

Linear-time distance mapping

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Borgefors' algorithm

Input:

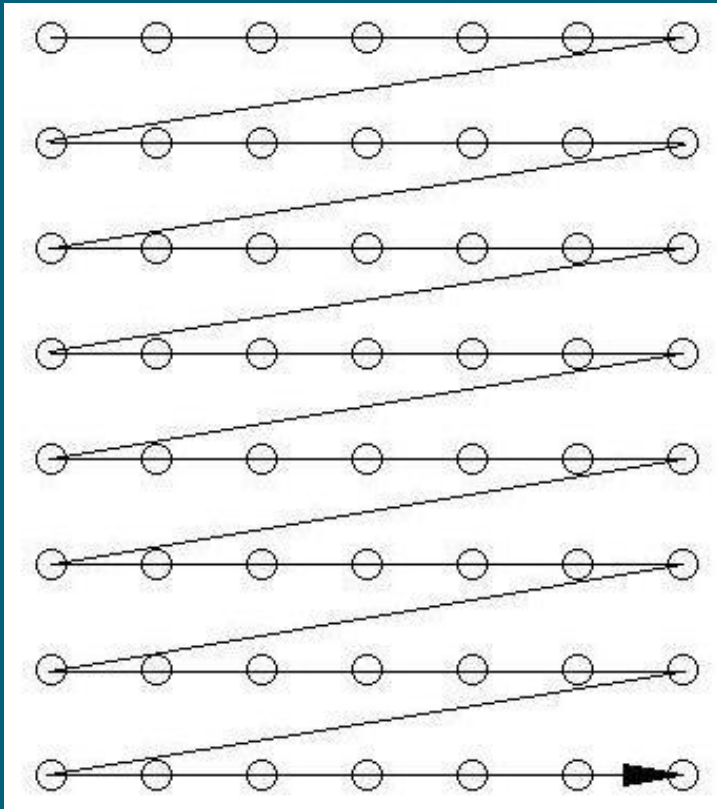
Binary array A containing feature elements (1's) and non-feature elements (0's).

Output:

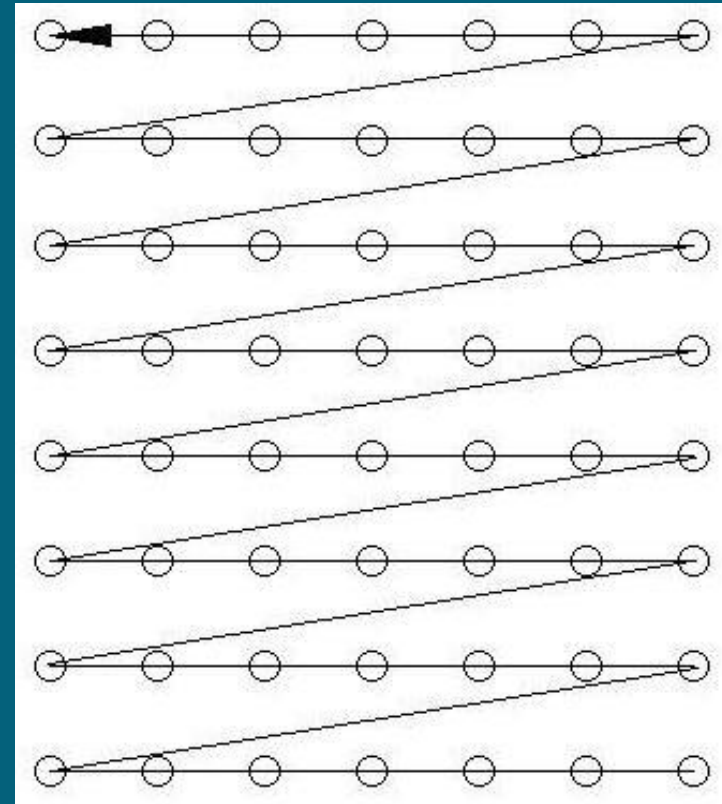
Distance map B : non-binary array containing the distance to the closest feature element.

```
remark initialization
for i=1 to n1 do
  for j=1 to n2 do
    if a(i,j)=1 then b(i,j)=0
    else b(i,j)=∞
remark forward scan
for i=1 to n1 do
  for j=1 to n2 do
    b(i,j)=min{
      b(i-1,j-1)+d2,
      b(i-1,j )+d1,
      b(i-1,j+1)+d2,
      b(i ,j-1)+d1,
      b(i ,j )
    }
remark backward scan
for i=n1 downto 1 do
  for j=n2 downto 1 do
    b(i,j)=min{
      b(i ,j ) ,
      b(i ,j+1)+d1,
      b(i+1,j-1)+d2,
      b(i+1,j )+d1,
      b(i+1,j+1)+d2
    }
```

