REPRESENTING VISUAL CONDITIONS IN A LEGAL KNOWLEDGE BASED SYSTEM

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ABSTRACT.

Legal KBSs are based on knowledge contained in legal texts such as legislation, regulations and case histories and the practice of domain experts charged with operationalising this legislation. Legal texts and their operationalisation can be analysed using textual analysis tools which lead to the production of a rule base which can be manipulated to establish a desired goal. In this paper we describe an approach to the development of legal KBSs where the legal texts include visual conditions which do not lend themselves to simple interpretation using textual analysis tools. The approach focuses on the use of preprocessors to generate descriptors derived from the geometrical interpretation of the visual data in question. These descriptors can then be used as direct input to a KBS without the need to include complex mathematics, to which KBS representations are not well suited, within individual rules. The approach was developed as part of a much larger project concerned with the production of a legal KBS to advise the navigators of ocean going vessels on how best to avoid collision with other vessels as prescribed by international maritime law. A fragment of the legislation on which this KBS is based is used as an example.

1. INTRODUCTION

The knowledge used by Knowledge Based Systems (KBSs) operating in legal domains is usually represented in the form of production rules, predicate logic or objects in a object hierarchy. Whatever the case the knowledge is first elicited and then analysed using some predefined methodology, usually supported by appropriate software tools. The aim is to produce a knowledge base which can be manipulated to solve problems. In the case of legal KBSs the problem addressed is usually of an advisory nature, "Is this person eligible for social security benefits" or "Is there any precedent to show that ... ". Notable examples of such systems in current use include the Retirement Pension Forecast and Advice System (RPFA) (Spirgel-Sinclair and Trevena 1988) and the VATIA system (Susskind and Tindall 1988). The raw knowledge on which these systems rest generally consists of legal texts, either legislation such as Acts of Parliament and associated regulations, or typescripts of case histories. Pieces of legislation are highly structured: because they are usually divided into parts, sections and paragraphs they readily lend themselves to hierarchical analysis using textual analysis tools and conversion into a suitable formalism (Routen and Bench-Capon 1991). Case histories can then be used to refine open-textured terms contained within the acts. We can also look to the *obiter dicta* of judges in individual cases, and the considered opinion of domain experts.

Thus legal KBSs can be described as KBSs whose "knowledge" has been gleaned from highly structured acts of Parliament, supported by secondary legislation, case law and *obiter dicta* which can be analysed using textual analysis tools. But is this always the case? The answer is not when the system needs to operationalise the terms used so as to take account of different ways in which the conditions may be detected.

We will illustrate this claim by considering an example taken from the international legislation governing collision avoidance between ocean going vessels. The practice of collision avoidance at sea is based on the International Regulations for Preventing Collisions at Sea (1972) as amended in 1989. These Regulations define a number of situations where, if risk of collision exists, a vessel is obliged to take suitable avoiding action. For example Rule 14(a) of the Collision Regulations States that:

> *When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the the other.*

Rule 14(b) then goes on to define the phrase "meeting on reciprocal or nearly reciprocal courses" thus:

> *Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night could see the masthead lights of the other in a line or nearly in a line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.*

Inspection of this second rule immediately reveals that it is intended to be operationalised by human beings who have the gift of sight, i.e. it contains visual elements which do not correspond to the operationalisations appropriate to other means of detecting this situation. In practice the situation is usually detected using equipment more sophisticated than a pair of binoculars: thus we need to operationalise the definitions in terms appropriate to observing a radar screen. In addition, since we wish to pass the data into a KBS, we need to further operationalise the definitions so that their satisfaction can be calculated automatically; this requires that we operationalise in the form of algorithms that can be applied to the raw data received by our sensing equipment. We thus have three operationalisations, for a human with binoculars, for a human with a radar screen and for a computer. All of these, however, relate to the same situations, and they need to be described in terms neutral between these operationalisations.

We will describe how the information in the legislation and its operationalisation can be analysed and incorporated into a KBS by considering the approach taken in the development of a navigational KBS designed to advise the navigators on board sea going vessels on how best to avoid collision with other vessels (Smeaton and Coenen 1990, Coenen and Smeaton 1990, Coenen and Smeaton 1991).

2. APPLICATION AND OPERATIONALISATION OF LEGISLATION

The concept of operationalisation espoused here is based on earlier work on how legislation can be made operational and applied, a general discussion of which can be found in Bench-Capon (1991). A brief summary of this work is therefore appropriate here.

