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e-Navigation in Arctic Conditions: Transmitting High Resolution Ice Routes in First-year Ice

Thomas Porathe, Maritime Human Factors Group, Dep. of Shipping and Marine Technology, Chalmers University of Technology, Sweden. *thomas.porathe@chalmers.se*

Abstract

A long time ago navigation was done solely by experience: the knowledge was in the head of local pilots. Through the centuries a symbolic system of buoys, cairns and charts developed: knowledge placed in the world, to paraphrase Donald Norman (1990). But Arctic navigation now poses a challenge that will need new solutions. Buoys cannot be stationed in ice as they will be swept away or pushed under. The ice sheet is a shifting, dynamic landscape with few landmarks. Further: in open water the buoy's function is to warn for stationary shallows, in ice there is the additional need to guide trough passable leads or broken ice channels that move, open and close with the wind and currents. How can e-Navigation tools like Virtual AtoNs assist in Arctic navigation?

In this paper findings from a study onboard a Swedish icebreaker in the one-year ice of the Bay of Bothnia are presented as well as proposals for new e-Navigation services to help improve efficiency of ice navigation. Dynamic "ice routes", sent from icebreakers to other ships entering into the ice will facilitate traffic management in the ice. Transmitting fuel consumption as well as speed for ships in the ice sheet will create a useful indicator of ice conditions. Using updated satellite photos of the ice sheet as underlay in ECDIS, will facilitate ice navigation.

1. Introduction

Knowledge in the world

Footpaths are a collective memory of preferred routes of generations of people. Through a selective process of many individuals voting with their feet the easiest or most direct passages have been selected, vegetation is kept down for the benefit of speed and navigation made simple: just follow the track. The psychologist Donald Norman talked about "knowledge in the head" and "knowledge in the world" (1990). He notes "whenever information needed to do a task is readily available in the world, the need for us to learn it diminishes." (p. 54) A path through the woods is such a recorded memory in the world. In the northern archipelagos of Sweden already the Bronze Age people started to build cairns on prominent islands to function as visible anchors for a path drawn in memory. When nautical charts started to become common onboard seagoing ships in the 18th century "paths" or fairways through the complicated archipelagos of Sweden where drawn there, in "the world." But ice navigation is different and our historical experience is limited.

Global warming and Arctic navigation

In the face of expected changes in Arctic ice conditions due to the Global Warming, wayshowing in these regions becomes of interest. The routes from the Atlantic to the Pacific Ocean though the Northwest Passage north of Canada and Alaska, and the Northern Sea Route, north of Russia, is expected to open permanently with or without assistance from icebreakers. Previously these passages have been blocked by thick multi-year ice, which is very hard, difficult even for large icebreakers to pass through. But with changing climate the routes more and more becoming ice free during the summer moths, only freezing during the winter, with so called first-year ice, which is much more negotiable using icebreakers. Icebreaker escort and winter traffic through one-year ice is something that Finland and Sweden have a long experience of, keeping the ports of the northern Sea of Bothnia open for winter traffic since the 1940's, and particularly after the 1970's when a number of large Swedish and Finnish icebreakers where built (Eriksson, 2006). Today, Sweden and Finland each have one of the largest icebreaker fleets in the world, second only to Russia.

This paper presents some findings from a four day long field study onboard the Swedish icebreaker *Frej* in the northern Sea of Bothnia 5-8 April 2011. These findings and some suggestions might be of value from an e-Navigation perspective in the face of a future northern sea route.

2. Method

The 22,000 hp icebreaker *Frej* is 107 meters long and 24 meters wide with a draught of 8.3 meters. He has a diesel-electric machinery, 2 front and 2 aft propellers. He is also equipped with a ballast system which can pump 600 metric tons of water from one side of the ship to the other in 45 seconds, allowing him to pendulum 13 degrees to each side of the upright position, thus helping the icebreaker to negotiate the ice sheet.

