Pattern Theory in Intelligence Analysis

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***Abstract*—Patterns are present everywhere in the world. Some exampels of where patterns can be found are in weather, traffic, social behaviour, music and text. The ability to recognize and understand these patterns is crucial for our ability to interpret the world around us. Thus, there are many research directions concerned with pattern analysis. In this paper we describe Pattern Theory, as formalized by Grenander, and we explain why the framework of Pattern Theory is well suited for use in information processing in intelligence applications.**

I. Pattern Theory

Pattern Theory as a research discipline was founded in the late 1960s by professor Ulf Grenander and has since been further developed by Grenander and the Pattern Theory group at Brown University [1], [2], [3]. Pattern Theory differs from related fields in that the emphasis is on exploration of the inherent structure of (real-world) patterns. More specifically, the approach is based on characterization of patterns in terms of statistical parameters. Some of the basic ideas of Pattern Theory are summarized below:

1) Mathematical models should be learned from real data and validated by sampling.
2) In order to handle variations and noise in observations of the real world, models must be partly stochastic.
3) One should always look for hidden variables and alternative encodings, in terms of which the patterns are more clearly described.
4) Patterns are subject to deformations of the following types: noise and blur, multi-scale superposition, domain warping, interruptions.
5) Models should be possible to use for pattern synthesis as well as analysis.

II. Pattern Theory and Intelligence analysis

Strictly speaking Pattern Theory is not an independent research discipline, it could better be described as a conceptual framework that links together a variety of methods and techniques for stochastic data analysis. We argue that there are several good reasons to incorporate the framework of Pattern Theory in research on data fusion and intelligence analysis:

- The philosophy of Pattern Theory allows for complex data types, such as ”situations”, to be treated in analogy with simple data types such as integers or text strings.
- Methods aim at exploring inherent structure in patterns and are thereby able to generate significant input to the intelligence analysis process.
- The statistical approach is well suited for dealing with real world data.
- Methods are compatible with graphical probabilistic modelling.

III. Applications and future work

An intelligence related application for Pattern Theory is characterization of patterns in time series data, for instance in streams of short messages such as traffic updates or police reports. The data that can be extracted from such messages is generally hetrogeneous (text, numbers, etc.) and subject to various ”deformations”. Thus, it is suitable to handle data in analogy with the pattern theory framework.

Some areas for future work are pointed out by the following questions:

- Could the combination of statistical methods from Pattern Theory and machine learning be successful when it is not known what types of patterns that are present in a data set?
- Could Minimum Description Length [5] theory help prevent overfitting when learning models from data?
- Could semantic tagging be a step towards a more uniform handling of data on different formats?
- How should dependence between continuous and discrete variables be handled? Is it necessary to discretize continuous variables or could there be more clever ways of dealing with the problem?
- Can random sets [4] be used as a general framework for working on Pattern Theory for complex data such as situations?

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