Online Knowledge Based Wind Assessment Tool

Capatina Octavian
Senior research renewable department
IPA Cluj Napoca Subsidiary
Cluj Napoca, Romania

Letia Ioan
Prof. dr. eng. Knowledge and AI department
UTCN, Computer&Automation Fac.
Cluj Napoca, Romania
letia@cs.utcluj ro

***Abstract* - The main problems of current site prospecting techniques as they occur in real scenarios is referring the disadvantages of the mesoscale mathematical model, based on which the wind assessment uncertainties are appreciated around 30%, just by the wind analyst [1]. Once we propose to change the running mathematical models for wind potential estimation with a hybrid method based on expert rules and objective facts provided by the interested users as direct observations. For the renewable energy domain this concept is relatively new in academic literature and not used in applicative research yet. The rules are extracted from experts and good practices reports, whilst the inference engine is fed with human observations regarding temperature, altitude, pressure, obstacles, distances, position, asymmetry degree of the vegetation, etc. Part of them will be pre-processed with metric relations for checking them against the rules premises. Secondly the knowledge based system will run online, being accessible by the interested users all over the world.**

Keywords - Knowledge, AI, wind assessment

I. INTRODUCTION

The traditional wind assessment process needs to be complemented with advanced approaches for site prospecting [2], measurement campaign, microscale horizontal / vertical extrapolation [3] and other innovative methods that are found available [4], [5]. In the list of research priorities of the state-of-the art of wind resource assessment (WRA) the highest percentage has been attributed to the development of remote sensing instruments (13%) and to the validation of wind resource assessment models in complex terrain (13%) [1]. Online knowledge based wind assessment tool, OKA, has the goal of providing a support system on the web for stakeholders to use in their WRA towards their end of making decisions [6], [7]. The collaborative governance for sustainable development badly needs a better accuracy of WRA, as recent studies have shown underestimation of wind resources provided by national surveys and overestimation in micro-sitting assessment [8]. Trying to improve on existing systems, we aim to achieve a hybrid knowledge decision support system able to exploit various kinds of data / information available: measurements, maps, metric relations, streams. The challenge consists in finding a reasonable architecture that can produce results at several levels of understanding of the problems the user is facing. We intend to build on our experience of different knowledge-based systems, covering fuzzy rules, fuzzy ontology's, stream reasoning, argumentation, justification. Given the complexity of such a system we have to go into a deeper level of analysis for the model needed. Although there are many systems for WRA, to the best of our knowledge, they do not try to combine human and mathematical / logical knowledge

OKA responds to the current need at European level to determine where a wind-based capacity can be built more cost-effectively. The task is achieved by developing an on-line decision support system for wind assessment, freely available for potential users. From the economic viewpoint, the system facilitates the entrance of individuals and small enterprises in the wind market, by speeding-up the initialization of a wind business project. From the technical perspective, it integrates heterogeneous knowledge, both digital and human. The strong point here relies on the combination of observation from the field with digital knowledge.

II. INPUTS AND OUTPUTS OF THE KNOWLEDGE BASED SYSTEM

To give an overall idea, we decide to describe the input and output of the system from the very beginning.

The requested *input* consists of: i) geographic coordinates, ii) valuable local data for a specific location in terms of human local observations (vegetation orientation, vegetation asymmetry, relief elements), iii) meteorological data and wind measured data - if exist, iv) data from wind related GIS maps or other form of wind description like probability distribution; v) technical constraints (the height of the turbine); vi) additional knowledge (known legal constraints), preferences (in terms of the types of data the system will use for assessment).

The *output* consists of a report that details the assessment of the requested location, justifies the uncertainties of the evaluation, and provides professional recommendations. The report provides users with the information necessary to make an informed investments decision or to plan a wind project. When generating recommendations, legal, infrastructure, or financial issues are considered. Thus the system is not limited to technical constraints, but aims to integrate the decision into a larger socio-economic context. The professional recommendation includes a cost estimate, a list of available incentives, or it outlines the next steps one needs to take or to enact a wind project. The report can serve as an effective tool for business entities, municipalities, or home owners who are considering wind energy when presenting options to decision makers such as a board of directors, budget committee, or credit officers. OKA will try to make a step forward of multi-criteria decision-making [6], [7] by exploiting also human local knowledge in the process.

III. THE TARGET AND OBJECTIVES OF THE KNOWLEDGE BASED SYSTEM

The proposed hybrid model – containing both knowledge form site observations and measured data – would be able to identify and assess the areas with high eolian potential. The approach allows avoiding some expensive measurements which in many complex terrain sites cannot be a reliable basis for correct assessments. The bulk of knowledge will be encapsulated as fuzzy rules.

