COMMUNITY-BASED GEOSPATIAL APPROACH TO BETTER UNDERSTAND THE COASTAL ENVIRONMENTS IN THE ESTUARY AND GULF OF ST LAWRENCE, QUÃ©BEC, CANADA

Participatory geomatics network for coastal mapping and monitoring

This article presents a participative geomatics project with the goal of increasing southern Québec's coastal communities' ability to map and monitor changes in their coastal environment. Capacity-building and empowerment using low-cost geomatics equipment, easy-to-use field protocols and semi-automated processing algorithms provide a resilience pathway for coastal communities facing the effects of climate change. This co-constructed project aims to develop a participatory network of individuals and groups capable of acquiring, processing and interpreting coastal geospatial data of the Estuary and Gulf of St Lawrence (eastern Canada).

The coastal zone is highly dynamic and exposed to multiple processes that are induced by global climate changes and anthropogenic activities. An increasing number of coastal communities are facing challenging conditions and need to adapt land management policies to ensure the sustainable use and protection of the coastal area. In order to take informed decisions about how and where to take action, local actors need to have a good understanding of their territory, at a scale that 'speaks to them'. The acquisition of precise and up-to-date data is therefore essential to increase resilience to a rapidly changing shoreline.

The Estuary and the Gulf of St. Lawrence. (Source: Government of Canada)

The flexibility provided by recent advances in the field of applied geomatics, in particular in low-cost precise positioning devices and open-sourced photogrammetry algorithms, brings a huge potential to geospatial data acquisition by and for non-experts. When combined with participation and concertation approaches, geospatial data is a key factor in territorial appropriation by local groups and individuals. Data production is a key component for responding to climate changes in the coastal zone, and provides an adaptation pathway for communities to better communicate local challenges with decision-makers. Map-making processes allow mappers to spatialize their environments by producing georeferenced knowledge and by reflecting on the environment and its evolution. Technology transfer in applied geomatics to local communities is both a challenge and an innovation opportunity. There is a need for local actors to be able to produce high-quality geospatial products of their territories, which will also help to increase the number of high-resolution studies of the coastal zone.

Innovative research programme

The Estuary and Gulf of St Lawrence in southern Québec (eastern Canada) has a 4,500km-long shoreline and is no exception to the rapid changes currently being faced worldwide in coastal regions. In the province of Québec, community groups called Comités ZIP (*Zone d'intervention prioritaire* – Priority Intervention Zone) act to enhance and preserve coastal and marine zones. Based on their experiences and knowledge of the coastal zone, the Comités ZIP recognize the need to develop tools and protocols for geospatial data acquisition and processing in coastal ecosystem monitoring studies.

Funded by the Québec Maritime Network (RQM), this project has emerged from a request of four Comités ZIP to develop a participatory geomatics network across the Estuary and Gulf of St Lawrence. The '*Mettre le Québec maritime sur la carte*' (Putting maritime Québec on the map) project brings together interdisciplinary experts in a co-constructed approach to bridge knowledge at different scales. From fundamental research (universities), to applied R&D (colleges) and local/practical knowledge (Comités ZIP), all participants work in a cross-sectorial approach that links geomatics, geomorphology, ecology, social sciences, engineering and innovative social practices.

Figure 1: Two â€˜actorsâ€™ located on a map can share knowledge, experience and data. They also depict the need for a direct link between the GNSS base and rover for real-time kinematic surveys. As a whole, the image underlines how map accuracy relies on communication. (QuÃ©bec Maritime Network)

The project orientations are based on six fundamental flagship concepts, evenly distributed between technology (geomatics) and social sciences (participation). Together, these concepts form fundamental milestones* to ensure the proper use, acceptance and appropriation of technology by community groups.

**** The project is currently ongoing. Therefore, some of the milestones presented here have been implemented, while others are still under construction. The milestones are presented here to showcase the project as a whole. Due to COVID-19 restrictions, most of the planned in-person participatory work has been cancelled or postponed.***

Easy-to-use tools and protocols

Advances in the field of photogrammetry have opened new avenues for mapping coastal regions using low-cost acquisition systems and easy-to-use processing schemes. The acquisition of georeferenced aerial images using a combined camera and GNSS receiver mounted on a range of vehicles such as UAVs, kites, poles or aircraft provides a lot of information about ground coverage, the location of coastal infrastructures and – for repeated surveys – coastal dynamics and evolution. The camera resolutions installed on commercially available UAVs allow the capture of high-resolution low-altitude images. The field campaigns undertaken using the DJI Mavic Mini and Mini 2, both equipped with a 12MP RGB camera, show great potential for low-cost and rapid image acquisition over a few linear kilometres of shoreline. Moreover, the weight of this UAV model (<250g) facilitates its use with regards to the current Transport Canada regulations.

The aerial images, once combined with ground control points (GCPs) surveyed using low-cost EMLID RS2 multi-band GNSS receivers in RTK mode, are used to produce high-resolution digital surface models (DSM) of coastal environments. Our research team has developed photogrammetric processing software built on a combination of open-source structure-from-motion (SfM) solutions and algorithms. More specifically, the solutions for feature extraction, sparse matching and initial orientation estimations are captured from a variety of open-source software and libraries, while the techniques of aero-triangulation or block bundle adjustment, dense matching and point cloud generation are developed in-house to accelerate the process. The idea is to make a minimal and easy-to-use user interface for this solution that reduces the technical barriers for non-experts and generates accurate and precise cartographic products such as orthomosaics, DSM and point clouds.