All legislation is founded on some primary legislation wherein the intentions of government, concerning some domain, are realised. In the case of collision avoidance at sea this is the Merchant Shipping Act, 1984, which is referred to as the principal Act. As well as laying down the broad lines of the intended law, primary legislation typically contains also a number of enabling provisions, which allow secondary legislation, such as regulations, to be made expanding and clarifying some of the primary provisions. The primary legislation will normally be couched in very general terms: for a number of practical reasons, it is more convenient for the legislator to express detailed provisions in regulations. We can thus see the secondary legislation as clarifying the intent of the primary legislation.

In the domain under consideration here the Merchant Shipping Act (with respect to collision avoidance) is clarified by The Regulations For Preventing Collision At Sea 1972.

Both the initial legislation and supporting regulations are clarified further by the interpretation of the provisions in decisions on particular cases. This case law is often used to refine open textured terms; for example the terms "if the circumstances of the case admit", "all available means appropriate" and "safe and practicable" which appear in the Collision Avoidance Regulations, have their extension fixed not by legislation, but by subsequent interpretation in the light of the circumstances of particular cases.

The initial legislation, regulations and supporting case law are then operationalised by adjudicators. These will be specialists in the domain who will display a certain amount of skill in interpretation, involving both a knowledge of the law and of relevant past decisions as well as an understanding of English and a certain amount of common sense. Effectively these specialists will make their knowledge operational by mapping it onto the facts that are available to them, or which they can directly observe. This will enable them to evaluate particular cases. The important point here is that, where as the legislation, regulations and supporting case law may be expressed in terms of non-observable or unavailable facts and concepts, all facts and concepts used in the operational definition can be directly determined by the domain specialist. Different experts will operationalise in different ways, in terms of what facts are available to them, or so as to optimise their decision making. This means that different specialists may regard different facts as relevant and perhaps, in certain cases, may draw different conclusions.

In some cases these operational definitions have been codified through procedures, guides and manuals issued by international or national governing bodies or by individual organisations responsible for applying aspects of legislation. In the case of the collision avoidance regulations we can refer to the Bridge Procedures Guide (1990), published by the International Chamber of Shipping, which gives guidance for watch keeping procedures and use of radar etc.

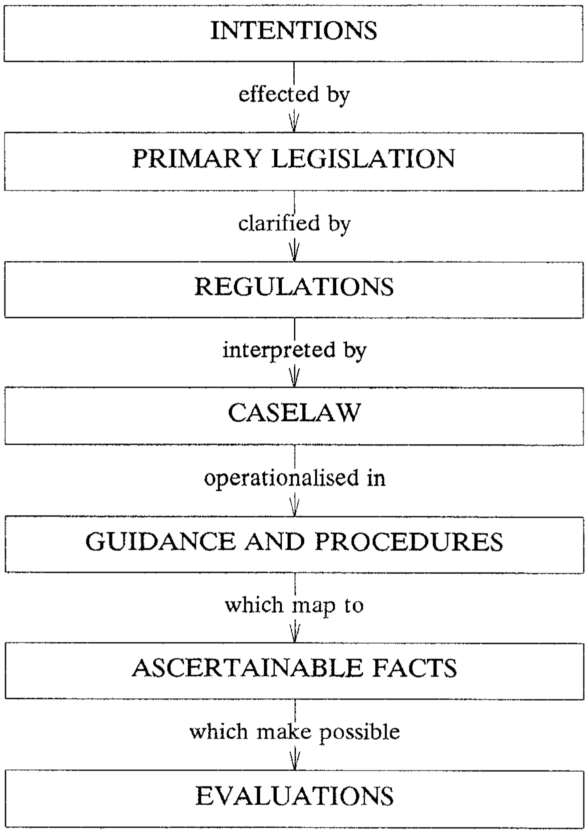

Figure 1: *Levels of knowledge in the application of the law*

Legislation can thus be characterised as consisting of a number of levels as outlined above (Figure 1). Legal KBSs can operate at any one of these levels or across several levels. For example the knowledge represented in the British Nationality Act system of Sergot et al. (1986) is drawn almost exclusively from the legislation level, whereas that represented in the Latent Damage Advisor of Capper and Susskind (1988) is to be found at the level of operationalisation, that of mapping facts onto cases. The Collision Avoidance System referred to here draws on both the regulation, operationalisation and mapping facts onto cases levels.

