



Medial Axis Construction and Applications in 3D Wireless Sensor Networks

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Outline

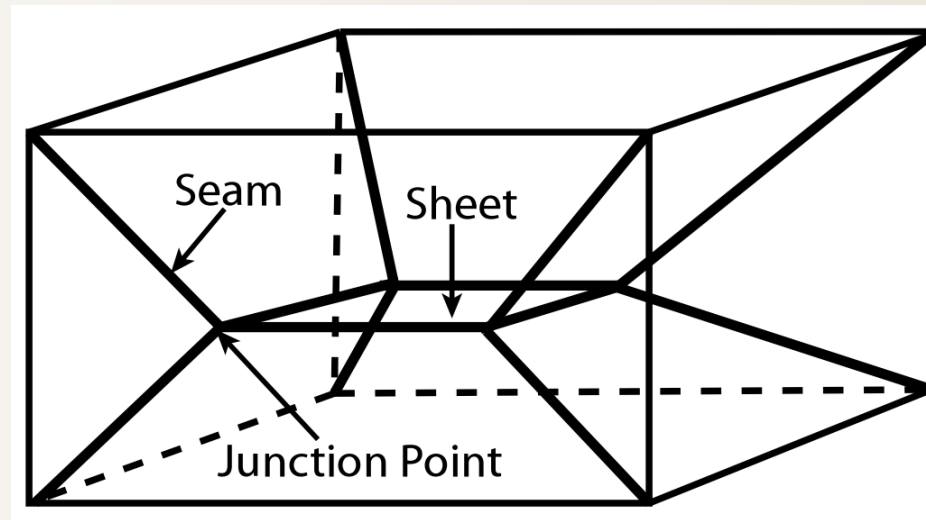
- Introduction
 - Medial axis in 2D networks
 - Challenges in 3D networks
- Medial axis construction in 3D networks
- Applications
 - Medial axis-based safe navigation
 - Medial axis-based distributed information storage and retrieval
- Conclusion

Medial Axis in 2D Networks

- The medial axis of a shape consists of a set of points that have more than one closest points on the boundary of the shape.
- The medial axis of a given shape provides a compact abstraction of its global topology and a proximity of its geometry.
- Applications of medial axis in two-dimensional (2D) sensor networks:
 - Routing
 - Navigation

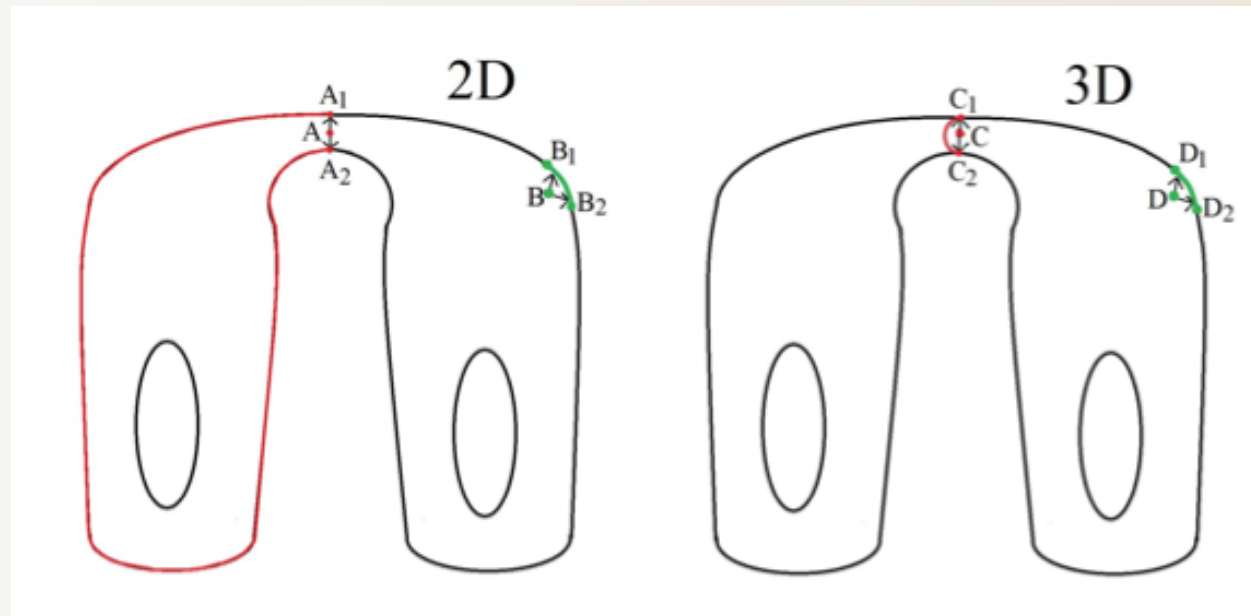
Challenges in 3D Networks

- The structure of the medial axis of a 3D shape involves greater complexity than the medial axis of a 2D planar shape.