The OKA targets all types of potential beneficiaries:

a) Small investors in eolian energy: usually they are interested to evaluate the isolated location for cottages, small farms, small irrigation capabilities, isolated surveillance systems, or radio, TV or GSM transmission stations. In most of these situations the consultancy costs can be prohibitive compared to the total investment.

b) Large capital investors: a large number of locations must be investigated for identifying those places where the wind potential can be exploited with sure benefits. Thus, a lot of money lost in many assessments and are peculated from the principal aims - set up wind parks.

c) The output of the system can be used by architects when designing residential area or industrial facilities and also to researcher from related domains as environment protection, meteorological or biodiversity.

d) In particular cases, such an evaluation can be used by the officer for credit approval as over check.

OKA proposes a decision support system for quick access of the potential investors to the evaluation of the wind potential in a particular area. The knowledge based system will run online, being accessible public and democratically without costs. Thus the first stage of informative evaluations or the so called wind assessment-site prospecting will be completely free. Based on it, in the micro sitting phase can be better planned. In this phase the wind evaluation is made based on standardized wind measurements, for at least one year, in order to be accepted by a bank as a certified assessment in case of credit approval. The main originality comes from the fact the system does not exploit satellite based data as the main input, but rule-based reasoning on common human observations from the current location.

IV. THE OKA STRUCTURE

The OKA project advances state of the art of the existing wind potential evaluation tools by stating two main applicative objectives, depicted in figure 1. The first objective aims at developing a new model for site prospecting based on a hybrid knowledge and data method. The new model provides a better assessment comparing to the current mesoscale-based model of 30% [1].

The output of this project consists in a knowledge based decision support system for eolian potential assessment. The system will run online, being accessible free for any potential investor or researcher in the renewable energy domain. The decision will be supported by the following capabilities:

1. computing the site prospective and the certainty factor of the assessment;

2. reasoning on heterogeneous data, collected statically and dynamically as continuous data streams

3. identifying the type and the amount of supplementary data needed to increase the certainty up to a specified threshold;

4. identifying discrepancies between expert knowledge and different assessments computed based on the current available measurements and local observation;

5. determine if a location is economically feasible and technically viable;

6. advising the user regarding the adequate class of turbine for a particular site, according to current standards (such as the IEC 61400-1 one);

7. designing the layout of the wind farm considering local topology and constraints;

8. providing detailed justifications of the premises on which the assessment and certainty was built.

At runtime, the system collects data and observations from the interested users by asking relevant questions. It also estimates how the certainty factor increases if a specific piece of knowledge would be provided. The input data includes by default a set of meteo and geographic measurements, which are used to tune the system and to predict the potential for a location. The system expects more local data and knowledge from the interested user, based on which more accurate prediction is provided. The main output from the fuzzy expert system is a map prediction on wind potential showing feature favorability after combining the effects of all of the input data.

The outcome can be synthesized as:

i) Holistic assessment of a point in a region that allows ranking of prospects and resource planning;

ii) Improving efficiency of development spending, increasing chances for credit approval, superior return of investments;

iii) Legal and economic support for securing investment decision.

The output includes the binomial (assessment - certainty factor), statements and associated justifications. Statements are of the form (data, inconsistencies) or (data, insufficient data for certainty above 85%), helping the user to identify the type or amount of data needed to increase the certainty factor. The wind potential will be assess for a specified height, and a corresponding turbine (wind potential insignificant/small/medium/high/very high, height, turbine type, certainty factor).

The technical instrumentation used as a starting point is given within the framework of aggregating continuous and heterogeneous data sources (stream reasoning) with uncertainties regarding available knowledge (fuzzy logic), and data inconsistencies (argumentation theory). The domain knowledge will be encapsulated as ontology's, whilst expert knowledge as fuzzy rules. Neuro-symbolic integration is the starting conceptual instrumentation that will be explored in order the aggregate expert knowledge with measured data.

When computing the certainty factor, both the uncertainty and fuzziness of the input data and the uncertainties occurring in the reasoning step should be taken into consideration [9], [10], [11], [12], [13]. If a site is economically feasible depends on the local legislation and how the difficulties and constraints imposed by the law affect the feasibility of a project. By integrating different knowledge sources (including legal knowledge bases), the wind analyst expert system will be able to address this subject too. Similar to [14] guidelines can be developed to minimize environment impact. Depending on the type of the turbine identified as adequate based don local constraints, factors such as the extent to which it can be dominant, co-dominant, or subdominant in the landscape, or color, scale, and illumination can be analyzed.

