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Design of an Open Source Framework for Oil Spill Decision Support System

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Abstract:

Oil spill in marine ecosystems have serious short term and long term effects on aquatics lifecycle and on social and economic activities. A Decision Support System (DSS) can assist environmental managers to visualize the distribution of oil pollution, identify sensitive areas that are likely to be exposed to oil pollutions, and assess vulnerable resources. This paper describes the design of an open source software framework and a prototype desktop software application of a DSS for oil spill management. This system can be connected to an open source oil spill simulation model. We also present a user interface for selecting the properties, time and location of a potential oil spill and for visualizing the oil spill affected area and its impact on coastal zone.

Background

Oil spill in marine ecosystems causes serious problems in environment including short term and long term effects on aquatics lifecycle and ecological, social and economic activities. Reducing the impacts of oil spill pollution requires planning and efficient decision making by the coastal zone management (Douvere, 2008; Nadim et al., 2008; Pak and Farajzadeh, 2007)

A decision support system (DSS) may be defined as an integrated, interactive and flexible computer system that supports all phases of decision-making with a user-friendly interface, data and expert knowledge (Fabbri, 1998). A key element of a DSS is a well-structured graphical user interface (GUI) supporting realistic development scenarios through a multitude of interactive thematic maps (Li et al., 2001) enabling the decision-maker to travel through the decisional process (Martin et al., 2004). An oil spill management DSS should establish a link between environmentally sensitive coastal locations and the oil spill trajectory, resulting in a vulnerability map to define protection priorities in coastal area (Pourvakshouri and Mansor 2003). The software system architecture of a web based real-time oil spill monitoring and management system consists of a database, central repository, disaster models, an alert system, command and control, and communication schemes with long-term, medium-term and short-term early warning outputs (Assilzadeh and Gao, 2010). One prototype example of a spatial oil spill DSS has been presented by Jolma et al. (2014).

While the previous studies present a general framework for an oil spill DSS, there are only limited open source DSS solutions available. For example the DSS designed by Jolma et al. (2014) relies on the output of a special simulation model that has only been developed for the Gulf of Finland. There is a need to develop an open source DSS framework that can be adapted for coastal zones in different parts of the world.

The goal of this study is to design and develop an open source prototype DSS software and user interface for coastal and marine area to assist managers and expert in planning, prevention and emergency response in the case of oil spill.We present the design methodology focusing on the link between the DSS GUI, data base, and a third-party oil spill simulation model. The use of the designed system is demonstrated in the north part of the Persian Gulf. We also show how this DSS can be modified for other coastal and marine areas.

The conceptual design of the DSS presented here consists of four sub systems: simulation subsystem, data base, decision making subsystem, visualization, and graphical user interface (Figure 1). The simulation subsystem relies on hydrodynamic and oil spill simulation software such as the Mike 3 / Mike Ecolab or the open source GNOME model (NOAA 2016).

The database subsystem contains inputs of the models such as data about characteristic wind, wave, and tidal conditions in the study area (Figure 2) in multidimensional raster or mesh format and the environmental sensitivity (ESI, coastline, protected areas) are in a GIS raster or shapefile format.

The visualization subsystem is used for showing simulation progress, mapping, and reporting. The mapping and spatial visualization component is enabled by the interactive map and legend controls from the DotSpatial (dotspatial.org) framework. In the map, the simulation model outputs with the spatial distribution of the oil volume for each time step of an oil spill event can be shown.

The GUI is used for navigating between different components of the DSS, and for entering input from the user such as the location and time of an oil spill event, change map layers and map scale, or display oil spill movie. We built the GUI using the Microsoft Visual Studio .NET framework Windows Forms components.