The two scans

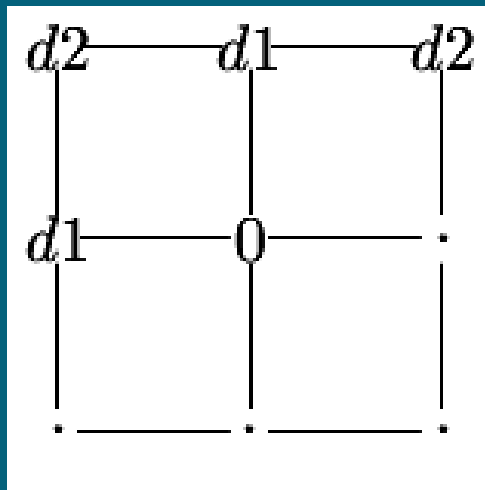


forward scan

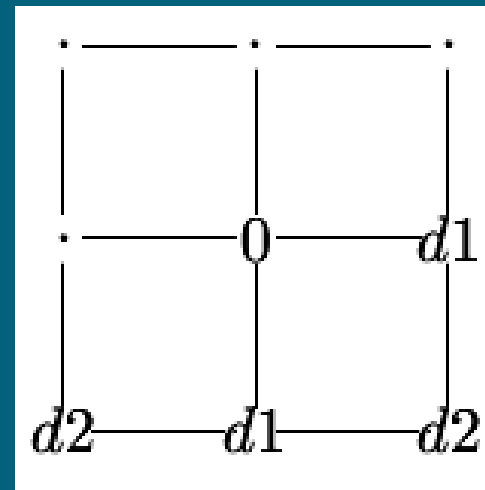


backward scan

Chamfer masks



forward scan



backward scan

best choice: $d1=3$, $d2=4$

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

initialization („.” $\rightarrow \infty$)

(3,4)-chamfer distance mapping

0	0	0	0	4	3	4	.	.	.
0	0	1	0	3	0	.	.	0	.
0	0	0	0	.	.	.	.	.	.
0	0	0	0	.	.	.	.	.	.
0	1	0	0	.	.	0	.	.	.
0	0	0	0	.	.	.	.	.	.

input (feature)

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

4	3	4	.
3	0	.	.
.	.	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	3	0	.
.	.	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	4	3	4
.	.	3	0	.
.	.	0	.	.
.
.	0	.	.	.
.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0	4	3	4	.	.
0	0	1	0	3	0	.	0	.
0	0	0	0	.	.	.	.	.
0	0	0	0	.	.	.	.	.
0	1	0	0	.	0	.	.	.
0	0	0	0	.	.	.	.	.

input (feature)

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

4	3	4	.
3	0	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	4	3	4
.	3	0 ⁰	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	4	3	4
.	.	0 ³	0 ⁴	.
.
.
.	0	.	.	.
.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
4	3	4	0
3	0	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
. ⁴	. ³	0 ⁴	3
. ³	. ⁰	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	.	.
.	.	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0 ⁴	3 ³	4
.	4	3 ³	.	0
.	.	.	.	
.	0	.	.	
.	.	.	.	

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
4	.	4 ⁴	3	4
3	.	0	.	.
.	0	.	.	.
.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
. ⁴	4 ³	3 ⁴	4
8 ³	. ⁰	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4 ⁴	3 ³	4 ⁴
8	7 ³	.	.
.	0	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3 ⁴	4 ³	4
8	7	6 ³	.	0
.	0	.	.	
.	.	.	.	

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
4	8 ³	7 ⁴	6	7
3	.	0	.	.
.	.	.	.	

