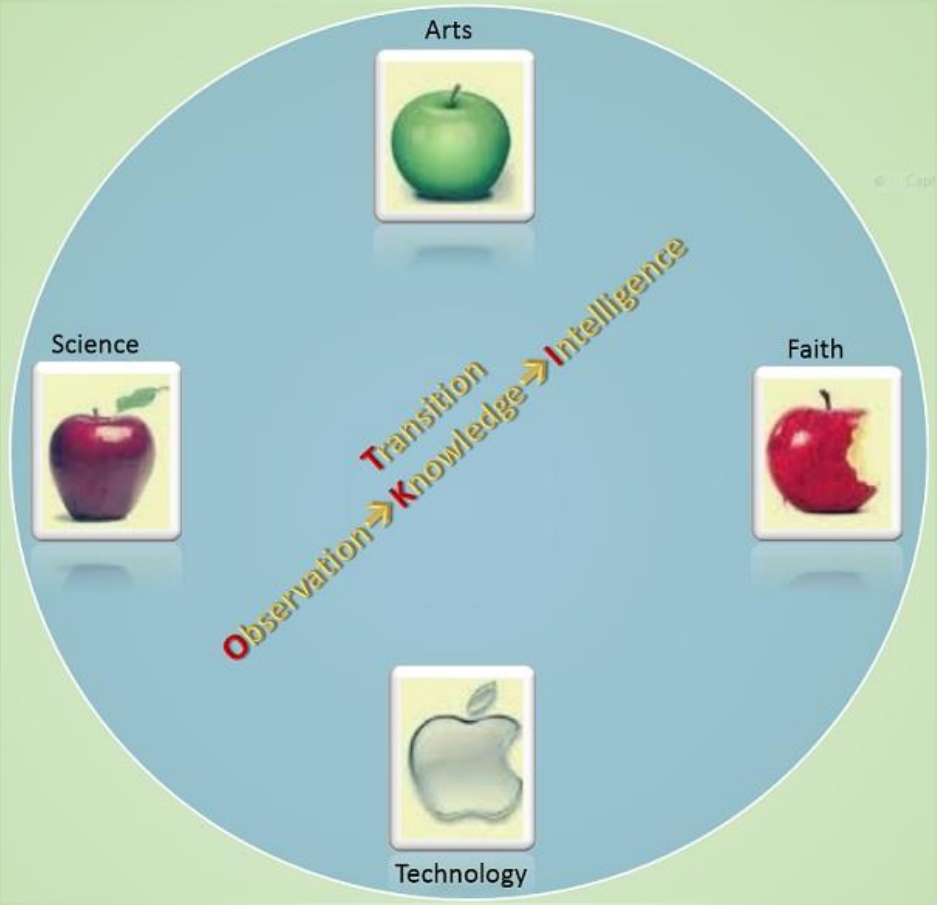

TRANSITION FROM OBSERVATION TO KNOWLEDGE TO INTELLIGENCE

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An Alibi Reasoner based on the Spatial Qualification Model

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Abstract. Investigating a given alibi in a crime case or litigation has been so tied to the efforts of the intelligent officers. Oftentimes, investigation by these intelligent officers takes years of fruitless or untreated investigations or cases. This paper aims at proposing a logical system (Alibi Reasoner) that formally reasons about the spatial location of the accused in a criminal case with a given alibi. A spatial qualification model that uses the quantified modal logic for its knowledge representation was employed. The nature inspired proposed logical system imbibed the commonsense approach to reasoning with reduced complexity. Sample alibi cases with past known locations and times of the accused and the locations and times of incidence were considered in the reasoning process. Prompt results that tell the accused's possibility of spatial presence were obtained. The reasoner has the ability to work with incomplete knowledge to decide on the possibility of the accused's presence at the scene of a crime to have participated in it.

Keywords: spatial qualification problem, qualitative reasoning, quantified modal logic, intelligent reasoning, criminology.

1. Introduction

In a typical setting, any litigation involving an alibi will require an intelligent reasoning process for judgments to be passed. An alibi, a legal excuse by an accused to have been present at a different location at the time of the given incidence, requires spatial reasoning to determine the possibility of presence of an intelligent agent at a certain location. For an alibi to be given, it means that an incidence is known to occur at a certain location and time. Hence, any litigation will have prior knowledge of an incidence and that of the given alibi to reason with. Before now, this kind of reasoning is left for the investigating officers to handle and the court relies on the outcome of their investigation to pass the final judgment.

