1 Purpose

The Forest Observatory Ontology (FOO) aims to describes wildlife digital data generated by sensors. The primary purpose is to backbone the Forest Observatory. That is, a linked datastore that not only allows unified access to heterogeneous wildlife data but also enables standardised data exchange between different computer systems and applications. .

2 Scope

Internet of Things (IoT) and Wildlife make up the evolving scope of FOO. It adopts and combines ontological resources from Sensor Observation Sample and Actuation (SOSA) and BBC wildlife Ontology (WO).

3 Implementation Language

The Web Ontology Language (OWL2) is used to implement FOO.

4 Intended End-Users

- Bio-Scientists.
- Wildlife Researchers.
- Computer Scientists.
- Data Scientists.

5 Intended Uses

- To build a linked datastore that integrates different kinds of wildlife data in a meaningful way.
- For reasoning, that is, draw conclusions about new events from data.
- Build prediction models.

6 Ontology Requirements

6.0.1 Non-Functional Requirements

- FOO must include IoT elements, such as sensors.
- FOO must include wildlife concepts, such as Taxon Rank.
- FOO must contain the relationship between the IoT and wildlife concepts.

6.0.2 Functional Requirements

- 106 curated competency questions (CQs), see table 1 and 2.
- 10 Natural Language Statements (NLSs), see table 3.

	Open Data		Sensor Data	
Competency Questions (CQs)	*Soil*	*Veg*	*GPS*	*Image*
CQ1 Where do elephant x forage?		*	*	
CQ2 What are the day(date) movement patterns for elephant x?			*	
CQ3 What are year (date range) movement patterns for elephant x?			*	
CQ4 What are the relationships between elephant x movement and human/urban areas?			*	*
CQ5 Has elephant x died?			*	
CQ6 Why has elephant x died?				*
CQ7 What are the suitable environmental conditions for elephant x to survive?	*	*	*	
CQ8 What do elephants x, y, z movements tell us?			*	
CQ9 How does elephant x use habitat site y?		*	*	
CQ10 What is the range of habitat site used by elephant x, y,z?		*	*	
CQ11 Where was elephant x location during the flood season at the Lower Kinabatangan area?			*	
CQ12 What was the average speed of elephant x during the flood season?			*	
CQ13 Is elephant x near the danger zone (poachers area) today?			*	
CQ14 How did elephant x movements change with climate change in 2014?			*	
CQ15 What is elephant x preferred habitats based on prolonged stays in areas?	*		*	
CQ16 How far was elephant x from the oil plantation fencing ?			*	
CQ17 When was elephant x near the oil plantation fencing?			*	
CQ18 What is the distance travelled between elephant x each stop (sleeping)?			*	
CQ19 Which elephants spend met this month?			*	
CQ20 Which sites revisited by elephant x this month?			*	
CQ21 What environment / habitat does elephant x prefer? Based on the prolong time spent in a certain area.	*	*	*	
CQ22 Is there any significant change in elephant x movement patterns between June and July 2015?			*	
CQ23 Has elephant x visited village y this year?			*	
CQ24 What is the movement range of elephant x during month y?			*	
CQ25 What is elephant x activity (speed) during month y?			*	
CQ26 Are there any inter activities between collared elephants during flood season?	*		*	
CQ27 What is elephant x tracking collar's battery activity ?			*	
CQ28 What habitat does elephant x select this season?	*	*	*	
CQ29 What is the average elevation of elephant x on a particular time range?			*	
CQ30 Which elephant came near logged site?		*	*	
CQ31 Which elephant came near semi-logged site?		*	*	
CQ32 Which elephants crossed the river ?			*	
CQ33 What is the canopy height for the distance travelled by elephant x during flood season?	*	*	*	
CQ34 Which elephants are near the oil palm plantations this week?			*	
CQ35 What is the home range for all collared elephants?			*	
CQ36 What is the distance travelled by elephant y in a certain period of time?			*	
CQ37 What is the altitude of the collared elephants?			*	
CQ38 What are the body/environment temperatures for collared elephants?			*	
CQ39 What is the behaviour of elephant x and y this month?			*	
CQ40 Does elephant x need help?			*	*
CQ41 What are the distribution patterns of elephant x and y during this month ?			*	
CQ42 Are elephants x and y favourite food in a particular area?		*	*	
CQ43 Do we need to create corridors along rivers/ palm plantation of it is not an obstacle for elephants to roam across the river?			*	
CQ44 What are the elephants collars fitted for almost two years?			*	
CQ45 What are the migration patterns for elephant x during flood season?			*	
CQ46 What are the favourite locations that elephant x like to visit during certain time of the year?			*	
CQ47 Where elephants are likely to come into contact with humans?			*	
CQ48 What are the places were elephants may be vulnerable?			*	
CQ49 Where can we assign locations to rangers?			*	
CQ50 How to track (investigate) the last location of a dead elephant ?			*	
CQ51 Will the elephants be arriving DGFC soon?.			*	
CQ52 How many satellites did the collar detect? (COV=0, speed =0)			*	
CQ53 Which elephants close to the river today?			*	
CQ54 Which elephants are close to oil plantations?			*	
CQ55 Which elephant roams near Sabahmas site?			*	
CQ56 Which elephant roams near small steep site ?			*	
CQ57 Which elephant is likely to visit Ribubonus, kg. Kiabau and Reka Halus 12ha?			*	
CQ58 What locations could have snares?			*	*
CQ59 Is elephant x sick, injured or dead?			*	*
CQ60 which elephant(s) are likely to conflict with human?			*	
CQ61 What is the soil condition during certain time of the year?	*			
CQ62 What are the types of soil available across the year? Dry, muddy, swamps	*			
CQ63 What are the soil characteristics with more or less nutrients, minerals?	*			
CQ64 What are the locations (soil type) that elephants prefer?	*			
CQ65 What are the mineral content (salt and others in a particular location)?	*			
CQ66 Is there any metals in the soil in that area?	*			
CQ67 What are the chemicals, agro- chemicals concentrations in the soil of a certain area?	*			
CQ68 Does the soil in location x contain disease pathogens?	*			
CQ69 Which area that needs pesticides spraying?	*			
CQ70 What is the soil moisture level in a specific location?	*			