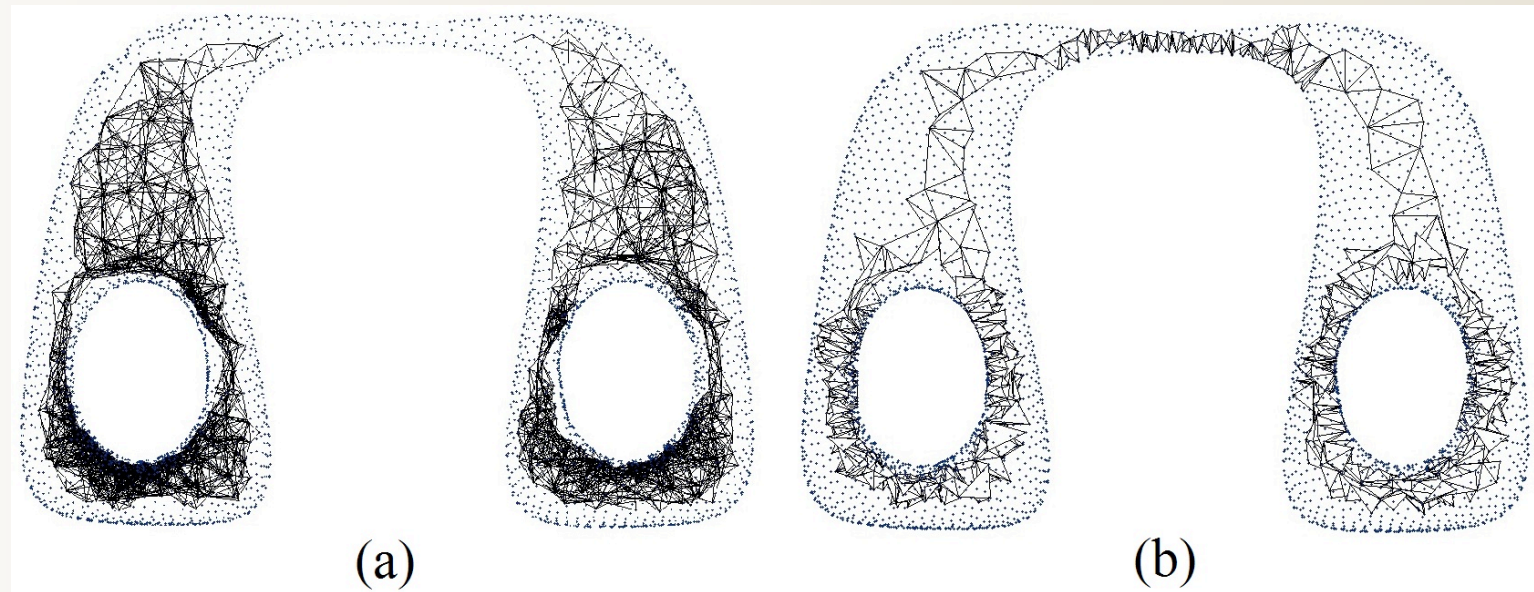
Challenges in 3D Networks

- Existing medial axis construction algorithm in 2D networks follows definition
- Can't be extended to 3D because it does not distinguish true medial axis nodes and noises in 3D networks.



Challenges in 3D Networks

- Existing algorithm results in disconnected medial axis and significant noises.



Medial Axis Construction in 3D networks

- Preparation

- We represent a 3D wireless sensor network by a graph $G(V, E)$, where V denotes the sensor nodes and E indicates the communication links in the network.
- We then construct a unit tetrahedron cell (UTC) structure of a given 3D sensor network.
- The extracted UTC mesh structure approximates well the geographic structure of the sensor network.

