Modelling Sustainability for an IoT-enabled Smart Green Campus using an Ontology-based Approach

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Introduction

- **Smart campuses**
  - Academic or non-academic institutions where digital infrastructures are in place to support the teaching, learning and research activities

- **Internet of Things (IoT)**
  - Enables the automation of the environment where sensors capture data about the environmental phenomena
  - Data are analysed for better resource management and proper decision-making

- **Campuses focus on being more sustainable**
  - In line with Sustainable Development Goal (SDG) 12 and SDG 13 defined by United Nations Millennium Declaration

- **A smart green campus thus aims to use natural resources such as energy and water efficiently**
  - To promote healthy living on the campus both indoors and outdoors with the help of technologies
Examples of Smart Green Campuses

Examples of smart green campuses
- Themes for smart green campuses namely Smart Learning, Smart Sharing, Smart Buildings and Smart Transport based on best practices for Dutch institutions
- Green indicators for Malaysian universities for measuring and monitoring green practices in higher education institutions
- Setup of a sustainability office/centre on campus for Saudi universities to assess campus sustainability

Sustainability offices or centres are already in place in several campuses around the world
- ANUgreen Sustainability Office at Australian National University Facilities and Services Division
- EcoCampus Management Centre set up at the Universiti Malaysia Sabah
- Aim: to monitor campus activities and operations in order to assess campus sustainability
Fig. 1: Smart Green Campus Example
The need for a Semantic Model

- As shown in Fig. 1, different systems capture data about the environment
  - Systems linked to several domains of a smart campus such as smart building, smart classroom, smart library or smart parking

- Research issue for Smart Campus (analogous to small city)
  - Data interoperability and fusion for monitoring the environment (air, soil, water)

- Need for a semantic model
  - To promote sharing and integration of data captured by various IoT systems on the campus
  - To represent data of different domains
  - To enhance interoperability among heterogeneous systems on the campus
  - To promote decision-making on the campus

- Ontology-based models
  - good expressivity
  - good formalization language with logic inference ability
Ontologies for Smart Green Campuses (1)

Ontologies for smart green campuses:

- **SAREF4BLDG** ontology
  - extends the **SAFEF** ontology
  - defines vocabulary for building devices and their location
  - Concepts such as *Building*, *BuildingSpace*, *PhysicalObject*, *TransportElement*, *VibrationIsolator* and *BuildingDevice* have been modelled

- **SmartWater**
  - IoT-based framework entitled to support smart water monitoring and management
  - vocabulary for water zones, storage reservoirs, distribution pipelines, IoT water sensors, smart meters and monitoring hubs for measuring consumption

- **Waste management** *(Kultsova et al., 2016)*
  - Ontology along with rule-based reasoning
  - *Waste Ontology, Ontology of Waste Management Methods and Ontology of Waste Management Subject* have been constructed

Ontologies for Smart Green Campuses (2)

- **Indoor Environmental Quality (IEQ) Ontology**
  - ontology for indoor monitoring
  - differentiates between pollutant inducing and pollutant reducing activities
  - reused the SSN ontology for sensor modelling

- **Conceptual framework for managing sustainability knowledge** (Yang et al., 2015)

- **Knowledge model for assessing sustainability** (Konys, 2018)
  - main concept *Criteria*
  - sub-classes namely *Scope, Complexity, Type of Approach, Issues, Domain* and *Indicator*
  - model validation using competency questions

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Gap Analysis

➢ Existence of ontologies
  ▪ different green indicators and specific aspect of green practice management
  ▪ sustainability assessment for a particular domain
  ▪ None have focused on green practice management and monitoring in an IoT-enabled smart green campus

➢ Several projects to achieve sustainability
  ▪ smart building or smart waste management systems
  ▪ Limited dissemination of their impact on sustainability

➢ Limited research
  ▪ How projects are represented and monitored with respect to sustainability frameworks or metrics

➢ Recommendations
  ▪ development of an integrated framework to facilitate dissemination of sustainability actions and initiatives on a smart campus along with their results
  ▪ need for a semantic model to represent green practice management and monitoring in the smart campus
    o promote sharing of information
    o informed decision making and planning
Proposed Ontology

