CHC-NSC 2018

www.chc-nsc2018.ca

Victoria, B.C. March 26-29, 2018 | Victoria, C.B. 26 au 29 mars 2018

Land and Sea Shaping the World
Terre et Mer Façonnant le Monde

Autonomous Navigation on US (Electronic) Nautical Charts

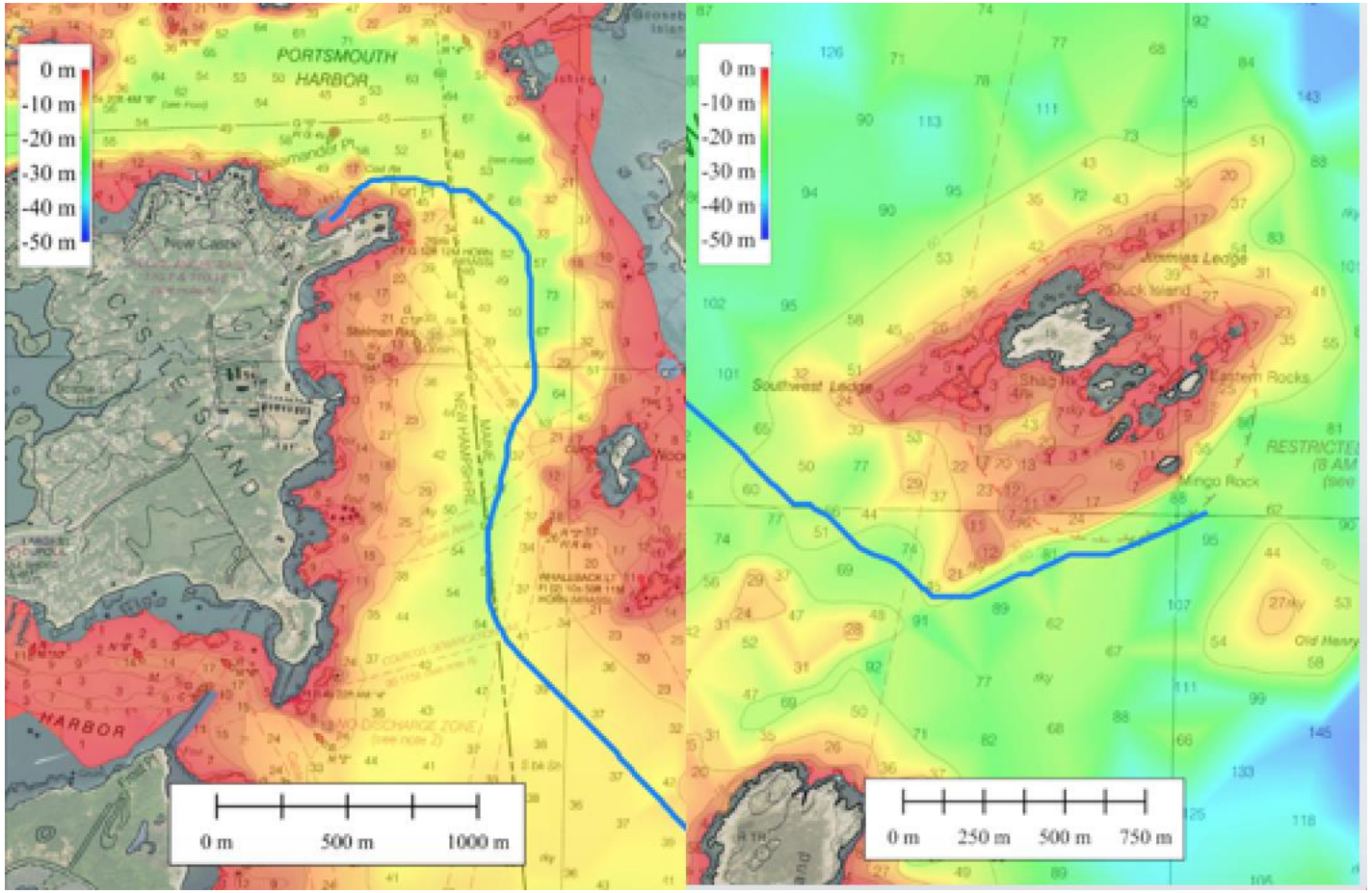
Val Schmidt

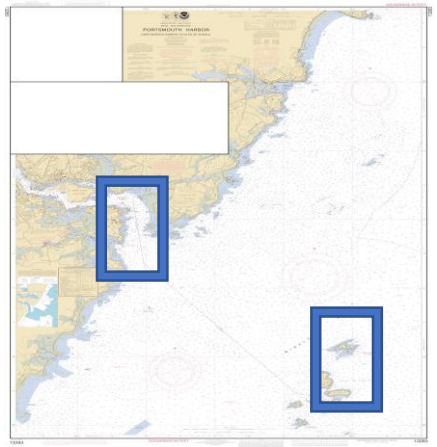
Center for Coastal and Ocean Mapping
University of New Hampshire