Medial Axis Construction in 3D networks

- Preparation

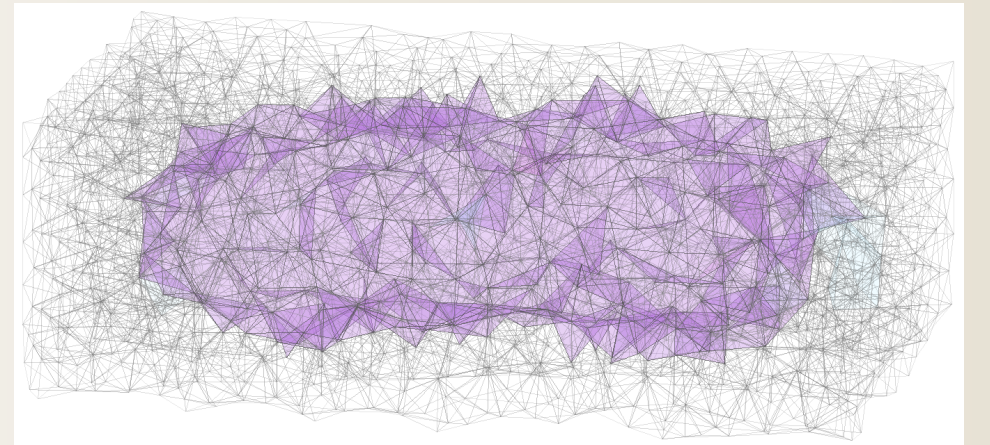
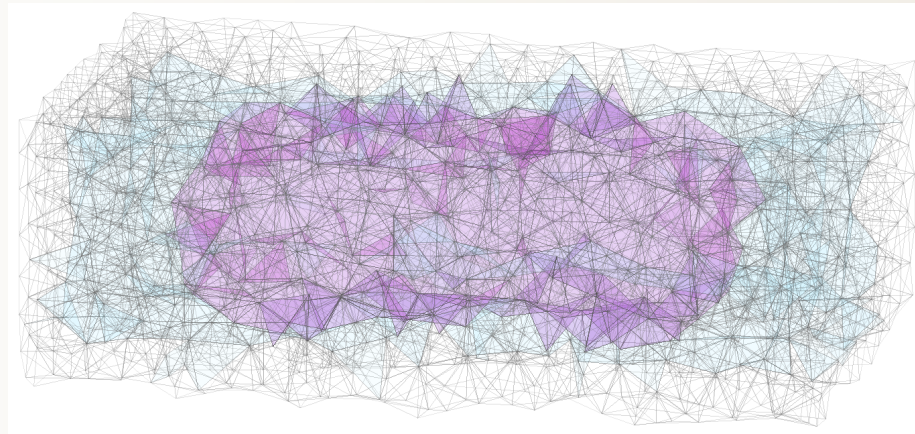
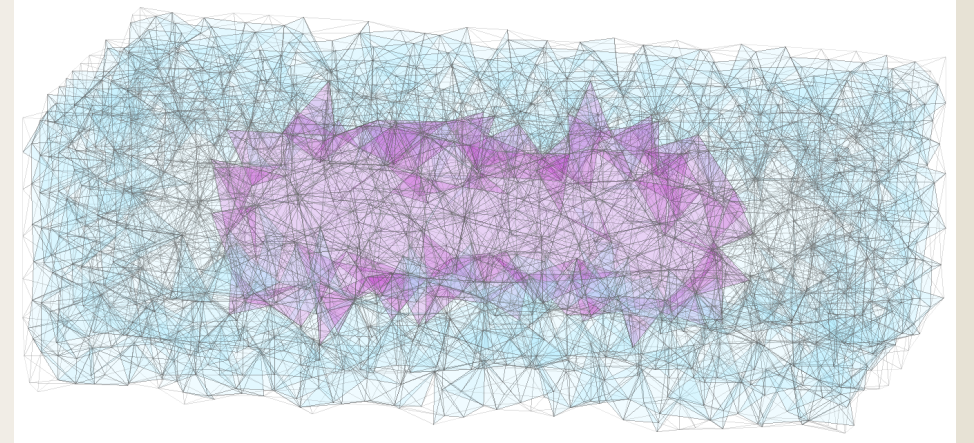
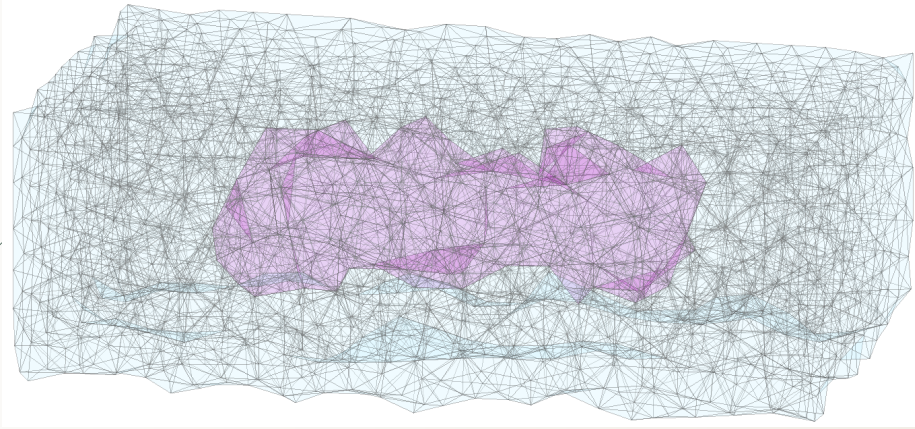
- Definition 1: A unit tetrahedron cell (UTC) is a tetrahedron formed by four network nodes, which does not intersect with any other tetrahedrons.
- Definition 2: Two UTCs are neighbors if and only if they share a face.
- Definition 3: A face is a boundary face if it is shared by one UTC only.
- Definition 4: A boundary surface of a network is a closed surface that consists of connected boundary faces. Each boundary surface is assigned a unique identifier.