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8 ⁴	7 ³	6 ⁴	7
11 ³	0 ⁰	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7 ⁴	6 ³	7 ⁴
11	0 ³	.	.
.	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6 ⁴	7 ³	4
11	0	3 ³	.	0
.	.	.	.	

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6	7	
4	11 ³	0 ⁴	3	6
3	0	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11 ⁴	0 ³	3 ⁴	6
4 ³	.	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0 ⁴	3 ³	6 ⁴
4	3 ³	.	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3 ⁴	6 ³
4	3	4 ³	.

forward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4	7

forward scan (completed)

(3,4)-chamfer distance mapping

.	.	.	.
.	.	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

initialization („.” $\rightarrow \infty$)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4	7

forward scan (influence zone 1)

(3,4)-chamfer distance mapping

.	.	.	.
.	.	0	.
.	.	.	.
.	.	.	.
.	0	.	.
.	.	.	.

initialization („.” $\rightarrow \infty$)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4	7

forward scan (influence zone 2)

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6	7	
11	0	3	6	
4	3	4	7 ⁰	3
	4	3	4	4

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4 ⁰	7 ³

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3 ⁰	4 ³	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4 ⁰	3 ³	4	7

backward scan



(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6	7	
11	0	3	6 ⁰	3
4	3	4 ⁴	7 ³	4

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3 ⁰	6 ³
4	3 ⁴	4 ³	7 ⁴

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0 ⁰	3 ³	6
4 ⁴	3 ³	4 ⁴	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6	7	
	11 ⁰	0 ³	3	6
4	4 ³	3 ⁴	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
8	7	6	7 ⁰	3
3	0	3 ⁴	6 ³	4
4	3	4	7	

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6 ⁰	7 ³
3	0 ⁴	3 ³	6 ⁴
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3	4
8	7 ⁰	4 ³	7
3 ⁴	0 ³	3 ⁴	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4	
	8 ⁰	3 ³	4	7
4	3 ³	0 ⁴	3	6
	4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3	
.	4	3	4 ⁰	3
4	3	4 ⁴	7 ³	4
3	0	3	6	
4	3	4	7	

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4	3 ⁰	4 ³
4	3 ⁴	4 ³	7 ⁴
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	4 ⁰	3 ³	4
4 ⁴	3 ³	4 ⁴	7
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0	3
.	0	3	4
4	4	3	4
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	.	0	3 ⁰	3
7	4	3 ⁴	4 ³	4
4	3	4	7	
3	0	3	6	
4	3	4	7	

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	.	0 ⁰	3 ³
7	4 ⁴	3 ³	4 ⁴
4	3	4	7
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.
.	0	0 ³	3
7 ⁴	4 ³	3 ⁴	4
4	3	4	7
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	.	
.	0	3 ³	0	3
4	7 ³	4 ⁴	3	4
4	3	4	7	
3	0	3	6	
4	3	4	7	

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	.	0	3
6	3	0 ⁴	3 ³	4
7	4	3	4	
4	3	4	7	
3	0	3	6	
4	3	4	7	

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	0	4 ³
6	3 ⁴	0 ³	3 ⁴
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

.	.	3 ³	4
6 ⁴	3 ³	0 ⁴	3
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

backward scan

(3,4)-chamfer distance mapping

0	0	0	0	.	4 ³	3	4	
0	0	1	0	4	6 ³	3 ⁴	0	3
0	0	0	0		7	4	3	4
0	0	0	0		4	3	4	7
0	1	0	0		3	0	3	6
0	0	0	0		4	3	4	7

input (feature)

backward scan

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

7	4	3	4
6	3	0	3
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

backward scan (completed)

(3,4)-chamfer distance mapping

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4	7

7	4	3	4
6	3	0	3
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

forward scan (completed) backward scan (influence zone 1)

(3,4)-chamfer distance mapping

.	.	.	.
.	.	0	3
.	4	3	4
8	7	6	7
11	0	3	6
4	3	4	7

7	4	3	4
6	3	0	3
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

forward scan (completed) backward scan (influence zone 2)

(3,4)-chamfer distance mapping

0	0	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	1	0	0
0	0	0	0

input (feature)

7	4	3	4
6	3	0	3
7	4	3	4
4	3	4	7
3	0	3	6
4	3	4	7

distance map