#chcnsc2018

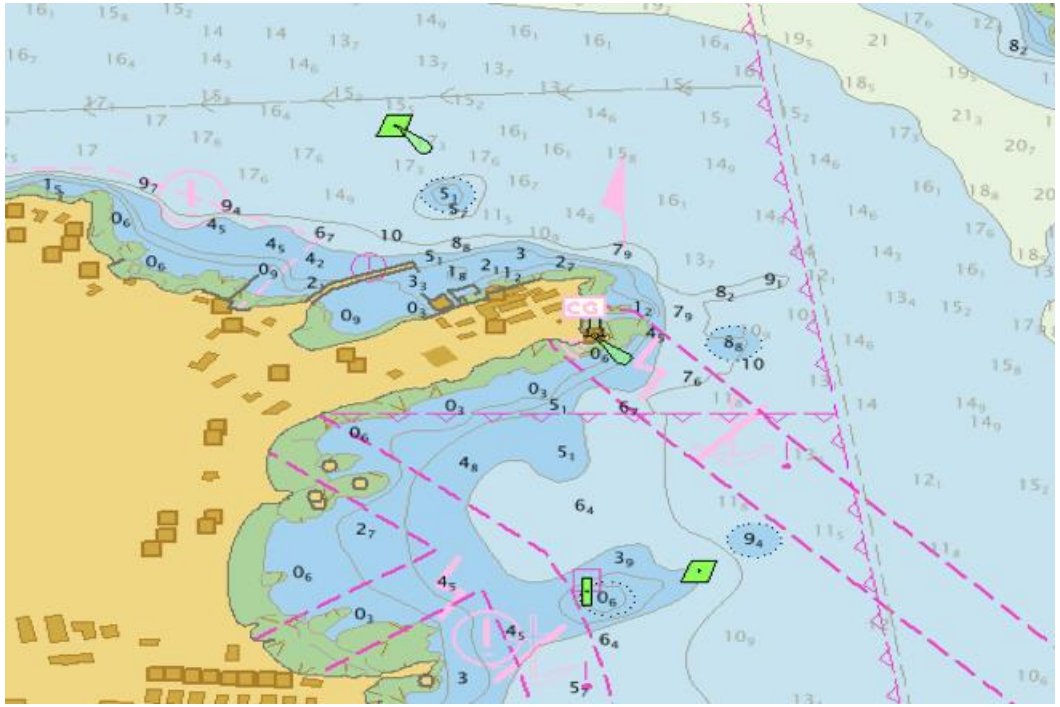
Common Algorithms for Autonomous Navigation (A*)