Figure 2: Easy-to-use DJI Mavin Mini UAV operated for the first time by ValÃ©rie Desrochers, project manager at the ComitÃ© ZIP Rive Nord de lâ€™Estuaire, as part of a salt marsh characterization project (Pointe-aux-Outardes, QuÃ©bec, Canada). The EMLID RS2 GNSS receiver is used to precisely locate the ground control points (GCPs) used for photogrammetric reconstruction.

Monitor precision to track changes

In order to properly use and interpret cartographic products, the users need to have a clear understanding of potential error sources and the expected precision of the methods. On a natural environment test bed, we assessed the precision and accuracy of aerial photographic surveys with SfM techniques for coastal change monitoring. Computed systematic errors and uncertainties in the methods for multiple land covers (vegetated/bare, coastal infrastructures, mud/sand/rock, etc.) and environmental conditions were used to determine a change detection threshold. This value represents the minimum amount of change required to reliably resolve coastal changes or the relative uncertainty for volume estimation. In a technology transfer approach, the computation of the uncertainties associated with different surveying scenarios raises awareness of error sources, and helps make the distinction between 'relative' and 'absolute' errors and between 'precision' and 'accuracy' for valid data interpretation. By adding this awareness, crowd-sourced data is associated with a known level of confidence and can be trusted by decision makers or potential users of the datasets.

Adaptability to coastal geodiversity

The Estuary and Gulf of St Lawrence coastal region is composed of a wide variety of coastal systems and environments (e.g. salt marshes, cliffs, beaches). The development of multiple data acquisition scenarios to cover the range of southern maritime Québec's geodiversity using UAVs and differential GNSS will significantly improve the data coverage capabilities. Photogrammetry is a technique that can be easily used in various conditions, from flat to vertical surfaces, and drones can access remote or hazardous environments. UAVs also have the power to obtain low-altitude oblique images, offering a ‘new’ perspective in which individuals can see personally relevant locations, notable landmarks or ongoing activities that can help to capture the scale at which ecogeomorphological and socio-economic processes act.

Figure 3: Example of images acquired using the DJI Mavic Mini in various coastal environments and conditions along the Estuary and Gulf of St Lawrence. A) Riprap protection system and rocky/gravelly foreshore of ÃŽles-aux-Coudres, Charlevoix. B) Sand bars near Pointe-aux-Outardes, CÃ´te-Nord. C) Icefoot ridges of the Battures de St-Fulgence, Saguenay. D) Vegetated backshore and sandy beach of St-IrÃ©nÃ©e, Charlevoix. E) Restauration work supervision in the St-AndrÃ©-de-Kamouraska, Bas-St-Laurent. F) Oblique view of the Plaine Checkley and the industrial zone of Pointe-Noire, CÃ´te-Nord.

Consultation and concertation

Due to the participatory mission of the Comités ZIP, coastal mapping and monitoring priorities have to be defined in cooperation with local actors. Public hearings, concertation and consultation meetings are used to gather local knowledge of socio-economic, ecological, geomorphological and economic challenges in the coastal zone. Socially innovative approaches to coastal zone management are used to prioritize the needs for coastal restoration or habitat remediation. Co-construction workshops, divergence/convergence activities, participatory mapping exercises and dynamic online meeting platforms are some of the tools and methods used to yield tangible cooperative action plans in which cartography and photogrammetry are preferred means to portray the coastal spaces.

Technology transfer as a tool to empowerment

Technology transfer, composed of field training, protocols, help support and multiple retroactions to improve tools and protocols, is applied to ensure technological empowerment of the Comités ZIP and the local communities. The added values of technical know-how and expertise give these Comités ZIP a credibility towards local partners and national decision makers. Transferred expertise and training builds capacity outside of large cities and creates a new data acquisition model where local groups can acquire, process and interpret high-quality geospatial information to collaborate, exchange and share knowledge. As a result, monitoring coastal change can now be undertaken by and for local actors.

Open data sharing and diffusion

Free and open access to geospatial data democratizes the use of community-based research projects. The semi-automated photogrammetric processing workflows developed in this project significantly reduce the complexity of data processing and accelerate result sharing and usage by the largest number of local groups, individuals and national agencies. We are currently evaluating the possibility of offering our workflow as a cloud-based, accessible yet affordable solution only to our non-profit users in the maritime sector. Finally, international collaborations with the GeoNadir platform to share datasets allow the Comités ZIP to reach out to an international participatory geomatics approach to map the most at-risk ecosystems. It is an excellent way to promote actions among an international network of drone mappers and to share experiences and images.

Conclusions

Technology is evolving rapidly, and community organizations and non-experts have the legitimacy to understand and own tools capable of giving them autonomy and increasing their involvement in the decision-making processes of the coastal region in which they live. The new participatory geomatics network based on collaboration and concertation increases the diversity of the actors responsible for coastal zone mapping in the St Lawrence region. This project offers vast potential for community-based empowerment using applied geomatics and social innovation while fostering collaboration between coastal zone users and decision makers.

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