3. OVERVIEW OF THE MARINE NAVIGATION KBS

The navigational KBS referred to here is designed to be fitted on the navigational bridges of ocean going vessels so as to provide the "on-watch" navigator with continuous real-time status reports and advice on how best to avoid collision with other vessels (and land based objects). The aim is to address the problems associated with information overload that navigators can often experience. This overload has been an indirect result of advances in navigational technology, especially radar, position fixing and maritime communication technologies. This in turn has led to an exponential increase in the amount of information available to navigators, which in turn has resulted in navigators not being able to assimilate all this information, sometimes with disastrous results; witness the Exxon Valdez disaster in Prince William Sound in 1989.

The system is currently in demonstrator form only, but it is designed to be "hard wired" into existing modern radar equipment. Research is progressing to this end with the inclusion of electronic charting facilities (see Smeaton et al. 1992). The system has been extensively tested using the ship simulator available at the Liverpool John Moores University using domain experts. To date the results have proved to be very encouraging.

4. TRADITIONAL DEVELOPMENT USING TEXTUAL ANALYSIS TOOLS

Typically a legal text such as the Collision Avoidance Regulations would be analysed using some textual analysis tool. For example KANT (Storrs and Burton 1989) as built into the MAUDE development environment (Coenen and Bench-Capon 1992) or PED which forms part of the KADS methodology (Wielinga *et al.* 1986). Typically the first step in the Knowledge analysis is to establish the ontology of the domain from a problem oriented perspective. Thus we might identify the relevant entities in the text by examining nouns and then consider the tests that can be implemented on those entities. We can then identify Entity Attribute Value triples by inspection of these tests on entities (and reference back to the source) and construct an object base or class hierarchy to determine the vocabulary of the intended system. The final phase might then be to produce a rule-base using the vocabulary defined in the object base. This is the methodology described in Bench-Capon and Coenen (1992).

If we consider the two fragments of legislation given above we might end up with two rules of the form:

```
(ownship action starboardAlteration)
if
   (target movement reciprocalCourse)
and
   (riskOfCollision exists true)

(target movement is reciprocalCourse)
if
   ((target mastheadLights inLine)
   or
   (target mastheadLights nearlyInLine))
and
   (target sideLights bothVisible)
```

Textual development techniques have been shown to work well in the development of legal rule bases. However in the above case we are left with three questions which require an additional level of analysis:

- What do we mean by side lights both visible?
- What do we mean by masthead lights in line or nearly in line?
- And most importantly how do we define risk of collision?

These questions are all concerned with the specific operationalisation contained in the source which assumes interpretation by a sighted person, unaided by radar equipment and the like.

Considering the first of the above questions, initially, we need look no further than Rule 21(b) of the Collision Avoidance Regulations which states:

> *"Sidelights" means a green light on the starboard side and a red light on the port side each showing an unbroken light over an arc of the horizon of 112.5° and so fixed as to show a light from right ahead to 22.5° abaft the beam on either side. ...*

We can therefore use this technical specification for sidelights to operationalise the term "side lights both visible" in geometrical terms which lend themselves to use by a person interpreting the data on a radar screen. In fact interviews with domain experts (navigators on board merchant vessels calling at the port of Liverpool) quickly revealed that this is precisely what happens when merchant ships are navigating in fog. Observations are made using radar equipment and the course and speed calculated trigonometrically. Therefore information concerning the location of targets can be passed to the navigational KBS and the same calculations made.

Thus according to the above fragment of legislation a head on situation can only exist if the other vessel is on an exact reciprocal course and located precisely on ownship's projected course line. This is not a very practical definition given the real life motion of vessels at sea, but it does provide us with a starting point. To obtain a better definition we must look to the working practice of navigators and the associated case law. Interviews with the same domain experts also reveals that in practice a reciprocal course situation is considered to exist if the other vessel is (a) located on ownship's projected course line ± a number of degrees and (b) it is on a reciprocal course ± a number of degrees. This practice is supported by the associated case law (see Corbet 1986); from a number of key cases where a collision has resulted due to misinterpretation of the Regulations, the courts have attempted to define the arc of the horizon over which both side lights may be visible by considering the engineering specification for such lights as contained in Annex 1 of the Collision Avoidance Regulations, Section 9(a)(i) of which states that:

> *In the forward direction, side lights ... must show the minimum required intensity. The intensity must decrease to reach practical cut-off between 1 and 3 degrees outside the prescribed sector.*

Thus side lights may show up to 3° onto the opposite side of the vessel, and therefore may be both be visible over an arc of the horizon of 6° (Figure 2).