Table 1: Competency questions extracted from research activities such as ethnographic research, interviews, and nominal and focus groups

	Open Data		Sensor Data	
Competency Questions (CQs)	*Soil*	*Veg*	*GPS*	*Image*
CQ71 What is the presence of minerals in the soil?	*			
CQ72 Is there signs for heavy metal in the soil?	*			
CQ73 Where are the salt-licks located?	*			
CQ74 What are the mineral and salts concentration in the soil that indicate the presence of salt-lick in a particular location?	*			
CQ75 What is the pH level in soil?	*			
CQ76 What is the temperature reading from the soil sensor?	*			
CQ77 What is the soil moisture in a certain location	*			
CQ78 Is the soil in this area healthy for animals?	*			
CQ79 Is the soil fertile in this area?	*			
CQ80 What is the moisture rate of the soil in this area (i.e., provide geo-location)	*			
CQ81 Where to plant crops for elephants (i.e., sol moisture rates)?	*			
CQ82 Could planting in safer areas (healthy soil) influence animal movements?	*			
CQ83 Could we predict crop yield based on soil data?	*			
CQ84 What soil metrics helps us predict flood?	*			
CQ85 What are the metrics of healthy soil with less/no chemical pollution from oil palm plantations?	*			
CQ86 Why elephants do not like to walk on wet soil (movement prediction)?	*			
CQ87 What are the chemical levels of the soil?	*			
CQ88 What are the soil nutrient levels ?	*			
CQ89 What are the effect of moisture on nutrients and oxygen levels?	*			
CQ90 What is the ideal soil moisture rate for an elephant to give birth?	*			
CQ91 What are the soil conditions in the areas that have elephant grass?	*			
CQ92 How to conserve suitable soils for the elephants to have food in the future (e.g., reduce using a fertiliser)?	*			
CQ93 What soil moisture do elephants spend most time on?	*			
CQ94 Is it based on the plants grown in that soil?	*			
CQ95 How does this compare to urban areas? Or logged areas?		*		
CQ96 What do elephants eat?		*		
CQ97 Where are elephant grass (Nappier),bark, Palm shoots, young leaves trunks, soft plants, and bananas?		*		
CQ98 Where do bamboo shoots grow?		*		
CQ99 Where could we found areas with inner trunk of the oil palms?		*		
CQ100 Where could we found areas with broad leaves?		*		
CQ101 Where could we found areas with vines?		*		
CQ102 How vegetation and site habitat information help understand elephants behaviour ?		*		
CQ103 Do elephants drink lots of water?			*	
CQ104 Where do we find fruit farms in lower Kinabatagan?		*		
CQ105 What areas have less trees?		*		
CQ106 What plant species to conserve in the areas the elephants visit?		*	*	

Table 2: Table1-Continued

	Open Data		Sensor Data	
Natural Language Statements (NLSs)	*Soil*	*Veg*	*GPS*	*Image*
NLS1 Tracking elephant location so that the wildlife department can give warning to local people about the arrival of the elephants.			*	*
NLS2 Examples for areas with elephant grass (Nappier), other grass, Bark, Palm shoots, young leaves trunks, soft plants, and, bananas.		*		
NLS3 Focus on the area of Lower Kinabatangan and the 14 collared elephants living there.			*	
NLS 4 Collared elephants will not go to primary forest's sites.		*	*	
NLS5 The datasets in this research could be used to generate predictions.			*	
NLS6 Elephants,do not intend to cause damage. It may occurs when their strong and huge bodies come in contact with things.			*	*
NLS 7 Nearly all wild pigs in the area of kinabatangan died from influenza viruses.				
NLS 8 There was a famous story about the Rhino who lost one leg from poaching. It survived on three legs for long time.				*
NLS9 Female Asian elephants are tusk-less.			*	*
NL10 Male Asian elephants are more likely to explore humans areas than females- for the benefit of maximising gain.			*	

Table 3: Natural language statements and what data-set can fulfill the task.