Since investigating officers are human, they are prone to certain factors such as inaccuracy and delay. In criminology, the causes of these inaccuracies and delays are the frontiers of the enactment of most of the criminal laws (Epsten, 1963) in practice today. Oftentimes, inaccurate results are triggered by other environmental factors such as corruption, that is, where the investigating officers are not self-disciplined or honest. In most parts of the world, the delay in some cases is a deliberate act by the investigating officers to satisfy their selfish interest. Following these inaccuracies and delays, many accused persons who are actually innocent suffer unnecessarily, as some of them may rot in jail for the crime they did not commit. This is injustice to humanity. In some cases, the court will pay huge amount as damages to the accused. In other to have a reasoning process void of these factors, we propose the use of an intelligent reasoner that is based on the spatial qualification logic (Akinkunmi and Bassey, 2013). Note that the reasoner takes into consideration, the rules governing any given alibi as it applies to criminology. Some of these rules were highlighted (Epstein, 1963; Maurer, 1954) to include due process where a given alibi has a deadline, the place and time clearly stated and the witnesses also available. Several strong reasons in favour of these alibi rules have also been provided.

Hence, this paper is aimed at using the spatial qualification model (SQM) to reason about the possibility of an agent's spatial presence at the

location and time of incidence from the location in any given alibi and/or known location and time. An intelligent reasoning task is required to determine the possibility of spatial presence of the accused. The use of the proposed reasoner will eliminate the inaccuracies and also speed up the reasoning process by the investigating officers as it strengthens the given alibi. Also, the use of the reasoner will reduce the number of unresolved cases and it will serve as one of the new technological techniques to solve cold cases (Keleher, 2011). Results can be made available immediately for judgment to take place.

The rest of the paper is organized as follows. Section two gives an overview of the spatial qualification model. Sample extract of known cases involving alibi are given in section three. Section four shows how SQM is applied to the reasoning process of the extracted cases. The possible results from the application are discussed as given in section five. Section six gives the conclusion of the paper.

2. Overview of Spatial Qualification Model (SQM)

Quantified (first-order) modal logic (Fitting, 1998) is the representation language used in modeling spatial qualification (Bassey and Akinkunmi, 2013). Each term can either be a constant symbol or variable symbols. The variables in each world/domain are *Individuals*, *Location* and *Time points*. Locations in this logic denote the notion of regions in spatial logics. Apart from the predicates denoting the standard eight disjoint pairwise spatial relations from the region connection calculi (RCC-8) (Randell et al., 1992), the major predicates in the logic include *Present_at* and *Reachable*.

The meanings of the classical logic operators are as given in the model semantics for first order predicate logic while that of the modal operators is attributed to them from the standard possible world semantics with the proposition $\Box\phi$ meaning that ϕ is true in all possible worlds accessible from the current world, and $\Diamond\phi$ meaning that ϕ is true in some world accessible from the current world. The SQM is a 4-tuple <W, R, D, I> which is built around the Kripke model, a triple <W, R, D> where W is a set of possible

worlds, R is the accessibility relation between pairs of worlds, and D is a definite domain from which individuals in the worlds are drawn and the interpretation function, Iv so that for any item t:

$$Iv[t] = \begin{cases} \text{v(t)} & \text{if t is a variable} \\ \text{I(t)} & \text{otherwise} \end{cases}$$

where, v(t) is the variation function with variable time, t.

SQM is denoted by M,w ⊨ φ, with formula φ being true in a world w of the model M. Thus the statement I[Present_at, w] ⊆ X × L × T holds for Present_at as well as for any other predicate, where X is the agent, L, the locations and T, time of presence.

Given that l is a location in space and l_1 a different location in space, the ability to reason with prior knowledge and tell of the possibility of an agent to be present at a location at a certain time is strongly dependent on the present location of the agent, the location of incidence and the reachability of the locations. Reachability is built around regional connections of locations defined in the RCC-8 base relations (Randell et al., 1992) and re-used in the spatial qualification logic to define the *Regionally_part_of* and the *Regionally_disjoint* relations (Akinkunmi and Bassey, 2013). Other theorems in the spatial qualification logic include the following.