A ”Cost” Map for Robotic Path Planning





Compilation Scale



Caris Base Editor, Viewed at Chart Scale

“Navigation” Scale

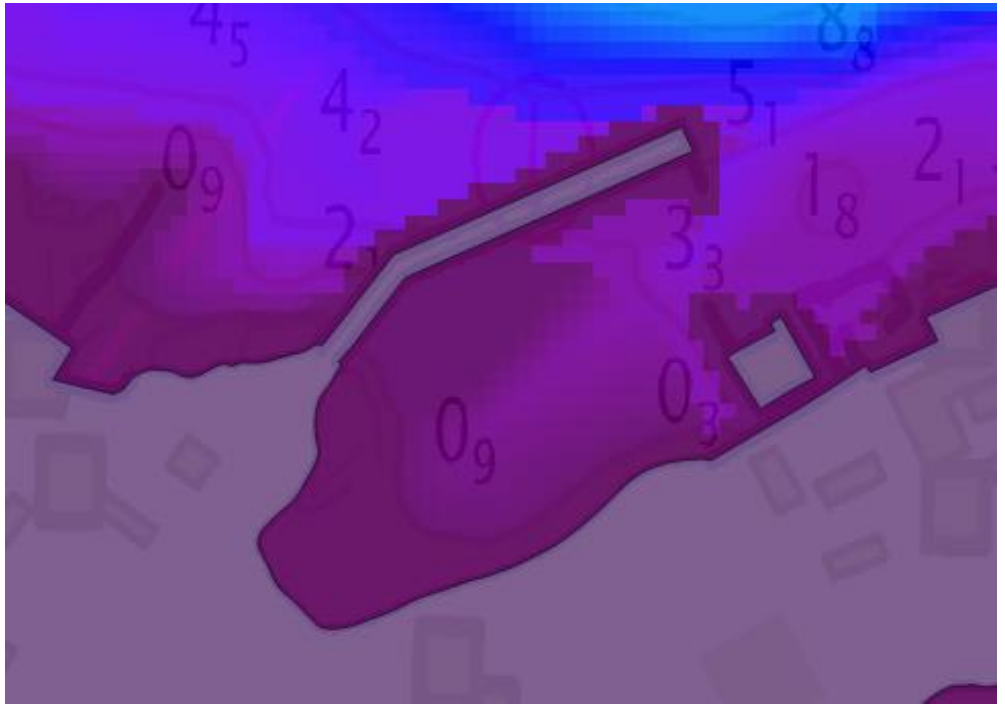
Compilation Scale

Caris Base Editor, Viewed at Scale

“Navigation” Scale