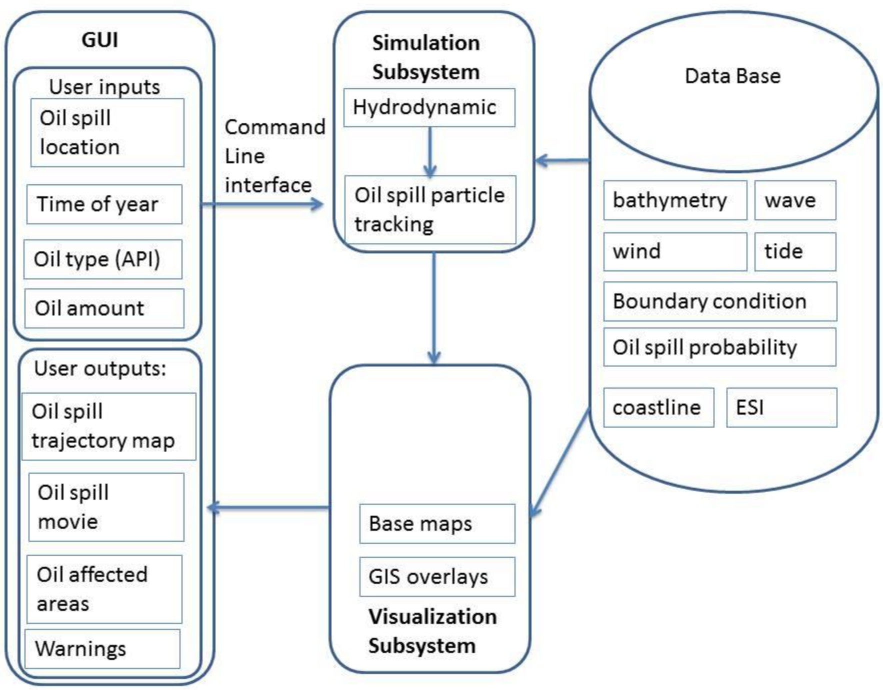

Figure 1 Conceptual Design of the DSS.