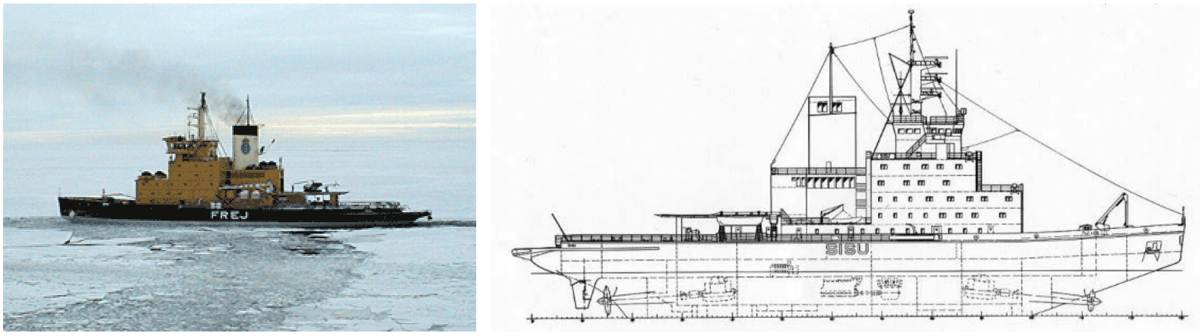

Fig. 1. The Swedish Maritime Administration's icebreaker Frej. *Three Swedish ships of this class were built 1974-77 by Wärtsilä ship yard in Finland (and also three Finnish ships of the same class, the blueprint is of the Finnish sister ship* Sisu*).*

The purpose of this field study was to learn to know how icebreaking is conducted in general and to investigate ice navigation in particular. In the face of ongoing work in several e-Navigation projects like BLAST, EfficenSea and Monal Lisa the goal was to collect user needs for e-Navigation in Arctic conditions, and the research question was to find out if any e-Navigation services could facilitate shipping in the ice.

The techniques used were observation and contextual interviews using video, photo and note-taking. During most of the four days I was present at the bridge observing the work, trying to stay out of way, and from time to time interviewing the bridge officers.

The icebreaker bridge crew consisted of a captain and five watch going officers. There were always two officers on the bridge. Three of these officers had long icebreaking experience, while two were relatively new to this particular line of work.

Maneuvering of an icebreaker is quite different from maneuvering a normal ship. The ice breaker has two forward-facing propellers in the bow and two in the aft. They also have a normal rudder, but often maneuver by only using the propellers. Using the propellers in different ways allow them to move the vessel sideways, or in any direction.

3. Results

The job of the icebreakers is to provide an escort service to other vessels. They open up channels in the ice sheet (see Fig. 2, left) and escorts convoys of ships through these channels (see Fig 2, right). Sometimes during severe conditions they have to connect a line and tug the ships one by one.

Fig. 2. Left, Frej *is opening a new channel through the 30-55 cm thick ice. By the red arrow she is brought to a complete stop by this seemingly insignificant ice ridge that shows very little of its true size above the ice sheet. Right, convoy service. Often the ships in the convoy get stuck and the ice breaker has to go back and break them free. During this maneuver, the other ships get stuck. It is a tedious work.*

In the video sequence from which the left picture in Figure 2 is taken from, the icebreaker *Frej* is negotiating unbroken 30-55 cm ice with ridges. In this kind of ice even the 22 000 hp *Frej* can get into trouble. Twenty meters further on in the left picture (red arrow) the ship ran into a ridge and came to a complete stop, forcing her to back off and take a detour. The everyday escort work is done in channels previously broken by him or some of his sister ships. The right picture depicts typical escort service, the icebreaker heading a convoy of vessels. They are all of some type of *ice class*, meaning that they have specially enforced hulls, certain minimum engine and minimum weight requirements. But they still need the assistance of the icebreakers.

The Swedish and Finnish icebreakers in the Bay and Sea of Bothnia are coordinated helping each other. Each icebreaker or group of icebreakers have a limited area in which they are responsible for escorting ships. This gives them an opportunity to learn the local ice and weather conditions. North or southbound convoys of ships are the handed over from one ice breaker to the next as they traverse the ice sheet.

Once the ships have passed through the channel, the crushed ice floats back into the channel and fills the passage, and if the temperature is below the freezing point, immediately starts to freeze solid again. Figure 3 shows such an ice channel. It is almost impossible to judge whether the channel is open and negotiable for an ordinary ship, or if it is an old frozen channel that needs an icebreaker to break it open again.

Fig.3. This is an open channel in the ice. An old, frozen channel would look exactly the same. In this case it is fairly simple, but not visible on this picture is the maze of new and old channels that is tangled over the ice sheet after a long winter. How do you find the right path?