Fuzzy rules. We use fuzzy rules on top of domain knowledge bases formalized with fuzzy description logic to aggregate relevant maps. The technique relies on dataming to identify potential clusters and derive fuzzy rules and expert knowledge to compute weights for ranking the relative importance of the variables of the domain. The fuzzy system is composed of several layers, encapsulating different types of fuzzy rules, like:

- Wind turbines are efficient in coast, hills, and mountains regions.
- The wind speed increases proportional with the power of 1/7 of the altitude.
- Theoretically, wind turbines can extracts up to 59% from the energy which passes through it. Practically, an efficient turbine extracts around 40% from the wind potential.
- A wind farm is more effective compared with several isolated turbines of the same power capacity.
- How much are the asymmetry of the trees as much the wind blows
- Minimum distance between a turbine an a residential area should be 300m.
- A turbine should be 12m higher then any obstacle within a range of 300m.
- Backwater effect leads to a decreasing power of a wind park with approximately 15%.
- If the terrain is flat for at least 500m and there are not obstacles, the metric relations for estimating the wind speed as a function of height can be used.

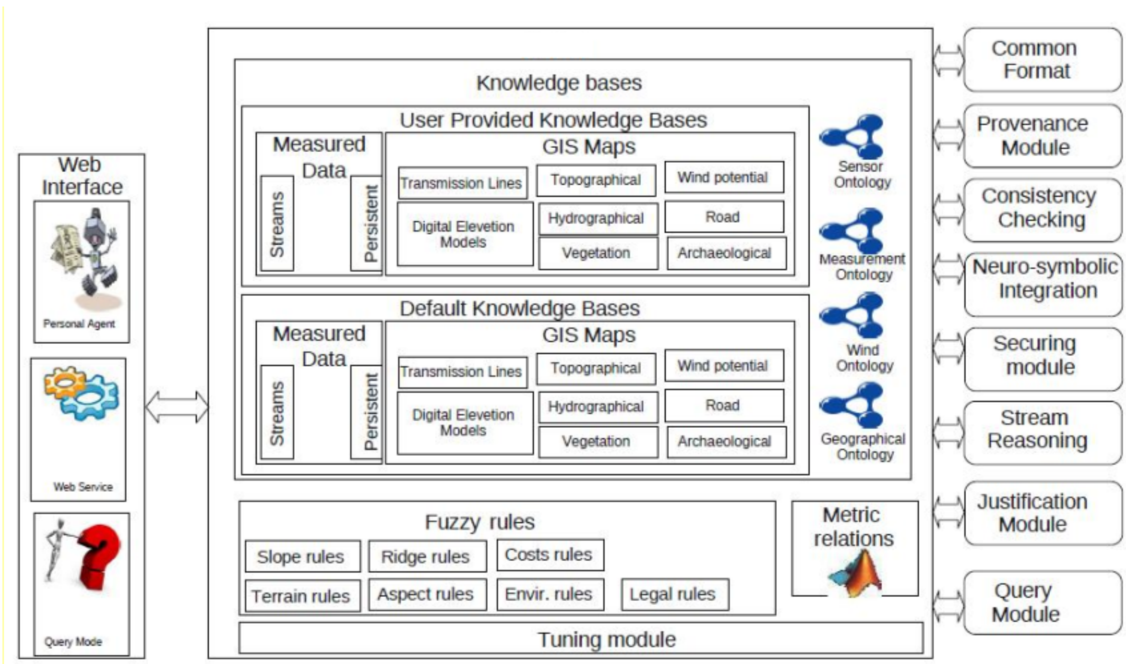

Figure 1. The Online knowledge based wind assessment tool structure

Metric relations. Several formulas can be used to approximate or extrapolate the available data. For instance, if the location is at 1000m high one can calculate the decreasing of air density rate and the decreasing rate of wind power. The metric relations are used to approximate the wind data which depends on other terrain constraints, so like obstacle dimension and topology at the desired altitude. In a common situation, if data measurement was performed for 50 m high, and the terrain constraints asked the installation of the turbine at 70 meters, these relations are used to assess the wind potential at a different height. Several metric relations are:

1. The cost of a watt installed off-shore is with 50% higher than one obtained from the coast.

2. The wind power depends on the air density, turbine size and wind speed, given by:

$$Pwind=0,5*\rho_{aer}*S*v \, , \quad (1)$$

Where:

Pwind - the wind power passing through the area *S* [kW],

ρ_{aer} – the air density [kg/m^3],

S - the area covered by the screw of the turbine [m^2],

V - the wind speed [m/s].