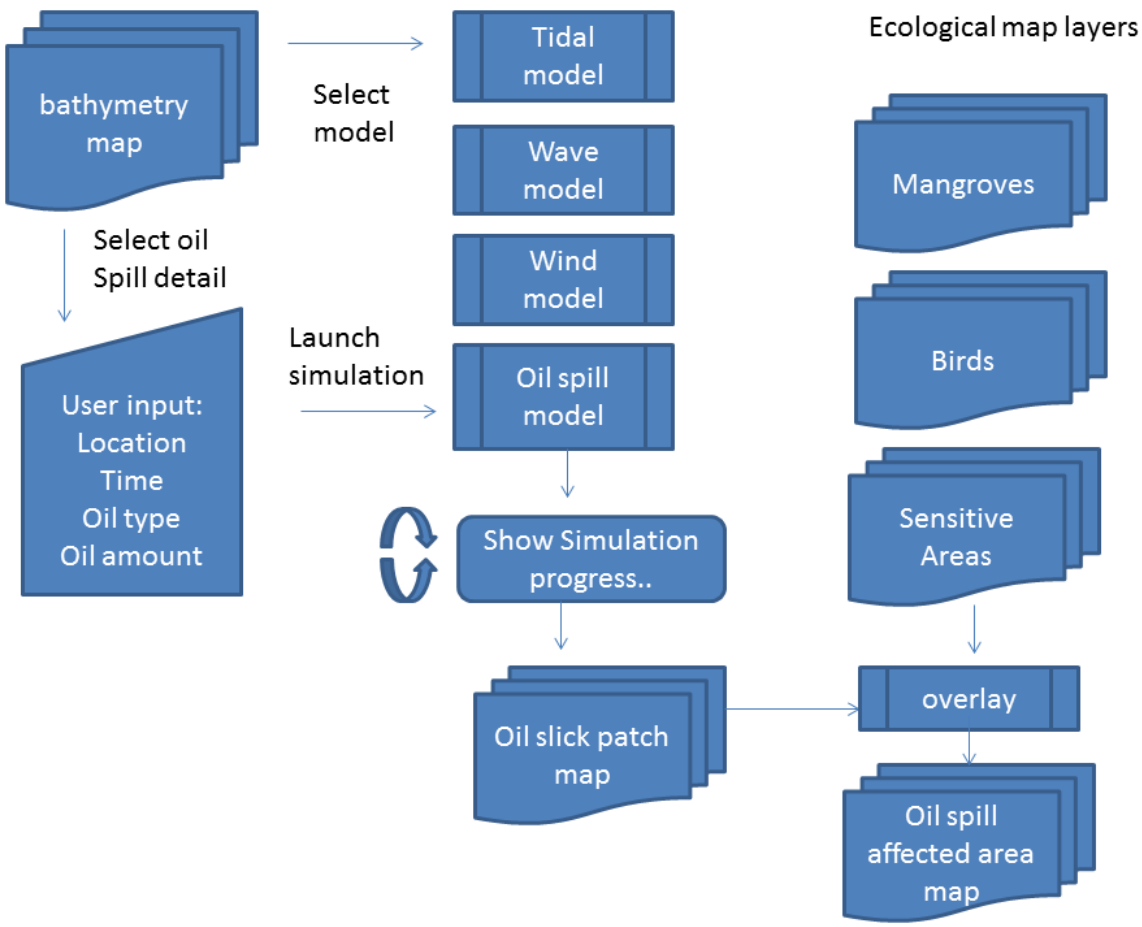

Figure 2 Input and output data and maps of the DSS

The simulation subsystem can be used in two ways: (1) Real-time simulation, and (2) Long-term simulation. The real-time simulation requires that the hydrodynamic, tidal, wave, wind and oil spill model software (Mike /ecolab or GNOME) are present on the user's system. Once the simulation is complete, a series of oil slick patch maps is generated for each time step of the forecast. These maps are stored as shapefiles in the database subsystem, and they can be visualized in the form of an animation (movie) to show the movement of oil spill and to indicate likely affected areas in the sea and in the coastal zone. For each time step, the oil patch maps can also be overlaid together with a map of sensitive areas. The sensitive areas are identified using the ESI methodology (Jensen et al., 1990), with 10 categories. Each category is associated

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with a list of recommended combat methods, aiding the decision maker in emergency response.

The long term simulation does not require an installation of oil spill simulation software on the user's system. Instead, it uses pre-calculated model outputs created by repeated scenario simulation runs, each run using a different time, location and oil amount. The time and oil amount in each scenario is picked by simple random sampling. The location is picked by weighted sampling based on an oil spill probability map (Mokhtari et al. 2015). An overlay of all oil spill trajectory scenarios indicates oil-affected areas.

Results

The initial prototype of the DSS is available as a standalone desktop application for Microsoft Windows. It is designed as localizable (it can be run in multiple languages). The GUI design consists of several window forms. When the user launches the DSS, an initial window with general information about the software and help is shown. The second form is used for choosing an oil spill location, time, and other oil spill parameters such as the month, day, hour, oil type, and oil volume. The user can select the oil spill source location point by clicking in the map, or by entering the coordinates as latitude / longitude degrees or as UTM. The oil type can be chosen from pre-defined oil types (Figure 3). The user can change the zoom level of the map, and set the background map to a satellite view to provide more background about the oil spill location (Figure 4).