Due to changing winds and currents the ice sheet floats back and forward. Wind pressure staple ice on top of each other creating ridges, broken channels are sometimes rapidly squeezed together or drifting into shallow water, wherefore the icebreakers constantly have to abandon old channels and break new ones. By the end of the season the ice sheet might look like a maze of new and old channels (see air photo in Figure 4, left). Finding the right open channel is a challenge – especially in foggy conditions which are common (Figure 4, right). Finding the open channel is important also for the icebreakers, as using old channels saves substantial amounts of fuel and time. Therefore it is of great importance to keep track of which channel is the current, open one.

Fig.4. Left: the ice sheet of the Northern Bay of Bothnia from the plane coming into Umeå airport. The maze of old channels is partly visible. The shadow of a ship is seen in the main fairway. Right: Foggy conditions are common when warm air blows in over the cold ice sheet. On the picture Frei *is approaching a ship stuck in the ice.*

IBNet

In the decision making process the bridge crew on the ice breakers have great help of *IBNet* (IceBreakerNet) developed by VTT in Finland. IBNet contains information of importance for the ice breakers, such as registers over ships and their ice classes, ports, current shipping restrictions and AIS based positions of ships which the system then color codes depending on ship type and destination.

The past track of each ship is displayed and color coded by speed. As ships in the ice most often go full speed ahead, the speed through the water will then give an indication of the ice conditions. (This does not apply to the icebreakers which may go slow on purpose.) A suggestion from the captain on *Frej* was to add information of the engine effect used to the track of the icebreakers, which would give a very good estimate of the severity of the ice.) The Finnish Meteorological Institute sends out daily satellite photos over the areas (see Figure 5) as well as weather and ice forecasts. Each icebreaker can also add information about ships, ice conditions and traffic situation. All information is then shared by the Finnish and Swedish ice breaker fleet as well as the ice breaker management in Norrkoping and Helsinki. (Swedish Maritime Administration, 2012)

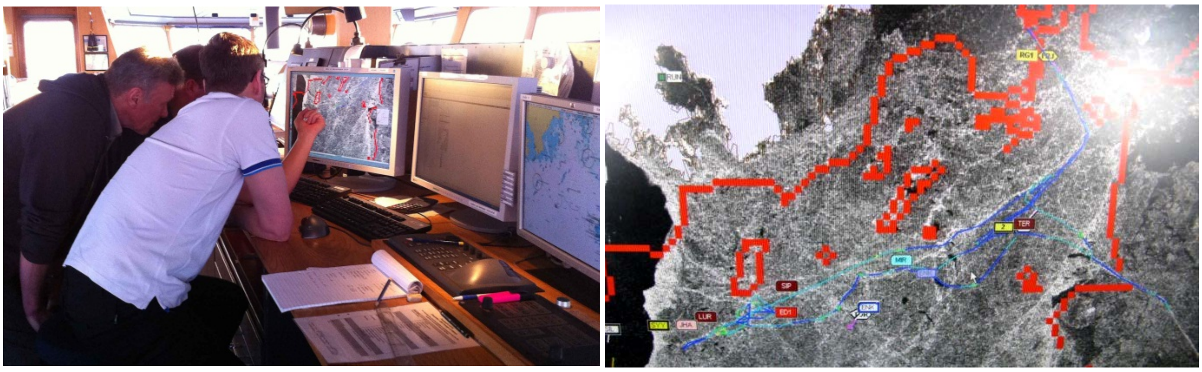

Fig.5. Left: the bridge crew is gathered in front of the IBNet screen, studying a fresh satellite picture. Overlaid on the satellite picture are the 10 meter safety contour (red), the prevailing wind, and the different ships in the area, ice breakers, and ordinary vessels color coded for their port of destination and with tracks color coded for speed.

The job of the icebreakers is to assist ships through the ice to ports in the north of Sweden and Finland and back into open water again. They do that by fetching the ship at the ice front or by relieving another icebreaker and then lead the single ship, or more often, lead a convoy of ships. If the ice is very sever and the assisted ship has weak engine power the icebreaker may have to connect tug lines.

If the ice is stable, it is most efficient, also for the icebreaker, to use a channel that has already been broken up. The problem is only that by the end of a year the ice sheet is full of new and abandoned channels. With experience the bridge officers can learn to distinguish channels and ice ridges on the special ice radar (Consilium Selesmar) used onboard (Figure 6, left), but the most used equipment is the Adveto ECDIS system (Figure 6, right).