Compilation Scale

Caris Base Editor, Viewed at Scale



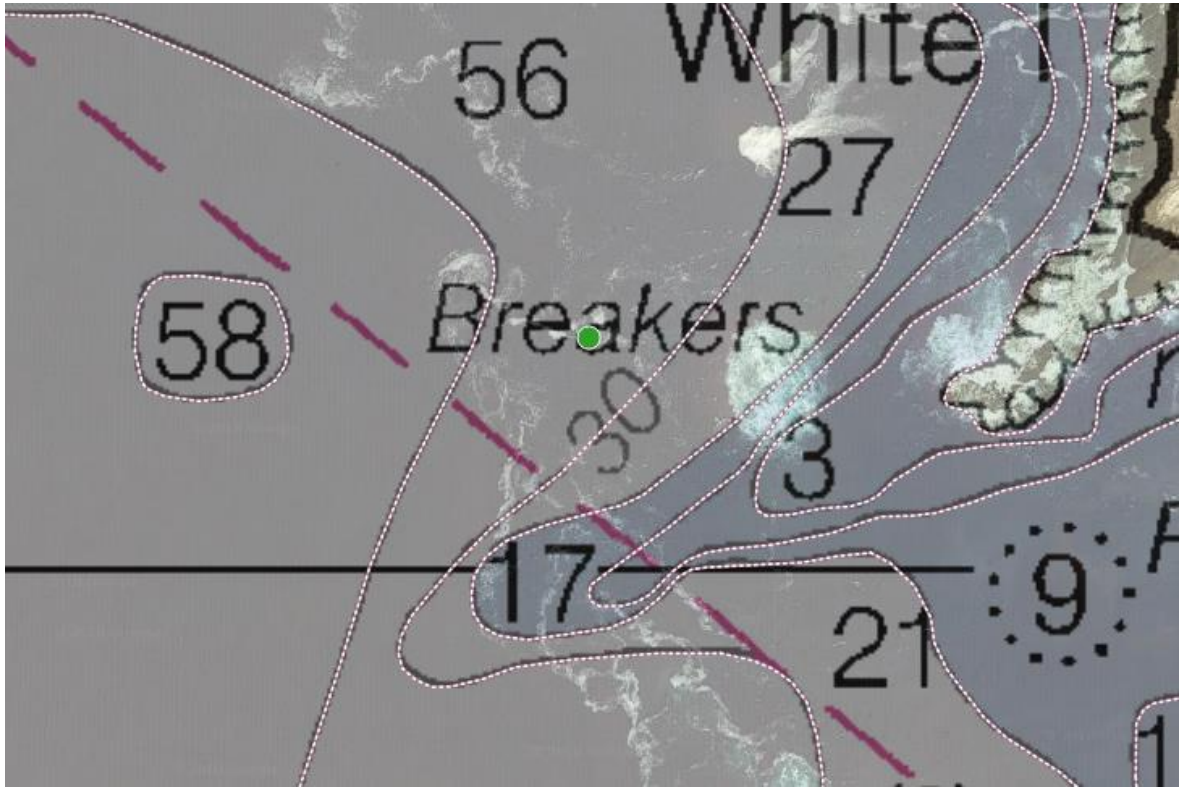
0.5 mm grid plus 0.5 mm buffering

Completeness

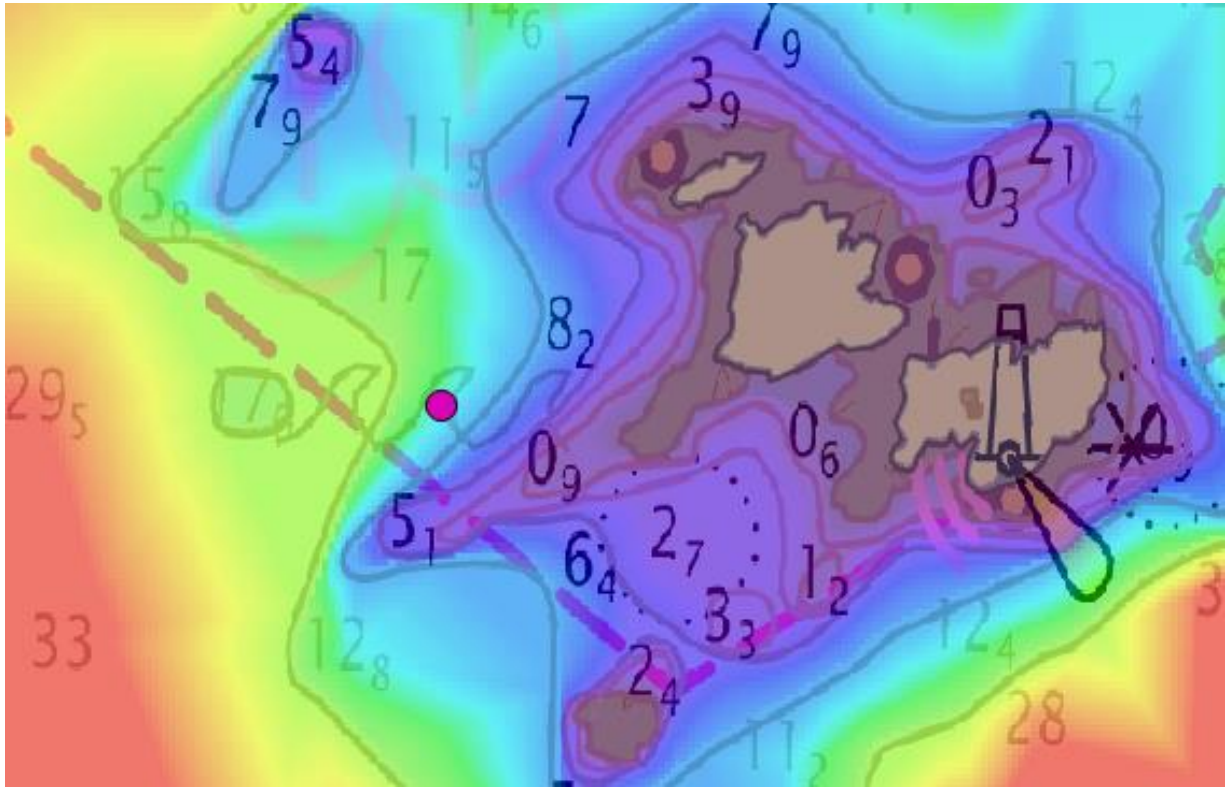
Google Maps

0.5 mm grid plus 0.5 mm buffering