T_{A1}: $\forall x.\ l.\ t.\ Present\_at(x,l,t) \Rightarrow \Box Present\_at(x,l,t)$

T_{A2}: $\forall x.\ l.\ t.\ Present\_at(x,l,t) \Rightarrow (\exists t_1,.\ t < t_1 \Rightarrow \Diamond Present\_at(x,l,t_1))$

T_{A3}: $\forall x, l_1, l_2, t_1, t_2.\ Reachable(x, l_1, l_2, (t_1, t_2)) \Leftrightarrow t_1 < t_2 \wedge (Present\_at(x, l_1, t_1) \Rightarrow \Diamond Present\_at(x, l_2, t_2))$

T_{A4}: $\forall x, l, t_1, t_2.\ t1 > t2 \Rightarrow Reachable(x, l, l, (t_1, t_2))$

T_{A5}: $\forall x, l_1, l_2, t_1, t_2.\ Reachable(x, l_1, l_2, (t_1, t_2)) \Leftrightarrow Reachable(x, l_2, l_1, (t_1, t_2))$

T_{A6}: $\forall x, l_1, l_2, t_1, t_2.\ Reachable(x, l_1, l_2, (t_1, t_2)) \wedge \forall t_3, t_4.\ t_3 < t_4 \wedge (t_4 - t_3) \geq (t_2 - t_1) \Rightarrow Reachable(x, l_1, l_2, (t_3, t_4)))$

T_{A7}: $\forall x, l, l_1, t.\ (Present\_at(x, l, t) \wedge Regionally\_part\_of(l, l_1)) \Rightarrow (Present\_at(x, l_1, t))$

T_{A8}: $\forall x, l, t.\ Present\_at(x, l, t) \Rightarrow \exists r, t_1.\ NTPP(l, r) \wedge Present\_at(x, r, t+t_1)$

T_{A9}: $\forall x, l, l_1, t.\ (Present\_at(x, l, t) \wedge Regionally\_disjoint(l,l_1)) \Rightarrow \neg\Diamond(Present\_at(x, l_1, t))$

T_{A10}: $\forall x, l_1, l_2, l_3, t_1, t_2, t_3.\ Reachable(x, l_1, l_2, (t_1, t_2)) \wedge Reachable(x, l_2, l_3, (t_2,t_3)) \Rightarrow Reachable(x, l_1, l_3, (t_1, t_3))$.

3. Sample Alibi Cases

The case studies consist of necessary information from the sample cases as retrieved from the South African database with the locations and times retained, but with the names of the accused changed to author's given names. The required extracted knowledge that may serve as input to the proposed reasoner in this paper is summarized in table 1.

Table 1: Input knowledge for an alibi reasoned
(*Extracted from South African database*)

Case	Incidence		Last Known		Alibi	
	Location	Time	Location	Time	Location	Time
Kidnapping and Rape of Mary involving Peter and Monday on 22nd August 2001.	Mitchells Plain, Cape Town	8 pm	Ogla Court, Manenberg	8 pm	House at Mitchells Plain	6:45-7:45 pm and 9 pm
Murder and Robbery involving Michael and Frederick on April 24, 2009	23 Contour Road, Fernloof, Hermanus	7:50 pm	7578 White City,	Throughout the day	White City in Hermanus	8.00 pm
Motor Vehicle Theft involving Gerald and Standard Bank on 26 October, 2006	Western Cape	8 pm	Rondeboch	7 pm	Wynberg	7:55 pm

4. Alibi Reasoning with SQM

With the use of the axioms making up the spatial qualification logic, reasoning about the possibility of spatial presence of the accused at the location of the crime can be done without delay. The investigating officer for the case will simply use the SQM reasoning software, referred to as the SQM reasoner. Reasoning with the system is done following the base axioms as follows. The framework for the alibi reasoner is as given in figure 1.