Medial Axis Construction in 3D networks

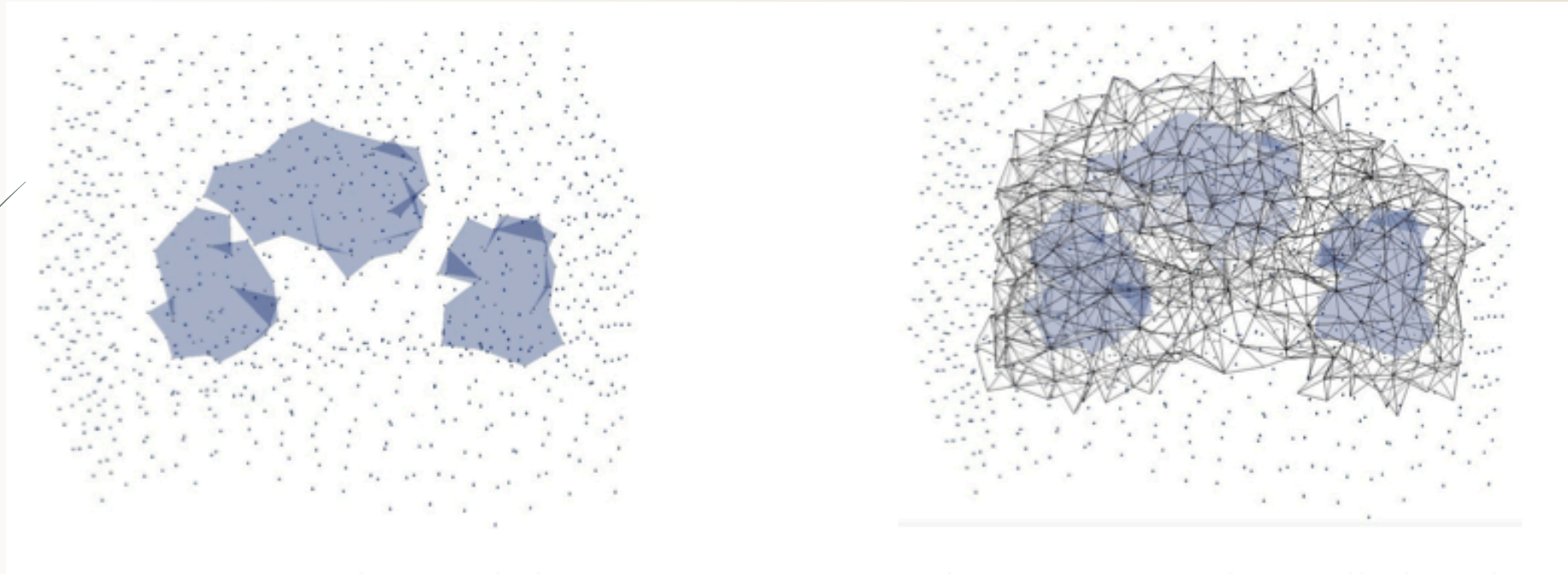
- Main Idea

- Based on the UTC mesh structure, the boundary surfaces grow at the same pace to “peel” off a layer of the UTC mesh structure in each iteration
- Outer surface grows inward and inner surface outward
- The iteration stops when those boundary surfaces meet and there is no space for further growing
- The algorithm yields a set of fully connected faces. They well approximate the accurate medial axis because each node has equal distance or differs by at most one hop to two closest boundary charts.