A similar process can be used to derive a definition for the term "mast head lights in a line or nearly in a line".

As a result we can define the head-on situation in geometrical terms, i.e. for two power driven-vessels to be meeting "head-on" the other vessel's course must be within ±3° off the reciprocal of ownships course and located ±3° off ownship's project course line. We can thus produce an operationalisation which conforms to working practices and the supporting case law, and takes account of the sensing equipment available.

To determine what is defined as a collision situation the Regulations provide only simplistic guidance. In navigation the risk in a situation depends on many factors. Again interviews with domain experts soon establishes that the experts consider risk of collision to exist if a target's Closest Point of Approach (CPA) is less than a given distance. We are then left with the problem of quantifying this distance. It turns out that this can be done empirically and a distance function established (this is discussed further in Section 5 below).

From the above discussion it is apparent that we can operationalise the visual element of the original fragments of legislation using geometric definitions which in turn are based on the output from sophisticated maritime navigation equipment.

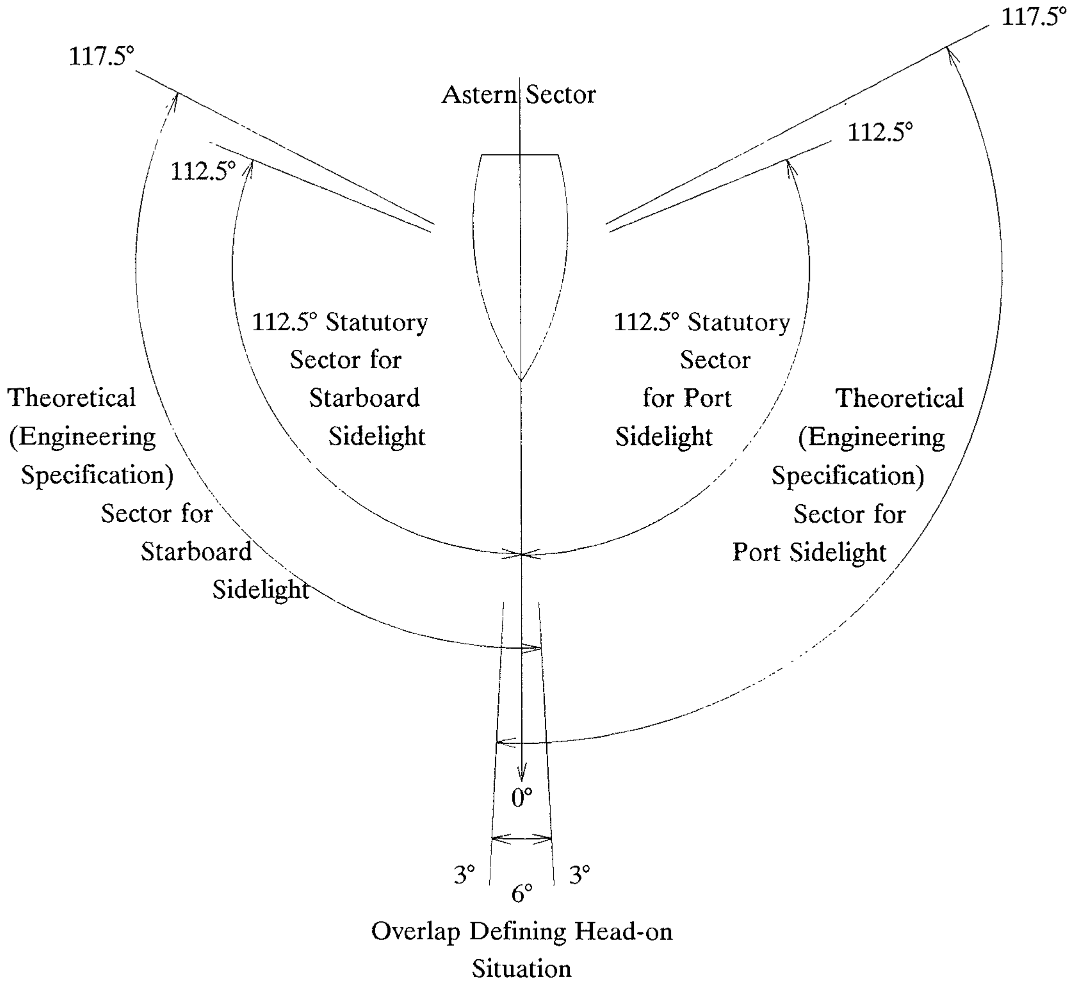

Figure 2: *Side light sectors*

Thus we can rewrite the second of the above rules thus:

```
(target inHeadOnSituation is true)
if
   (target bearing = ownshipCourse ±3°)
and
   (target course = ownshipCourse + 180°
                                   ±3°)
and
   (target cpa < (distance function))
```

This rule will clearly produce the desired result; the necessary parameters can be supplied by direct input via RS232 connections from a modern radar. However, there are a number of disadvantages associated with this rule:

1. The KBS has to include a target tracking component.
2. Dynamic trigonometric calculations need to be made to determine parameters such as target courses.
3. These calculations have to be made repeatedly on each cycle (every 20 seconds) and for each detected target (possibly as many as twenty).
4. Mathematical comparisons need to be made within the rules.

The above all led to the requirement to operationalise the terms in the form of mathematical algorithms if full advantage is to be taken of the computer system.