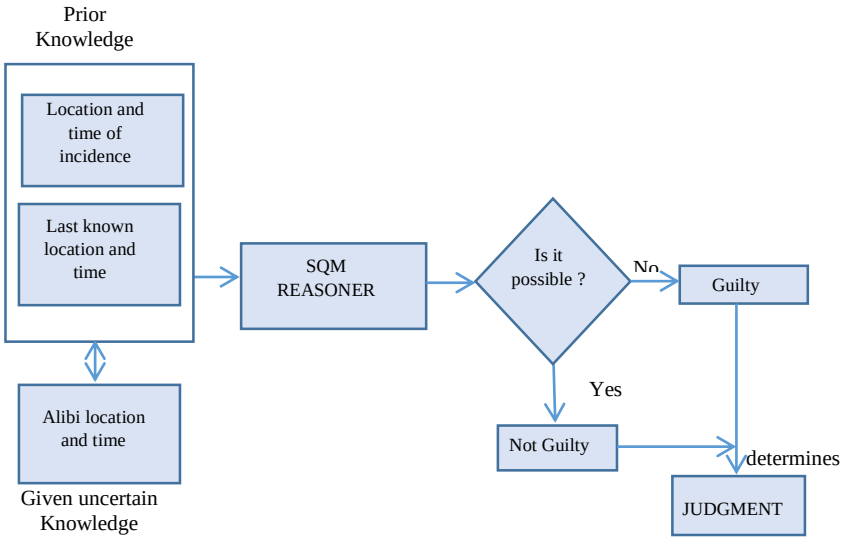

Figure 1: An Alibi Reasoner Framework

From figure 1, prior knowledge consisting of the location and time of the incidence and the last known location of the agent involved and the location and time of the alibi, are given as input. This input, sent to the SQM reasoner, triggers the reasoner to reason about the possibility of a single intelligent agent to be involved in the incidence described in prior knowledge and as well be present at the last known location given. The possibility of its presence will generate results such as “guilty” or “not guilty”. These result will in-turn affect or determine the judgment passed on the matter.

From the axioms in the spatial qualification logic, reasoning about a given alibi can be done as follows:

Using axiom T_{A1}, known facts about the accused can be represented thus:

$$\forall\ accused, l_k, t_k.\ Present\_at(accused, l_k, t_k)$$
$$\Rightarrow \Box Present\_at(accused, l_k, t_k)$$

This means that for all the accused present at location l_k at time t_k, it implies that the accused is necessarily or always present at l_k at time, t_k.

Also, axiom T_{A2} in SQM can be used to represent the possibility of an intelligent agent's spatial presence as given:

$$\forall\ accused, l_k, t_k.\ Present\_at(accused, l_k, t_k) \Rightarrow (\exists t_{k1}.\ t_k < t_{k1}$$
$$\Rightarrow \Diamond Present\_at(accused, l_k, t_k))$$

The *Reachable* predicate can also be used to define the possibility of presence of the accused at the location and time of incidence from the location and time in the given alibi or from the last location and time as follows:

$$\forall accused,\ l_{k1},\ l_{k2},\ t_{k1},\ t_{k2}.\ Reachable(accused,\ l_{k1},\ l_{k2},\ (t_{k1}, t_{k2}))$$
$$\Leftrightarrow t_{k1} < t_{k2} \wedge (Present\_at(accused,\ l_{k1},\ t_{k1})$$
$$\Rightarrow \Diamond Present\_at(accused,\ l_{k1},\ t_{k1}))$$

Note that l_{k1} and l_{k2} represent the location of incidence and the location in the given alibi respectively. In like manner, t_{k1} and t_{k2} represent the time of spatial presence of the accused at l_{k1} and l_{k2} respectively.

Reachable as it is used in the above axiom to define the possibility of presence can be defined thus:

$$\forall\ accused, l_k, t_{k1}, t_{k2}.\ t_{k1} > t_{k2} \Rightarrow Reachable(accused,\ l_k,\ l_k,\ (t_{k1},\ t_{k2}))$$

This means that an accused, spatially located as given in the alibi, can reach the location and time of incidence if $t_{k2} > t_{k1}$. Also, a location is reachable from itself if the difference in time does not change the location of the accused. Here, the accused can remain at the same location.

Apart from this reflexive property, reachability also exhibits the commutative and transitive property as described in the axioms below :

$$\forall accused, l_{k1}, l_{k2}, t_{k1}, t_{k2}.\ Reachable(accused,\ l_{k1},\ l_{k2},\ (t_{k1},\ t_{k2}))$$

$$\Leftrightarrow Reachable(accused, l_{k2}, l_{k1}, (t_{k1}, t_{k2}))$$

$$\forall accused,l_{k1},l_{k2},l_{k3}, t_{k1}, t_{k2}, t_{k3}.\ Reachable(accused, l_{k1}, l_{k2}, (t_{k1},t_{k2}))$$
$$\wedge\ Reachable(accused, l_{k2}, l_{k3}, (t_{k2}, t_{k3}))$$
$$\Rightarrow Reachable(accused, l_{k1}, l_{k3}, (t_{k1}, t_{k3})).$$