Feature Position and Display

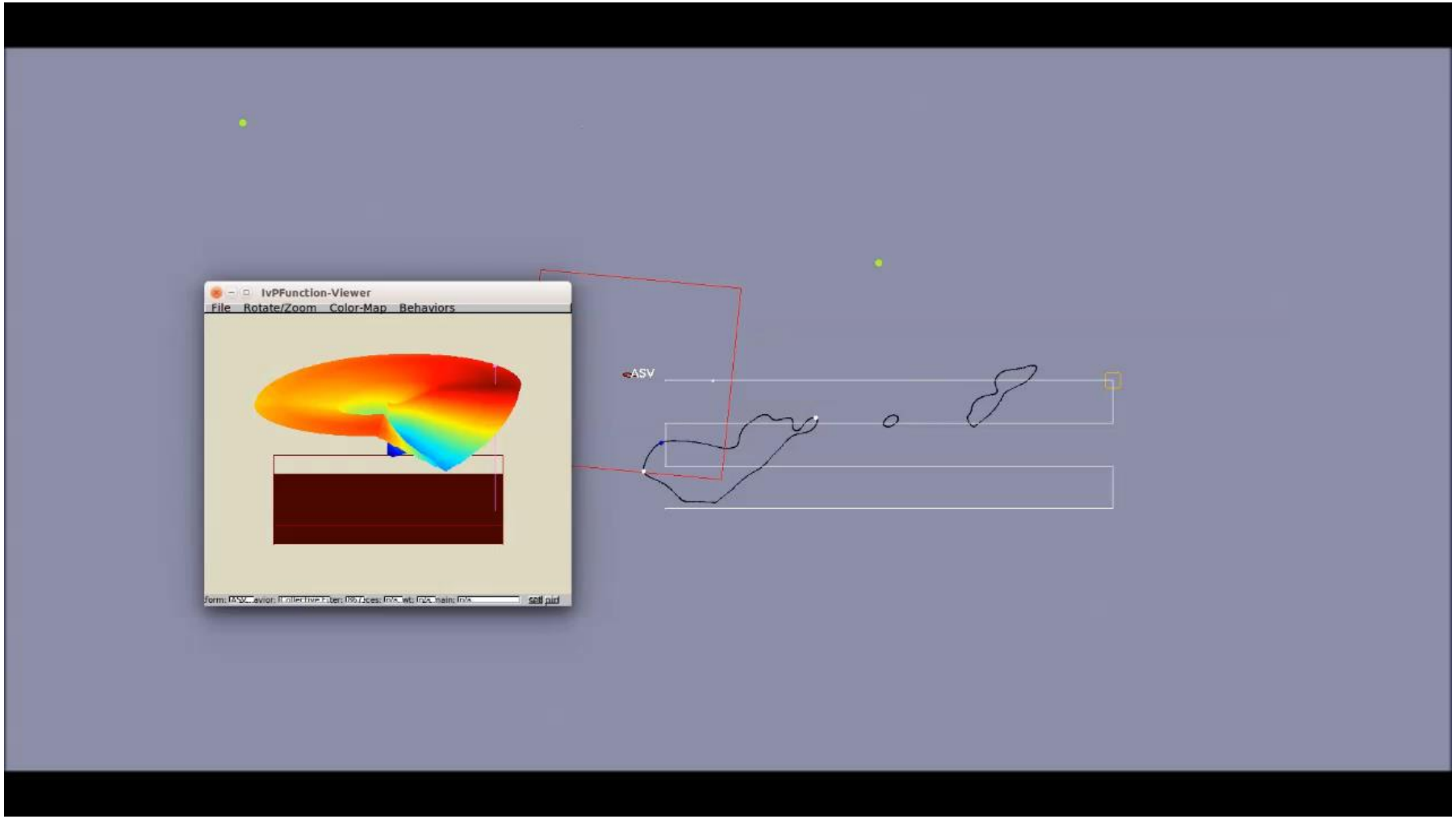


Raster Chart and Satellite Image



ENC with Bathymetric Survey Data

Real-time Object Avoidance



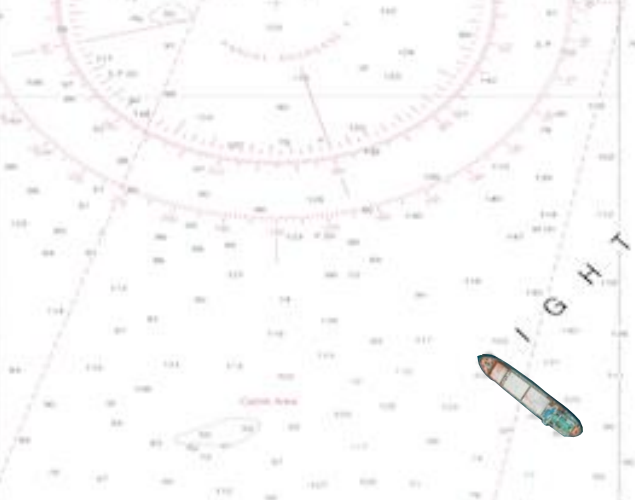
Fast Retrieval of Data by Spatial Search