➢ Methodology
  ▪ The NeOn methodology has been chosen to develop the ontology
    o favors projects with several different domains that are not well understood
    o favors projects where requirements can change during the development process
    o promotes the reuse of ontological and non-ontological resources.
<table>
<thead>
<tr>
<th><strong>Ontology Requirements Specification Document</strong></th>
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<tbody>
<tr>
<td><strong>Purpose</strong> The purpose of developing the ontology is to represent knowledge with respect to monitoring and management of green practices by the Green Office in a smart campus.</td>
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<td><strong>Scope</strong> The ontology will tackle several green indicators regarding a smart campus. The level of granularity is directly related to the competency questions and terms identified.</td>
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<td><strong>Implementation Language</strong> The ontology has to be implemented in OWL 2.</td>
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<td><strong>Intended End-Users</strong> The relevant users of the semantic model would be students, academic staff and non-academic staff of a smart campus.</td>
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<td><strong>Non-Functional Requirements</strong> The ontology should be based on standards for green practice management and sustainability for smart campuses.</td>
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<td><strong>Functional Requirements:</strong></td>
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<td><strong>Groups of Competency Questions:</strong></td>
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<td>1. Who are the members of the Green/Sustainability office?</td>
</tr>
<tr>
<td>2. Do the members belong to a particular faculty? If yes, which faculty?</td>
</tr>
<tr>
<td>3. Which green practice is being tackled by the Green/Sustainability office?</td>
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<tr>
<td>4. Which green projects are monitored by the Green/Sustainability office?</td>
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<tr>
<td>5. Which green activities are monitored by the Green/Sustainability office?</td>
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<tr>
<td>6. Which projects fall under which green practice?</td>
</tr>
<tr>
<td>7. Who is working on which green project?</td>
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<tr>
<td>8. Who is working on which green activity?</td>
</tr>
<tr>
<td>9. Which metrics assess which green practice?</td>
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Class Diagram
Reuse of Existing Ontologies

- **FOAF**
  - FOAF stands for Friend-of-a friend
  - Defines vocabulary for a person and consists of several attributes like name, title and age.

- **SOSA**
  - Provides vocabulary for sensors in terms of capabilities, measurement processes, observations and deployments

- **Standards**
  - *ISO 37120:2018* is a standard for sustainable cities and communities
Assessment Approach

- Green Office or sustainability office/centre
  - framework for green campus sustainability assessment
  - tool that details guidelines for sustainability evaluation
  - indicators or metrics for measuring progress towards sustainability

- Several frameworks have been set up for sustainability evaluation in the context of a university
  - One example is *UI GreenMetric World University Ranking (GM)*
    - evaluates a university performance based on the following criteria: Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation and Education and Research
    - used to rank a green campus and its environmental sustainability based on 39 indicators
Additional Concepts

➢ Green Projects
  ▪ projects undertaken in a smart green campus in order to work towards sustainability
  ▪ examples include Smart Buildings, Smart Drip Irrigation, Smart Waste Management System, Smart Canteen System and Smart Parking
  ▪ dissemination on the impact of these projects on sustainability

➢ Green Activities
  ▪ fundamental for creating awareness about climate change and SDGs
  ▪ events organized on campus to create awareness
  ▪ programmes developed and integrated in the curriculum to sensitize learners about sustainable development
Conclusion and Future Works

- None of the existing ontologies have focused on the management and monitoring aspects of green practices in a smart campus environment.
  - Knowledge regarding green projects and activities has not been represented formally, hindering reuse and sharing of information.

- The proposed ontology, SmartGreenCampOnto caters for several aspects like IoT, green projects, green activities and sustainability assessment in a smart campus environment based on frameworks.
  - Ontology reuse: FOAF and SOSA along with relevant standards such as ISO 37120
  - Common understanding of the domain
    - to allow university management personnel to take informed decisions towards achieving sustainability goals

- In future, the proposed ontology will be developed using Protégé Ontology Editor.
  - Semantic Web Rule Language (SWRL) will be used to define inference rules that will perform semantic reasoning.
  - SPARQL queries will be used to evaluate the competency questions defined in the ORSD.