Reachability of an accused from the last known location or the location in the given alibi to the location of incidence may be duration dependent as shown below:

$$\forall accused,l_{k1},l_{k2},t_{k1}, t_{k2}.\ Reachable(accused, l_{k1}, l_{k2}, (t_{k1}, t_{k2}))$$
$$\wedge\ \forall t_{k3}, t_{k4}.\ t_{k3} < t_{k4} \wedge (t_{k4} - t_{k3}) \geq (t_{k2} - t_{k1})$$
$$\Rightarrow Reachable(Reachable(accused, l_{k1}, l_{k2}, (t_{k3}, t_{k4})))$$

A last known location or given location in the alibi may be regionally part of the location of incidence, thereby confirming the presence of an accused at the location of incidence. This is shown in the following axiom

$$\forall accused,l_{k1},l_{k2},t_k.\ Present\_at(accused,l_{k1},t_k)$$
$$\wedge\ Regionally\_part\_of(l_{k1},l_{k2}) \Rightarrow Present\_at(accused,l_{k2},t_k)$$

The absence or the impossibility of spatial presence of an accused at the location of incidence can simply be determined using the already defined Regionally_disjoint predicate as follows:

$$\forall\ accused,l_{k1},l_{k2},t_k.\ Present\_at(accused,l_{k1},t_k)$$
$$\wedge\ Regionally\_disjoint(l_{k1},l_{k2}))$$
$$\Rightarrow \neg\Diamond(Present\_at(accused,l_{k2},t_k))$$

This presence of the accused in conjunction with the Regionally_disjoint predicate implies the negation of the possibility of presence of the accused.

5. Discussion of Results

From the above derived axioms from SQM, reasoning about the locations and time of the accused is done based on the prior knowledge which comprise of the last known fact about the accused and that from the given alibi. Implementing the set of axioms in section 4 will result in *AN ALIBI REASONER*, where derivations such as possibility and impossibility

of an accused to be spatial present at the location and time of incidence. The possibility is enhanced by the *Present_at* and *Reachable* axiom. The *Present_at* predicate holds the prior knowledge of the accused's spatial presence. The *Reachable* predicate uses the locations and the duration between them based on the given time to determine the possibility of its reachability. The determination is done by comparing the duration to reach one location from another with the resulting time from a GPS to cover that particular distance based on an assumed speed limit for the route.

The tool used to link to the GPS is the Google Map Distance Calculator which is freely available on any internet ready device. If the reasoner returns that it is possible for an accused to be present at the location of incidence, the judgment that the accused is GUILTY can come up, without unnecessary delays. Impossibility is actually the negation of the possibility and it paves way for NOT GUILTY to be passed as the judgment.

6. Conclusion

A court case with an alibi involving the accused spatial qualification may take some time for judgment to be passed as this is dependent on the investigating officers' report which validates the truth of the given alibi. This delay may cause the accused that is actually innocent untold pains as he/she remains in custody during the trial. The use of SQM for reasoning gives a set of axioms whose implementation results in the ALIBI REASONER. The use of this reasoner returns POSSIBLE or NOT POSSIBLE. Interpreting this in lieu of a court case, we take it that the accused is GUILTY or NOT GUILTY. The judgment on the accused is passed thus without delay and waste of time. Hence, the ALIBI REASONER is one important tool that is necessary for court cases with given alibi that may require spatial qualification.

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Some scientific fields that are currently receiving more attention both from scientific communities and in the general public are competitive intelligence, smart city (intelligent city), and territorial intelligence. Common to all these fields are the concepts of information, information systems, knowledge, intelligence, decision-support systems, ubiquities, etc. The advantages for industries (production and service industries) and governments (federal, state and local governments) cannot be overemphasized. This resurgence is due to the impact of technologies for dematerialization of objects and human activities.

Since the term “intelligence” is central for the theme of this conference, there is need to specify its meaning that we are using for the conference.

Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do.

Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria.

From this definition, it is obvious that intelligence in a way or the other rely on the process of **observation** (comprehending our surroundings) and ensuring that the observation is transformed into **knowledge** ("catching on," "making sense of things”, or "figuring out what to do”).

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