What

Where

Layer ID	Layer name	Number of features	Geometry type
1	ACHARE	2	Polygon
2	BCNLAT	9	Point
3	BCNSPP	6	Point
7	BOYISD	1	Point
8	BOYLAT	56	Point
9	BOYSAW	3	Point
10	BOYSPP	10	Point
4	BRIDGE	1	LineString
4	BRIDGE	29	Polygon
6	BUAARE	7	Point
6	BUAARE	8	Polygon
5	BUISGL	928	Point
5	BUISGL	253	Polygon
62	C_AGGR	2	None
63	C_ASSO	5	None
11	CBLARE	10	Polygon
12	CBLOHD	8	LineString
14	CGUSTA	1	Point
15	COALNE	308	LineString
13	CTNARE	1	Point
13	CTNARE	5	Polygon
16	DAYMAR	14	Point
17	DEPARE	922	Polygon
18	DEPCNT	963	LineString
21	DMPGRD	1	Polygon
19	DRGARE	9	Polygon
20	DRYDOC	4	Polygon
0	DSID	0	None
22	DYKCON	1	LineString

S-57 Layers



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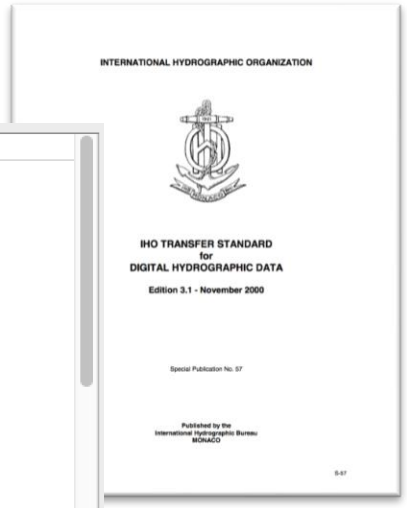
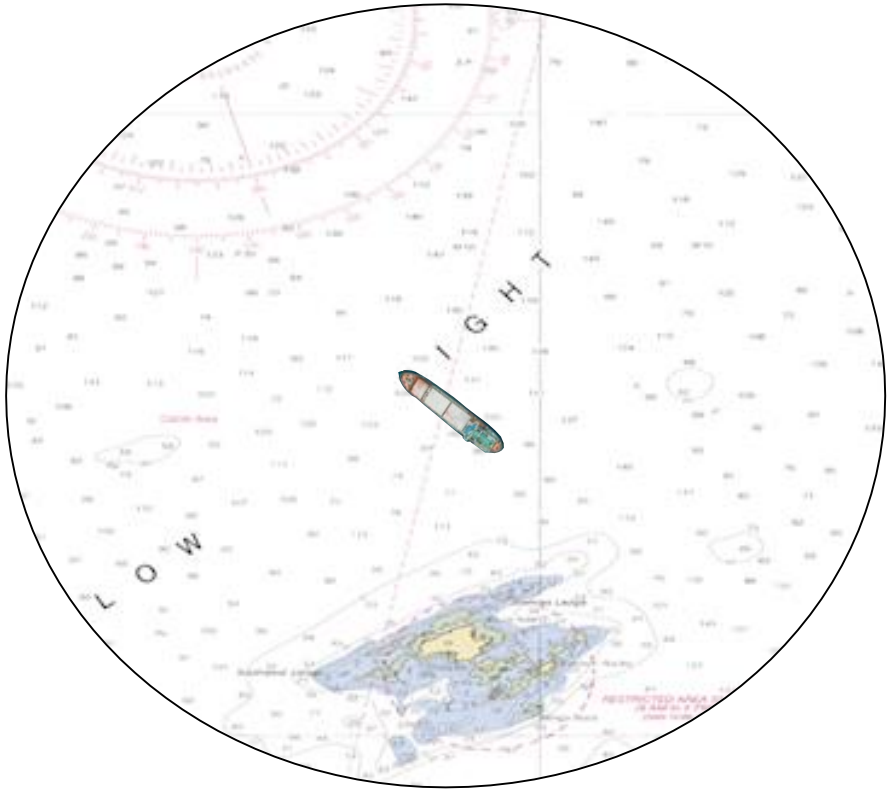
19	DRGARE	9	Polygon
20	DRYDOC	4	Polygon
0	DSID	0	None
22	DYKCON	1	LineString



