Chapter 19

A New Fuzzy Rule Interpolation Approach to Terrorism Risk Assessment

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ABSTRACT

Terrorist attacks launched by extremist groups or individuals have caused catastrophic consequences worldwide. Terrorism risk assessment therefore plays a crucial role in national and international security. Fuzzy reasoning based terrorism risk assessment systems offer a significant potential of providing decision support in combating terrorism, where highly complex situations may be involved. Nevertheless, little has been done in developing and applying an integrated hierarchical bidirectional (forward/backward) fuzzy rule interpolation mechanism that is tailored to suit decision support for terrorism risk assessment. This paper presents such an integrated approach that is capable of dealing with dynamic and insufficient information in the risk assessing process. In particular, the hierarchical system implementing the proposed techniques can predict the likelihood of terrorism attacks on different segments of focused attention. The results of an experimental investigation of this implemented system are represented, demonstrating the potential and efficacy of the proposed approach.

1. INTRODUCTION

Terrorism and especially suicide terrorist campaigns are now being focused on more and more by governments, the media and general public. It is imperative to have a comprehensive security risk management program including effective risk assessment and appropriate decision support. Terrorism risk assessment (TRA) therefore plays a crucial role in national and international security. In order to predict terrorist
behaviors from a given set of evidence (including hypothesized), it is often necessary for investigators to
reconstruct the possible scenarios that may have taken place. The difficulty of such constructed assess-
ments lies with the inherent complexity and uncertainty of the underlying problem domain, which may
be too challenging to directly comprehend (Ezell et al., 2010). Fuzzy reasoning-based systems (Darby,
2006), (Inyaem et al., 2010) can be beneficial in dealing with the shortage of knowledge or information,
especially when concepts such as the “likelihood” of terrorist attacks become expressions involving
uncertain qualitative values.

In the literature, a number of fuzzy reasoning-based TRA systems have been developed in an effort
to assist the task of combating terrorism, including (Akgun et al., 2010), (Bowles et al., 1995), (Darby,
2006), (Inyaem et al., 2010), (Shen et al., 2006). A fuzzy decision-making support system may generate
plausible scenarios so that investigators can analyze them hypothetically as well as objectively (Shen
et al., 2006). Fuzzy inference systems have also been used to classify terrorism events (Inyaem et al.,
2010), (Jiang et al., 2016). In addition, a fuzzy belief/plausibility measure has been proposed (Darby,
2006) to capture the uncertainty of evaluating the risks of intentional terrorist acts, and a fuzzy ontology
construction methodology regarding terrorism events is proposed in (Inyaem et al., 2010). Approaches
that evaluate the terrorist scenarios using approximate reasoning have also been implemented in terms
of linguistic beliefs (Bowles et al., 1995).

The use of the aforementioned fuzzy reasoning-based TRA systems has revealed two major chal-
lenges: high-dimensionality (Wang, 2014), and sparse rule base problems (John Garrick et al., 2004).
To model a fuzzy system with $K$ variables and $M$ fuzzy sets in each dimension, the number of necessary
rules $|R|$ that are required to fully cover a given domain is

$$|R| = M^K$$  \hspace{1cm} (1)

The amount of data required to generate such a rule base increases exponentially with the number of
input variables. This problem of rules explosion (often referred to the “curse of dimensionality” in ma-
chine learning (Fan, 2015), (Song et al., 1993), reduces the transparency and interpretability of the re-
sultant fuzzy systems, whilst increasing significant computational complexity. Thus, it is essential to
reduce either $K$ or $M$, or both. A hierarchical fuzzy system (HFS) (Raju et al., 1991), (Anitha et al.,
2010) is often effective in reducing $K$. It consists of a number of hierarchically connected, low dimen-
sional fuzzy sub-systems, so that the number of rules in the system may appropriately increase only
linearly with the number of input variables.

Reducing the number of fuzzy terms $K$ of each variable may result in a sparse fuzzy rule base. Besides,
for terrorism problem, there may not be sufficient historical data to support the creation of the needed
rules that would cover the entire problem space. Unfortunately, if a given observation has no overlap
with antecedent values, no rule can be invoked in classical fuzzy inference, and no consequence can be
derived. Fuzzy rule interpolation (FRI) was originally proposed in (Koczy & Hirota, 1993a), (Koczy &
Hirota, 1993b) to deal with reasoning problem in the presence of such insufficient knowledge (sparse
rule bases). In hierarchical systems, situations may become even more complicated where certain crucial
antecedents may be absent from given observations. This is because such missing antecedents may be
involved in the subsequent (sub-system) inference process, causing the final conclusion cannot be de-
duced. To address the underlying problem of performing interpolation for certain antecedent variables,
an initial technique for backward fuzzy rule interpolation (BFRI) (Jin et al., 2014) has been proposed.
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