With these competing operationalisations, however, it is important that they do not become conflated and confused in the representation. We do not want to see rules containing a mixture of definitions appropriate to visual sighting, use of radar and mathematical algorithms. What we need is a much more sophisticated description of the domain, which will allow the rules to be couched in terms which are neutral between these various operationalisations. To this end the research team developed the concept of *descriptors* (Smeaton and Coenen 1991). These were defined as simple plain language phrases, largely drawn from the legislation itself, used to summarise the much more complex and specific operational concepts. A pre-processor was built to generate descriptors through a process of tracking and trigonometrical calculation. The generated descriptors could then be passed to the KBS in the form of input or raw data, thus dispensing with the need to include inefficient mathematical calculations and comparisons within rules. Further the use of descriptors lead to a much more elegant implementation.

The system used two principal types of descriptor, status descriptors and risk descriptors, stored in a number of *target frames*, one for each detected target.

5. STATUS DESCRIPTORS

To describe the movement of targets each is allocated two status descriptors, a primary status descriptor and a secondary status descriptor. The primary descriptor describes the general movement of targets and the secondary descriptor supplies more detail. The descriptors are instantiated with the result of tracking algorithms and trigonometric calculations. Together they described every conceivable "view" of a target without including any explicit mathematical data.

The Collision Avoidance Regulations actually identify three collision situations:

1. Head-on.
2. Overtaking.
3. Crossing.

each of which can be defined in terms of navigation light configurations as described above. However, to cover every conceivable view these definitions were extended to include non-encounter situations. Thus if we consider the reciprocal course collision situation detailed above this is described by two descriptors `reciprocalCourse` and `headOn`. The first is defined as a situation where the target's true course is equal to ownship's reciprocal course ±3°, the second where ownship is located ±3° on either side of ownship's project course line. However, the reciprocal course situation is also applicable where no risk of collision exists, thus a number of additional secondary descriptors were introduced to be used in association with the `reciprocalCourse` primary descriptor:

1. Starboard pass to indicate that a target is passing safely to starboard of ownship.
2. Port pass to indicate that a target is passing safely to port of ownship.
3. Clear to indicate that a target has safely passed (either to starboard or port) and is now "clear" of ownship.

In total ten primary descriptors and ten secondary descriptors were identified, according to the content of the Collision Avoidance Regulations and interviews with domain experts, out of which 36 possible combinations are physically realizable. These are listed in Table 1.