Fig.6. Left, the Consilium Selesmare ice radar and right, the Adveto ECDIS. Past track of several resent vessel movements gives a view of open ice channels in the area.

On the Adveto ECDIS the Swedish and Finnish icebreakers can upload the historic track from themselves, or any other ship that passed through the ice recently. Taking into consideration possible movements of the ice, they can use the historic track as a “footpath” through the ice sheet. In Figure 7, left, a screen shot from the Adveto system can be seen. The time is a little before nine in the morning, *Frej* has been freeing two ships (the *Fembria* and the *Helena*) from the ice (the historic track from his maneuvers loosening the ship can be seen) and he is now leading the convoy through the ice using his own track from about 2300 hrs the night before. In Figure 7, right, the situation (a little earlier) can be seen on the regular Furuno ECDIS screen. This system had no possibility to display historic tracks in the same way.

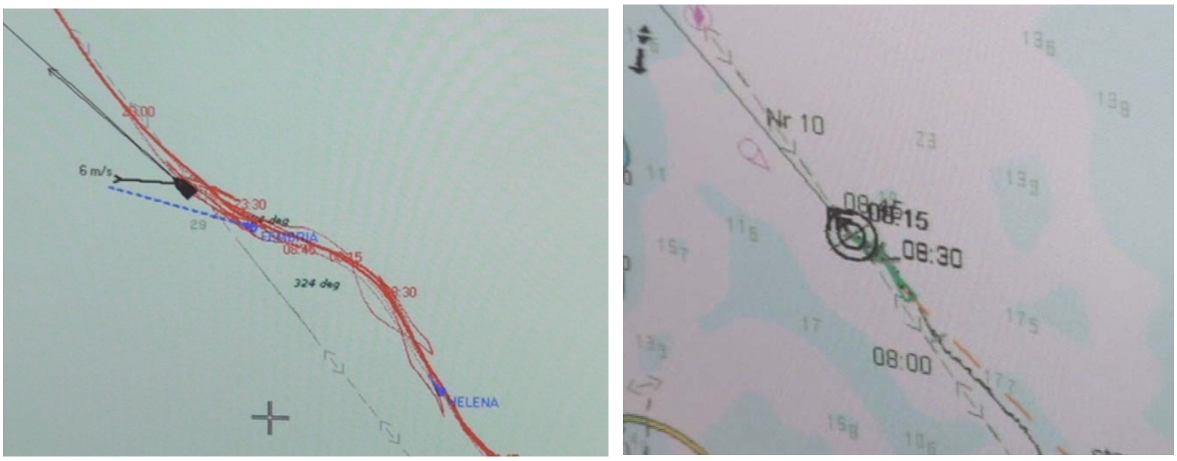

Fig.7. Left, a screen shot from the Adveto ECDIS, the ice breaker is escorting a convoy of two ships at 8.45 in the morning. He is using the historic track of himself from about 23.00 the previous night, showing that the ice sheet has been stable and not drifting. To the right is a screen shot from the regular Furuno ECDIS a little earlier. The historic track cannot be called up here.

The bridge officers where very pleased with being able to use this feature which made their work a lot easier. One of the bridge officers onboard Frej even said: “The day they take away the Adveto system I will quit this job.”

Having to go and fetch all but the most powerful ships makes the job of an icebreaker very inefficient, and at times ships have to wait for assistance, stuck in the ice, for several days. (During my visit we went and fetched a ship that had been waiting for three days stuck in the ice.) Quite a lot of ships would be able to travel themselves through an open channel if they only could find the way. But with no ice radar, bad visibility, the difficulty to distinguish an open channel from a frozen one, and knowing which channel is the right one, the icebreakers have to escort most ships. “We sometimes try to give them waypoints by reading coordinates over the VHF, but they think it is too much work to type them all into their ECDIS, so they take shortcuts and get stuck,” the captain explains in an interview. “Just ten meters outside the channel, and they get stuck.”

Adveto is a small Swedish ECDIS manufacturer, whose equipment is not very common. So the method of calling up the historic track of an icebreaker cannot be used by most ships as they are equipped with other types of ECDIS systems.