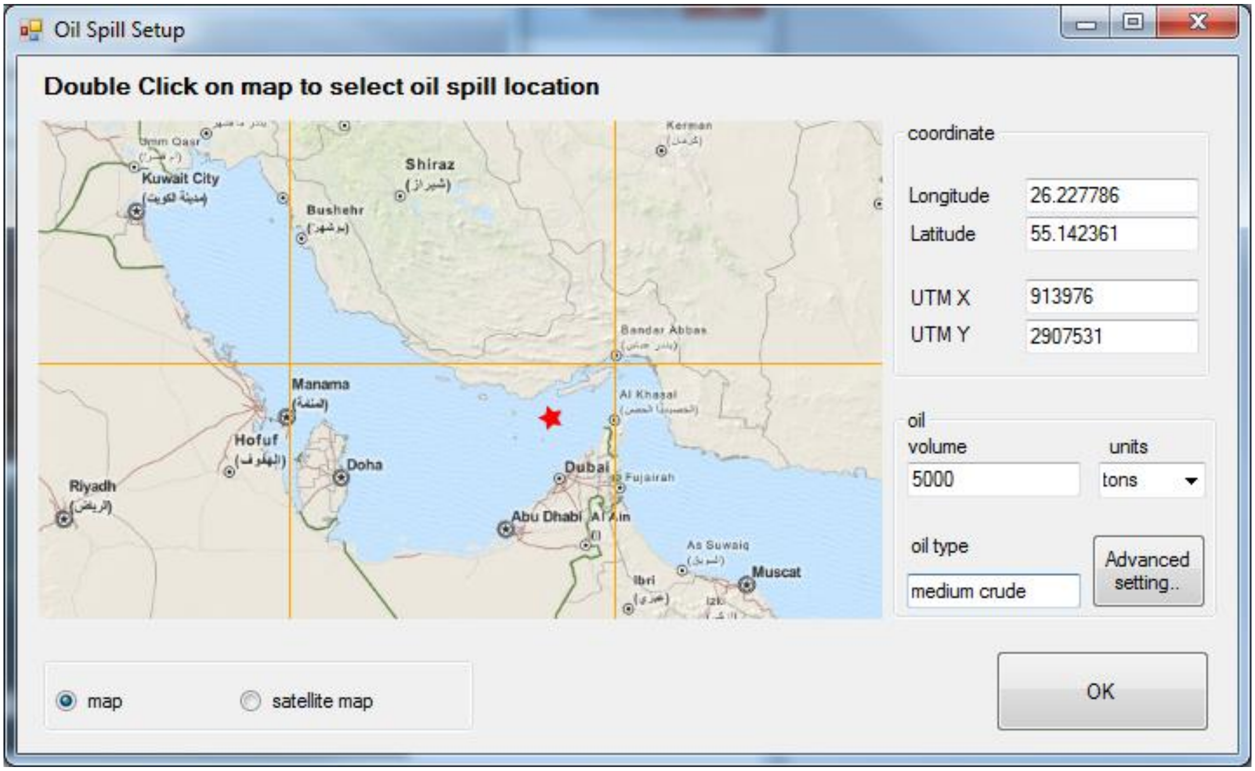

Figure 3 Selecting oil spill location, time, and oil properties using map or manual entry of coordinates

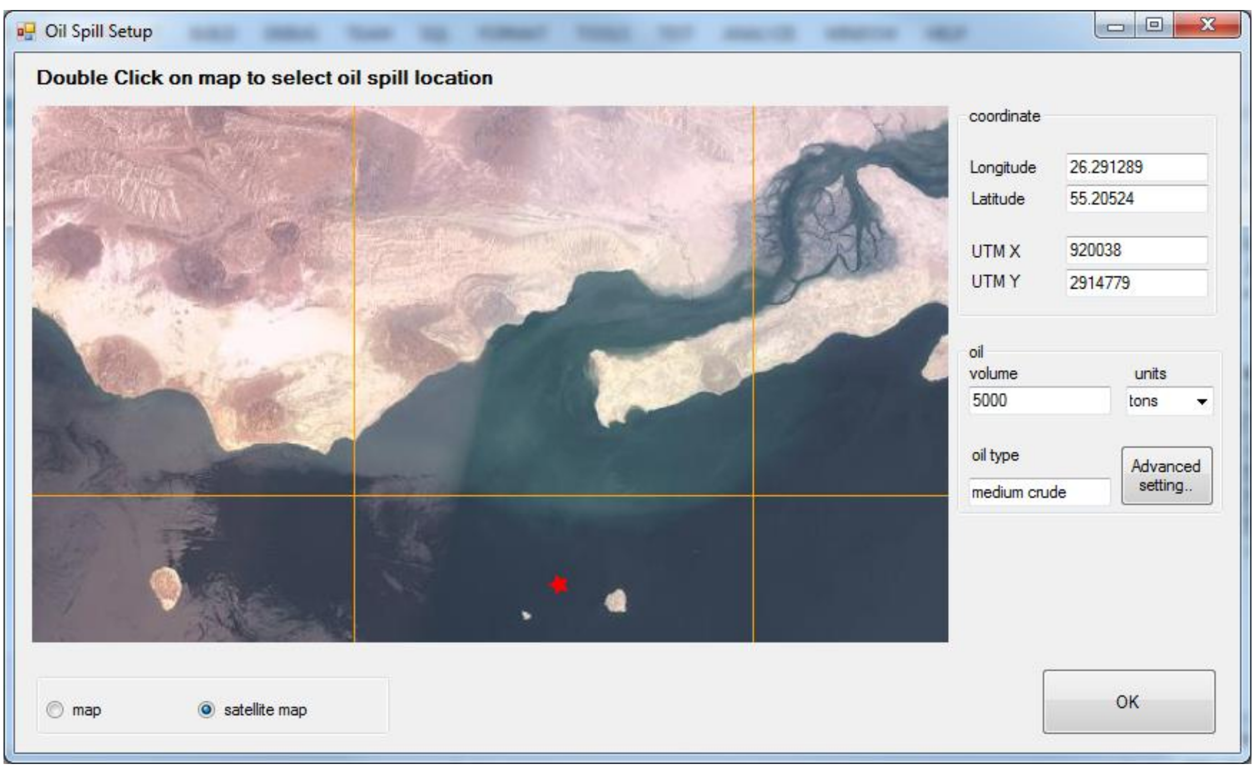

Figure 4 Detailed view of oil spill location using satellite background map

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The most important part of the user interface is the third, main window with an interactive map showing coastline sensitivity together with the oil spill affected areas. Selecting a coastline segment displays a warning window with detailed information about the ESI value, ESI description, and recommended oil spill combat strategies (Figure 5).