At first glance some of the secondary descriptors given in Table 1 may seem ambiguous, therefore some further explanation is appropriate. The `clear` secondary descriptor is used to describe the situation where a target has passed its CPA. The `head-on` secondary

Status Descriptors			
	Primary Descriptors		Secondary Descriptors
1	Target overtaking ownship	1	Clear
2	Ownship overtaking target	2	Head-on
3	Target overtaken ownship	3	On collision course
4	Ownship overtaken target	4	Crossing starboard to port
5	Stopped	5	Crossing port to starboard
6	Reciprocal course	6	Passing to starboard
7	Crossing starboard to port	7	Passing to port
8	Crossing port to starboard	8	Passing ahead
9	Crossed from starboard to port	9	Passing astern
10	Crossed from port to starboard	10	Crossing

Table 1: *Status descriptors*

Risk Descriptors		
	Primary Descriptors	Secondary Descriptors
1	risk of collision	Emergency
2	risk of collision	Collision course
3	risk of collision	Close quarter situation
4	no risk of collision	Close quarter situation developing
5	no risk of collision	Passing clear
6	no risk of collision	Passed and clear

Table 2: *Risk descriptors*

descriptor is a more specialised form of the `on collision course` descriptor. The crossing descriptors are used in connection with the overtaking primary descriptors only. The `passing to starboard` and `passing to port` secondary descriptors are used to give a more precise meaning to the `reciprocal course` and overtaking primary descriptors where the crossing, `head-on` and `on collision course` secondary descriptors are not applicable. The `passing ahead` and `passing astern` secondary descriptors are used with the crossing primary descriptors where the `on collision course` secondary descriptor is not applicable. Finally the `crossing` secondary descriptor is used in connection with the crossing primary status descriptors where the `clear` secondary descriptor is not yet applicable, i.e. the target has not yet reached its CPA but has crossed over ownship's projected course line.

Thus to give one more example a target located astern that is no longer a threat (i.e. at has passed its CPA) would have `clear` as a secondary descriptor and either `Ownship overtaken target`, `Stopped Reciprocal course`, `Crossed from starboard to port` or `Crossed from port to starboard` as a primary descriptor depending on the geometry of the case.

6. RISK DESCRIPTORS

The risk descriptor is used to indicate the degree of risk associated with a detected target. Again the descriptor is made up of two descriptors, a primary descriptor and a secondary descriptor. The first can be instantiated with `riskOfCollision` or `noRiskOfCollision`, the second qualifies these two descriptors. The possible combinations are given in Table 2.

The risk primary status descriptor, to consider one of these, defines the situation where a target is expected to pass within a certain distance of ownship. As in most practical affairs, the risk in a situation depends on many parameters and the specification of a widely acceptable function for risk assessment is clearly impractical. Indeed some of the base parameters, such as the state of mind of the assessor, would seem to be unquantifiable. However, through extensive analysis of collision situations, the research team were able to identify the most relevant parameters, namely the closing speed, the manoeuvrability of ownship (T), the direction of the threat (F1), the state of visibility (F2) and the proximity of land masses (F3). Using these factors an effective risk heuristic was developed by selecting an easily modelled shape (a circle) and ensuring that the instantaneous radius (r) of this shape reflected the identified factors. Thus:

$$r = (R + (T\ closing\_speed\ F1))\ F2\ F3$$

Where R represents an absolute minimum radius. The functional form and detail of the parameters used are largely empirical and it is at this point in particular that subjective nautical expertise, as gleaned from domain experts, was introduced to effectively supplement the knowledge contained in the Regulations. This risk heuristic is used to defined the risk of collision primary risk descriptor.

7. CONCLUSIONS

The use of descriptors thus allows us to rewrite the rules developed in Section 2 above as a single rule of the form given below. This is a much more elegant representation which has the essential advantage that the essence of the provision is separated out from the ways in which the various terms will be determined to apply. In particular the need for "expensive" mathematical calculations and comparisons are not involved, the necessary calculation being carried out by a preprocessor written in a more appropriate mathematical language. The representation also has the advantage that it is a much richer representation of the domain. For example comparison of the above rule with that presented in section 2 shows that `riskOfCollision` is now a possible value for the attribute `primaryRiskDescriptor` rather than being treated as a simple Boolean attribute. This helps to show the relationship between terms used in the legislation which can be detected only through the foregoing kind of analysis.

```
(ownship action is starboardAlteration)
if
   (target primaryStatusDescriptor is
                          reciprocalCourse)
and
   (target secondaryStatusDescriptor is
                                    headOn)
and
   (target primaryRiskDescriptor is
                           riskOfCollision)
```

Thus in this paper we have described how careful consideration of the ways in which terms used in legislation will be operationalised can enable visual conditions to be represented in a legal KBS, without recourse to the inclusion of complex mathematics, or the conflation of different operational descriptions.

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