3. The power law encapsulates how the wind speed varies with the height, given by:

$$V(h)=V(h_{mas})*(h/h_{mas})^{\alpha} \quad (2)$$

Where:

V(h) - the wind speed at the height *h,* [m],

h_{mas} - the measurement height. [m].

α is 1/7.

4. The logarithmic law assesses the wind speed variation based on the existing obstacles at the ground:

$$V(h)=V(h_{mas})*ln(h/h_{obst})/ln(h_{mas}/h_{obst}) \quad (3)$$

Where:

V(h) - the wind speed at the height *h* agl [m/s],

h_{mas} - the measurement height agl [m],

h_{obst} - the equivalent height of obstacle [m].

5. The temperature depends on the altitude as following:

$$T= T0 – L*(alt+10) \quad (4)$$

Where:

T is the temperature at 10m agl [°K],

T0 – is the temperature at 0m altitude [°K],

L – the a constant 0.0065 [°K/m].

6. The pressure varies with the altitude as:

$$P=P0* (1-L*h/T0) \, g*M/R*L \quad (6).$$

And so on.

V. Conclusion

Such ONLINE tool based on knowledge and data could be and effective tool for everybody from everywhere for the first wind resources assessment.

References

[1] J S Rodrigo, State of the Art of Wind Resource Assessment, WAUDIT, CENER, 2010.

[2] J M L M Palma, F A Castro, L F Ribeiro, A H Rodrigues, A P Pinto, Linear and Nonlinear Models in Wind Resource Assessment and Wind Turbine Micro-siting in Complex Terrain, *Journal of Wind Engineering and Industrial Aerodynamics*, 96 (2008), 2308-2326.

[3] *K W Ayotte,* Computational Modelling for Wind Energy Assessment, *Journal of Wind Engineering and Industrial Aerodynamics*, 96 (2008), 1571-1590.

[4] O. Capatina, T. Grosan, R. Trimbitas, Wind Potential determination in a known area, Proceedings of 2008 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR 2008), 22-25 May 2008, Vol. 3, pp. 296-299.

[5] R. Trimbitas, T. Grosan, O. Capatina, Mathematical Tools for Wind ssessment, nnals of the Tiberiu Popoviciu Seminar of Functional Equations, Approximation and Convexity, ISSN 1584-4536, vol. 8, 2010, pp. 193-205.

[6] A H I Lee, H H Chen, HY Kang, Multi-criteria Decision Making ob Strategic Selection of Wind Farms, *Renewable Energy*, 34 (2009), 120-126.

[7] J R San Cristobal, Multi-criteria Decision-making in the Selection of a renewable Energy Project in Spain: The Vikor Model, Renewable Energy, 36 (20011), 498-502.

[8] D N Mah, P Hills – "Collaborative Governance for Sustainable Development: Wind Resource Assessment in Xinjiang and Guangdong Provinces, China", *Sustainable Development*, 2011, to appear.

[9] I. A. Letia, A Groza - Argumentative Agents Within a Fuzzy Description Logic Framework, 7th International Workshop, ArgMAS 2010, Toronto, Canada, May 10, 2010, Revised Selected and Invited Papers, McBurney, P. Rahwan, I. Parsons, S.(Eds.), LNAI 6614, 2011.

[10] I.A. Letia, A. Groza - "Arguing with Justifications Between Collaborating Agents" ArgMAS, Taipei, Taiwan, May, 2011 (to appear in LNAI, Springer).

[11] I.A. Letia, A. Groza - „Description Plausible Logic Programs for Stream Reasoning", submitted at 32nd Real Time Systems Symposium, Vienna, Austria, December, 2011.

[12] I A Letia, O Pop - Simplifying Ontologies for Smoother Interaction in Heterogeneous Environments, International Workshop on WEB Intelligence & Communities, Lyon, France, 2011.

[13] I. A. Letia, A. Groza, Modelling Imprecise Arguments in Description Logic, *Advances in Electrical and Computer Engineering*, ISSN 1582-7445, vol. 9, no. 3, pp. 94-99, 2009

[14] D.R. Miller, S. Bell, M. McKeen, P.L. Horne, J.G. Morrice and D. Donnelly – Assessment of Landscape Sensitivity to Wind Turbine Development in Highland, Technical Report, Macaulay Land Research Instit ute, 2010