A cohesive methodology for the delimitation of maritime zones and boundaries

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A B S T R A C T

The delimitation of maritime zones and boundaries foreseen by the United Nations Convention on the Law of the Sea is a factor of economic growth, effective management of the coastal and ocean environment and the cornerstone for maritime spatial planning. Maritime boundaries form the outermost limits of coastal states and their accurate computation is a matter of national priority. The final delimitation agreement is ultimately a political decision; however the cartographer/GIS expert should portray the zones' limits with the best possible accuracy. Existing applications tend to address this issue with their weakness being that the delimitation is a complex and time-consuming process. There, the subject is addressed in a fragmented way with the user composing the outer limits from partial results. This paper presents a cohesive methodology for the automated delimitation of the median lines and maritime zones between all states in a region based on the Voronoi tessellation of maritime space. Furthermore, through a case study, it presents and evaluates the results of this methodology and its implementation and demonstrates its ability to delimit the zones and boundaries, unilaterally and bilaterally, without the user's intervention.

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1. Introduction

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) (UN, 1982) codifies different maritime zones within which coastal states exercise a range of rights, from sovereignty to policing. The delineation and delimitation of maritime zones and boundaries is of particular importance for the coastal states from the point of view of maritime trade, management, sea protection and the utilization of living and non-living resources.

In the past, the delimitation process was carried out by the cartographers directly on paper charts. The evolution of Geographic Information Systems (GIS) technology facilitated considerably the cartographers' work with providing the tools to address problems hardly handled with the conventional manual methods. The use of GIS applications for the documentation of maritime claims has been accepted by the International Court of Justice (ICJ) (Carrera, cited in Fowler and Treml, 2001). However and particularly with respect to the delimitation of bilateral limits, the existing solutions constitute time consuming, semi-automatic, multi-step and complicated processes, which require continuous user's intervention.

In the framework of an extended study on the delineation and delimitation of maritime zones and boundaries, this paper suggests, evaluates and validates a cohesive methodology and its implementation for the automated delimitation of maritime zones, both unilaterally and bilaterally. In the following sections, this paper provides some background information on UNCLOS and the weaknesses of existing GIS approaches, followed by the methodology and the results of the developed application through a series of maps on a case study of a fictitious area covering possible geographic situations and configurations of the coastlines. With the proposed methodology the median lines between all coastal states in the region and their respective maritime zones up to the median lines, are constructed without user's intervention. The application developed addresses any combination of normal, bay-closing lines and straight baselines. In addition, the turning points on the median line and the maritime zones' limits as well as their corresponding critical points on the baselines are determined. Finally, the construction lines connecting the median line's turning points and their corresponding critical points on the baselines are also created along with the calculation of their length.

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2. Background

According to UNCLOS provisions the reference where from the maritime zones are measured are the baselines demarcating land territory and internal waters from the sea, as they are portrayed on large-scale charts officially recognized by the coastal states involved. Baselines can be any combination of natural coastline and straight line segments. Hereinto the term 'straight line segments' refers to bay-closing lines, straight baselines or straight archipelagic baselines in accordance with provisions of Articles 7, 10 and 47 of UNCLOS. The maritime zones stipulated by UNCLOS are: (a) the Territorial Sea, a 12-Nautical Mile (NM) zone surrounding the baselines; (b) the Contiguous Zone, a zone adjacent to the territorial sea extending to no more than 24 NM from the baselines; (c) the Exclusive Economic Zone, an area beyond and adjacent to the territorial sea, which may not extend beyond 200 NM from the baselines; and (d) the Continental Shelf, an area that extends beyond the territorial sea to the outer limit of the continental margin. The continental shelf is formed through the combination of geological parameters as provided for in Article 76 of the Convention. The said geological parameters apply to the area beyond the 200 NM from the baselines, known as the Extended Continental Shelf, as up to the 200 NM limit the continental shelf is another distant constraint maritime zone that is delineated regardless of the geological formation of the seabed.

The dominant method for the unilateral delineation of maritime zones to their maximum allowable breadth has been that of the conventional line constructed as the combination of the 'envelope of arcs' for the natural coastline and the 'replica line' (or tracé parallèle) for straight baselines. To implement the envelope of arcs from a point on the normal baseline, an arc is drawn at a distance equal to the breadth of the maritime zone (Boggs, 1930) and the, so called, envelope line is the locus of the intersections of the farthest arcs. This is compliant with the provisions of Article 4 of UNCLOS for a line 'every point of which is at a distance from the nearest point of the baseline equal to the breadth of the territorial sea', which is inferred to be applicable as well to the other maritime zones. On the other hand, the replica line is created with the transfer of the straight line segments seawards at a distance equal to the zone's breadth. The outer limit of the maritime zone is formed by the combination of the two lines (Fig. 1).