S-57 Layers



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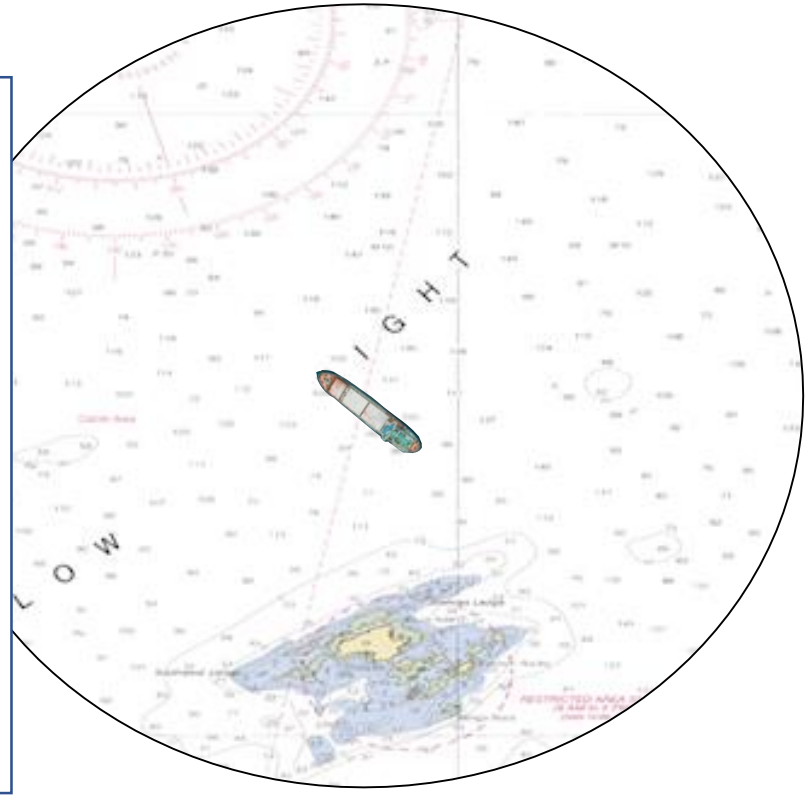
S-57 Layers

ECDIS

SENC



Spatial Indexing

“C-Squares” Indexing

e.g.:
3414:227 *(1-degree square with origin at 42 ° S, 147 ° E)*

additional degrees E [140+7] =147
additional degrees S [40+2] = 42
***5-degree quadrant**, i.e.*

1	2
3	4

tens of degrees E (i.e., 140)
tens of degrees S (i.e., 40)
global sector (1=NE, 3=SE, 5=SW, 7=NW)

“R-Tree” Indexing

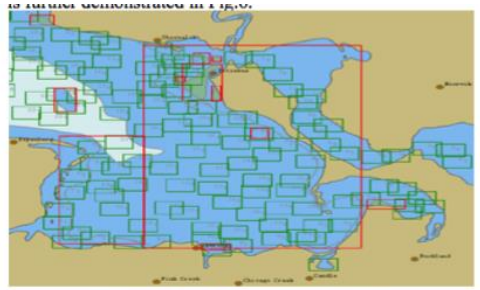


Figure 5. Bounding boxes of ENC objects.

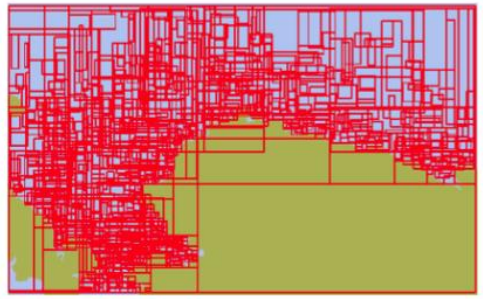


Figure 6. R-tree index of ENC objects.

Proposal to Include a Grid Referencing System in S-100, *HSSC, Singapore, October 2009*

Y. Yu, H. Zhu, L. Yang, and C. Wang, “Spatial Indexing for Effective Visualization of Vector-Based Electronic Nautical Chart,” *(ICIICII)*, 2016, pp. 323–326.

Keys to Autonomous Navigation on ENCs

Notes for the Cartographer

- Organize for fast spatial search.
  - ***(Spatial Indexing)***
- Produce cost maps at 0.5 mm at compilation scale.
  - ***(Produce higher scale charts, fit for purpose. Variable Resolution?)***
- Buffer point and line features.
  - ***(Represent points and lines as polygons – nothing < 2D!)***
- Be wary of cartographic license.
  - ***(Encode both physical and display location.)***

Thank you.

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University of New Hampshire