A whish expressed by the bridge officers onboard Frej*, was the ability to cut out a relevant snippet of some icebreaker’s or other ship’s historic track, change it into an high density waypoint route and send it addressed to a particular ship so that they could amend it to their active route in any ECDIS and find the open ice channel by themselves. In that way, the bridge officers said, the icebreaker could park in the middle of their area and function as a traffic center and only need to fetch the most vulnerable ships.*

The user need expressed by the bridge officers of the icebreaker *Frey* should be technically feasible using the methods of AIS messages studied sending intended and suggested routes in the EfficenSea project (Porathe, Lützhöft, & Praetorius, 2012).

4. Discussion

In September 2007 the Northwest Passage, the direct shipping route between Europe and Asia via the Arctic Ocean became ice free for the first time since satellite records began in 1978 (National Geographic, 2007). Much fuel and time is saved via this short cut instead of using the Panama or Suez canals, or even passing the Cape Horn or Cape of Good Hope on such a route between the Atlantic and the Pacific ocean. The traffic intensity is already now rising. In 2009 the two coursing ship *Hanseatic* and *Bremen* transited the Northwest Passage and the number of ships in passing the Bearing Strait rose from 245 in 2008 to 325 in 2010 (Colvin, 2011). Considering the savings using this way, one might expect that great efforts will be made to keep it open for vessel traffic not only in the summer months, but also during the winter.

The disappearance of multi-year ice from the shipping routes opens the possibility to organize icebreaker escort in the same way that has been practiced in the Baltic Sea and Bay of Bothnia for many decenniums now.

Aids to navigation will, however, be a challenge for the Maritime Administrations involved. Physical aids to navigation will be difficult to use due to environmental reasons. On the other hand, virtual aids to navigation as envisaged in the IMO's e-Navigation concept offers interesting possibilities. Based on coming robust and redundant satellite based positioning and timing services, the ability to send exact and high resolution tracks based on satellite, vessel and icebreaker information directly to ships should be of great value and could reduce the need for escort services, just as proposed by the bridge crew of *Frej*. Returning information from each ship of the ice conditions, e.g. by displaying the effect needed (e.g. fuel consumption per nautical mile) to traverse the ice, along with normal meteorological information, might further improve prognosis for projected future conditions.

In the EfficienSea EU e-Navigation project (http://efficiensea.eu/) the ability to send suggested routes and search patterns from VTS and Rescue Services to addressed ships was tested with good results. The AIS system was then used to carry the information. A more robust system with higher bandwidth will have to be used, but as long as an international standardization agreement can be provided, there should be limited technical problems.

4. Conclusions

Based on a study onboard an icebreaker in the Bay of Bothnia between Sweden and Finland the following user needs to facilitate shipping in one-year ice was found:

1. Minimize need for icebreaker escort by offer detailed wayshowing to vessels entering the ice sheet. This can be done by giving icebreakers or other vessel management systems possibilities to send high resolution ECDIS routes (waypoints) directly to an addressed ship, and letting the ship import such routes into the active, monitored route on their ECDIS systems.
2. Create a standard for allowing satellite pictures as an underlay in ECDIS and radar.
3. Create a standard for how vessels transiting ice areas can broadcast information about engine effect used. This measurement could be used to add to the picture of the prevailing ice conditions.

References

Colvin, C. C. (2011). USCG D17 Arctic Brief, 27 January 2011. Seventeenth Coast Guard District, Coast Guard Forces, Alaska. http://www.uscg.mil/d17/Arctic%20Overview%20Feb2011.pdf [Acc. 2012-07-11]

Eriksson, M. (2006). Sjötransporter och regional omvandling: Reglering av den Norrländska vintersjöfarten 1940-1975. Licentiate thesis, Umeå University, Occasional Papers in Economic History No. 11 2006

National Geographic. (2007). http://news.nationalgeographic.com/news/2007/09/070917-northwest-passage.html [Acc. 2012-07-11]

Norman, D. (1990). The Design of Everyday Things. New York: The Perseus Books Group..

Porathe, T., Lützhöft, M., & Praetorius, G. (2012). What is your intention? Communicating routes in electronic nautical charts. Elsevier, Procedia - Social and Behavioral Sciences (48), pp.3266-3273.

Swedish Maritime Administration. (2012). http://www.sjofartsverket.se/en/About-us/Activities/Icebreaking/IBNet/ [acc. 2012-06-30]