With respect to the bilateral delineation of maritime limits, that is when the respective maritime zones of two coastal states overlap, the cartographer/GIS expert must define the median line 'every point of which is equidistant from the nearest points on the baselines' (UN, 1982, Article 15). To contribute to the implementation of the above delimitation methods, the International Hydrographic Organization (IHO) issued a manual on the Technical Aspects of the Law Of the Sea (TALOS, 2014), currently in its 5th edition, which provides a comprehensive guidance for the implementation of the various aspects of UNCLOS.

3. Problem statement and related work

With the existing GIS applications, cartographers/GIS experts may delineate maritime zones with the utilization of semi-automatic modules. Particularly, with one of the available software modules the unilateral delineation of the distant constraint maritime zones can be carried out for the entirety of baselines of a single coastal state. With another application, the determination and delineation of juridical bays can be performed without user's intervention (Kastrisios and Tsoulos, 2016). With third dedicated software, it is feasible to draw the bilateral limits between coastal states but with the following constraints and difficulties.

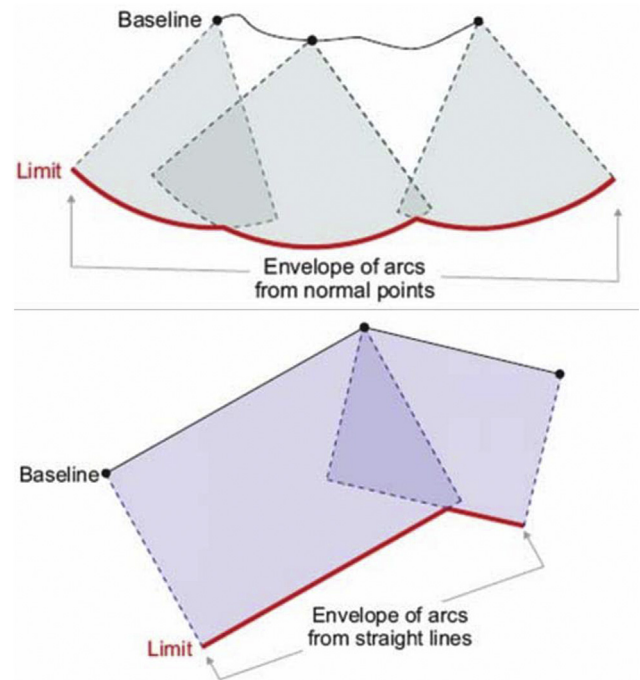In detail, for the bilateral delimitation among two or more

Fig. 1. The outer limit of a maritime zone is a combination of the envelope of arcs and the replica lines (Levesque et al., 2008).

coastal states, which have declared mixed baselines, the cartographer needs to demarcate the median lines between normal baselines for all possible combinations of the respective states, then for the normal and straight lines and finally between straight lines. The process is performed for parts of the region and is repeated for the full extent of the baselines. Then, the results are manually combined to compose the median lines between the states involved. Following the formation of the median lines and for the bilateral delimitation of maritime zones, the cartographer constructs the zones at their maximum breadth and subsequently clips them so that they do not extend beyond the median line.

It becomes evident that the available solutions although they facilitate the task of maritime limits delimitation, they address the subject in a fragmented, semi-automated and time-consuming way. Therefore, the development of a cohesive methodology that addresses the above mentioned constraints is considered necessary. This methodology, as presented in the following section, does not claim to turn amateurs into experts but to further enhance and facilitate cartographers/GIS experts work. It is noted that within this paper and -according to TALOS- 'for descriptive purposes, it is advantageous to disregard the complexities of a curved surface, so the terms of plane geometry are used' (TALOS, 2014).

4. Methodology analysis

The following paragraphs elaborate on the proposed methodology for the delineation and delimitation of maritime zones and boundaries both unilaterally and bilaterally, formulating the requirements that an automated process must address. More specifically it must:

(1) Delineate all maritime zones unilaterally at their maximum breadth, with their inner limits being in accordance to Articles 3, 33, 55 and 76.
(2) Delimit the median line between opposite baselines.
(3) Delimit the median line between adjacent baselines.