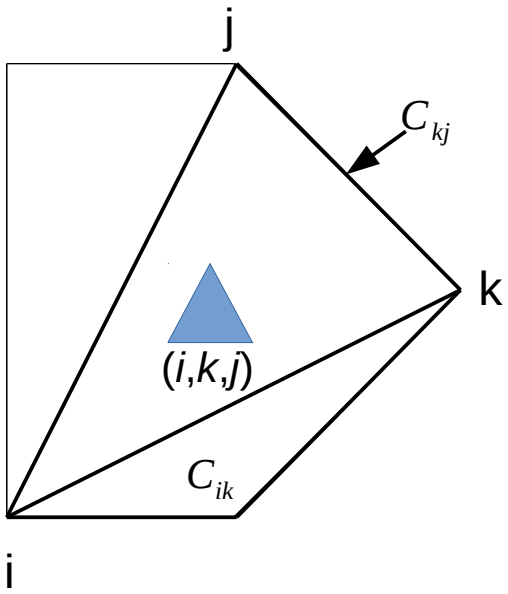
- Problem: Find the triangulation of the convex set such that the cost is minimal (sum of triangle perimeters).



- **Applications:**
  - Useful in graphics to decompose a complex object into triangle mesh, which can be effectively processed by graphics cards (more general 3D version).

Solving triangulation by using dynamic programming

Let C_{ij} be a minimal cost of a sub-triangulation from point i to j, then the following formula minimizes the cost of two sub-polygons and triangle (i, k, j) where points are counter-clockwise ordered.



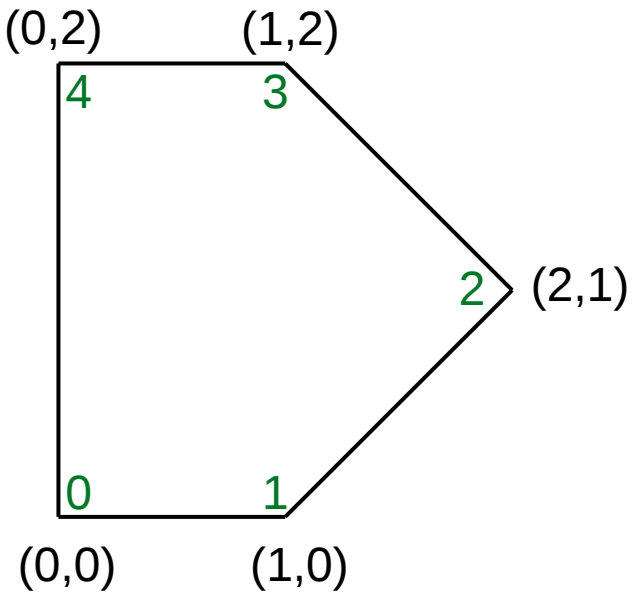
if j < i+2

$$C_{ij} = 0$$

else

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

Solving triangulation by using dynamic programming



$$(0,1,2)=1+\sqrt{2}+\sqrt{5}\simeq 4.65$$
$$(1,2,3)=\sqrt{2}+\sqrt{2}+2\simeq 4.83$$
$$(2,3,4)=\sqrt{2}+1+\sqrt{5}\simeq 4.65$$
$$(0,1,3)=1+2+\sqrt{5}\simeq 5.24$$
$$(0,2,3)=\sqrt{5}+\sqrt{2}+\sqrt{5}\simeq 5.89$$
$$(1,2,4)=\sqrt{2}+\sqrt{5}+\sqrt{5}\simeq 5.89$$
$$(1,3,4)=2+1+\sqrt{5}\simeq 5.24$$
$$(0,1,4)=1+\sqrt{5}+2\simeq 5.24$$
$$(0,2,4)=\sqrt{5}+\sqrt{5}+2\simeq 6.47$$
$$(0,3,4)=\sqrt{5}+1+2\simeq 5.24$$

C — j →, i ↓

0	0	4.65	10.1	**15.3**
-	0	0	4.83	10.1
-	-	0	0	4.65
-	-	-	0	0
-	-	-	-	0

Pseudocode:

for (diff = 0; diff < n; ++diff)
  for (i = 0; j = diff; j < n; ++i; ++j)
    if (j < i+2)
      C_{ij} = 0.0
    else
      C_{ij} = inf;
      for (int k = i+1; k < j; ++k)
        cost = $C_{ik}+C_{kj}+\|ik\|+\|kj\|+\|ji\|$
        if (C_{ij} > cost)
          C_{ij} = cost

return $C_{0\,n-1}$

Triangulation assignment

- Use the **provided snippet of code** (needed for upload system)
  - ➔ reads test problems
  - ➔ measures runtime
  - ➔ generates *.svg files to show the triangulation
  - ➔ try ‘--help’ to see the supported program arguments
- **Assignment:**
  - ➔ implement a parallel and vectorized min-cost triangulation
  - ➔ parallelize the code using OpenMP 4.0 or higher
  - ➔ upload your solution to Course Ware
- **Outcomes of the algorithm:**
  - ➔ the cost of the minimal triangulation
  - ➔ triangulation – vector of triangles, triangle is *tuple<int, int, int>* where the integers are indices to the vector *points*, see the provided snippet.

Triangulation assignment

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 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 Course Ware, it should inform you whether the vectorization is successful.
- 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 upload system.
- Compile your code with ‘-march=native -Ofast -fopenmp’ to maximize the probability of the vectorization.