Medial Axis Construction in 3D networks - Demo



Medial Axis Construction in 3D networks



Medial Axis Construction in 3D networks

- Time Complexity and Communication Cost

- We measure the communication cost by the number of the exchanged messages.
- The proposed algorithm is distributed and the computation is completely local.
- Both the time complexity and communication cost of UTC mesh-based medial axis construction are linear to the size of the network $O(n)$.

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Applications - Medial Axis-Based Safe Navigation

- Assume a set of wireless sensors deployed in a 3D domain.
- Each sensor acquires necessary environmental data and performs local computation to determine a risk factor.
- The safe navigation problem in 3D is to determine a route to a safe exit based on the reported risk factors, aiming to maximize the minimum distance from the route to any dangerous areas.

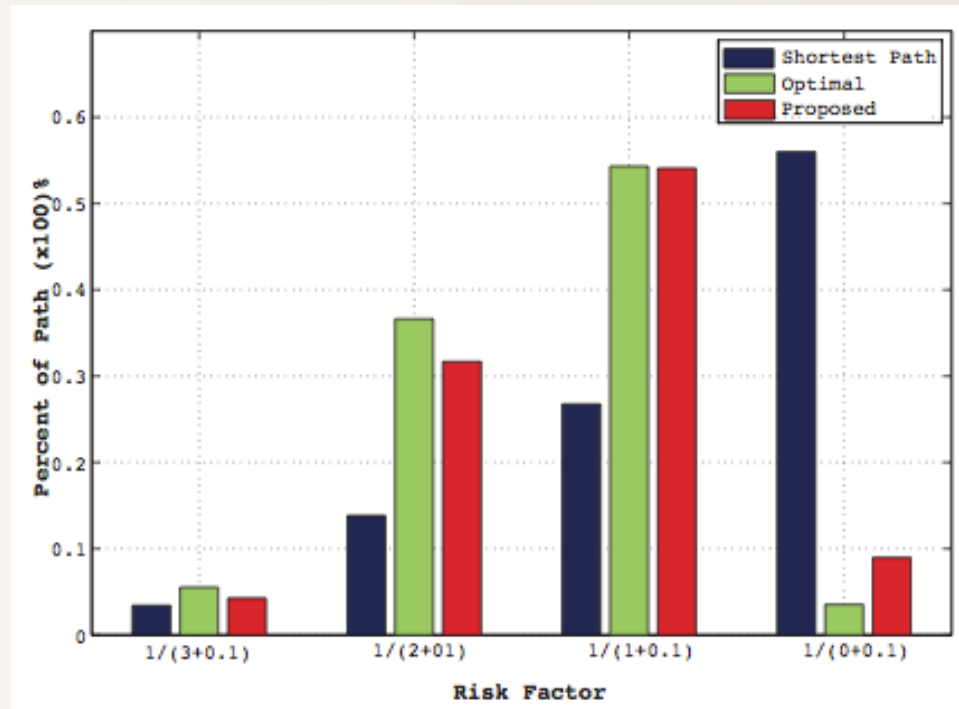


Applications - Medial Axis-Based Safe Navigation

- We can consider dangerous areas inside a 3D sensor network as inner holes (un-accessible).
- Sensors around these holes are boundary nodes and can be easily identified by their extremely high risk factors.
- The area outside the network field is also treated as a special hole because of unknown high risks.
- The locally safest regions reside on medial axis.

Applications - Medial Axis-Based Safe Navigation

- ➔ Performance evaluation: randomly choose 1000 internal locations of a network to safely route to a few selected safe exits.





Applications - Medial Axis-Based Distributed Information Storage and Retrieval

- Since a medial axis resides at the “center” and extends according to the shape of the network, it supports efficient data storage and query.
- A subset of medial axis nodes are uniformly chosen as storage nodes.
- A datum is stored at one (or all) storage nodes on the medial axis of the network.
- For data retrieval, a query travels to the nearest storage node to collect data.



CONCLUSION

- A distributed algorithm with linear time complexity and communication cost that builds a well-structured medial axis of a 3D sensor network without knowing its global shape or global position information.
- Applied the computed medial axis for two applications, i.e., safe navigation and distributed information storage and retrieval in 3D sensor networks.



Questions?