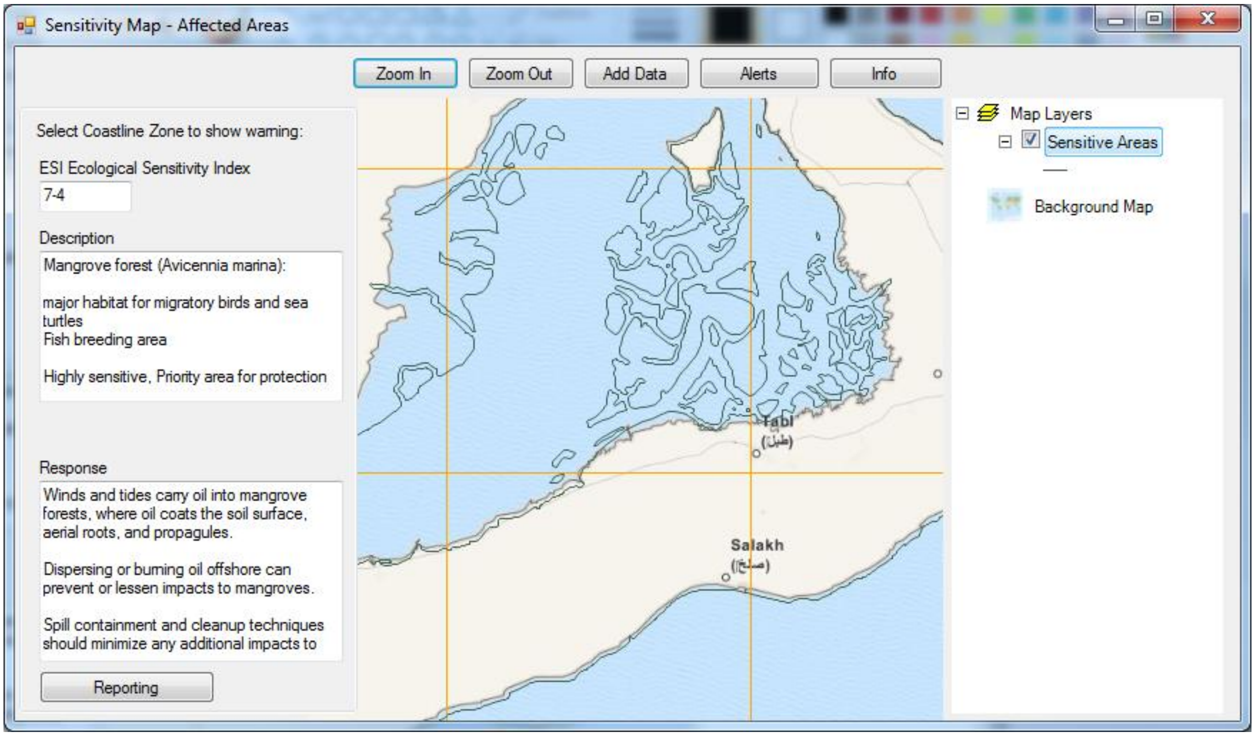

Figure 5 Sensitivity and ESI map with the warning box

Discussion

In our design we have followed guidelines of Fabbri (1998), Pourvakshouri and Mansor (2009), Assilzadeh and Gao (2010) and Jolma et al (2014). Several challenges were encountered in the design and development process. The first challenge was developing a high quality data base with information about ecological sensitivity, bathymetry, wind, wave and tidal conditions. Some of these datasets had to be newly created, for example the wind characteristics by aggregating ECMWF meteorological model wind hindcasts.

The second challenge was developing the simulation model. Many of the model output data files were not in a standard format and their use in the DSS required a customized file conversion procedure. Similar to Jolma et al (2014), our DSS depends on a third-party oil spill simulation model. The advantage or our DSS design is the connection with an open source oil spill model (GNOME) which allows the whole system to be re-distributed under an open source license.

Conclusion

We have designed a prototype decision support system for oil spill management in the Persian Gulf. We expect this system to be primarily used by experts for contingency planning, placement of emergency response facilities, and protection of the coastal zone. More usability testing will be necessary to make the system fully operational, user-friendly, and suitable for the needs of coastal zone managers. For future work, we recommend developing a web-based system and a mobile version of the dss for easier use in real time in the area.

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