Use of Ontology to Facilitate the Creation of Synthetic Imagery of Industrial Facilities

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***Abstract*—Algorithms which perform auto-annotation of remotely sensed imagery need to undergo verification and validation (V&V) such that the end user can make a fitness-for-use judgment regarding their particular application and can be assured of a high level of confidence in achieving success. Synthesizing these data is one means of obtaining the imagery required to conduct benchmark testing. This paper presents a system to create benchmark imagery of industrial facilities for conducting V&V of auto-annotation algorithms. The method proposes to leverage an ontology of industrial facilities to capture domain knowledge regarding both the industrial process flow as well as the objects required to support the industrial process at a particular production level.**

Keywords-verification and validation; benchmark imagery; industrial facility; synthetic image

I. BACKGROUND

The recent rise in collection of remotely sensed imagery of the Earth is driving the need for automated means to process these data to extract important information for addressing a variety of civilian and intelligence problems. One problem to be addressed is the detection, identification, characterization, and monitoring of industrial facilities. Auto-annotation algorithms are being developed which strive to meet this need [1]. An important step in the development of such auto-annotation algorithms is a verification and validation (V&V) strategy [2]. A properly designed and implemented V&V strategy establishes and quantifies the conditions under which an auto-annotation algorithm can be applied to imagery with an expectation of success. Furthermore, a key component of the V&V methodology is a large, well-designed set of benchmark imagery [3], [4]. Due to the large number of extrinsic factors and their levels which must be provided for (e.g., various view angles, times of day, seasons, backgrounds, etc.), and the resulting combinatorial explosion, creation of realistic synthetic imagery must be considered as a means to obtain the required number and variety of benchmark imagery for conducting V&V [5].

Herein we propose an approach to synthesizing benchmark imagery of industrial facilities. Achieving realism means more than photo-realism. The facility layout must truly represent the actual process flow of a real industrial process, as well as the object types, sizes, and number required to meet a particular level of production capacity. Therefore, central to our approach is an application-level ontology that provides a principled means to organize the various types of industrial facilities and to determine the objects which compose a particular facility. Our review of the relevant literature indicates that while work is beginning in the use of ontologies for auto-annotation of imagery (e.g., [6]), very little work has been conducted to date on the use of ontologies to synthesize the imagery required to conduct V&V of such algorithms.

II. SYNTHETIC IMAGE CREATION

The proposed system is described here and illustrated in Fig. 1. The process would be initiated by the user defining the type of industry to be modeled (e.g., aluminum smelting), and the production rate (e.g., 175 kilotons per year) [7]. Extrinsic parameters (e.g., view angle, time of day, season, clutter, etc.) would also be defined at this point. Setting the type of industry would queue the system to select the associated process flow from a process flow database. The process flows in this database would be stored as networks (e.g., linked-list trees). The nodes of the process flow networks would set the type of objects required to conduct the process (e.g., tanks) and the object's use (e.g., storage). The desired production rate would drive the sizing and number of these objects. Since these characteristics are interrelated, a structural engineering database would provide limits on the realistic minimum and maximum dimensions allowed for each object. These limits would resolve the ambiguity in the number of objects required to provide the storage capacity necessary to support the desired production rate, without violating structural engineering constraints.

The process flow, required objects, and their size and number would then be used in a facility layout algorithm to arrange and orient all the objects. A spatial topology might be enforced, formulated through a cost minimization criterion [8], or it could be statistical in nature [9].

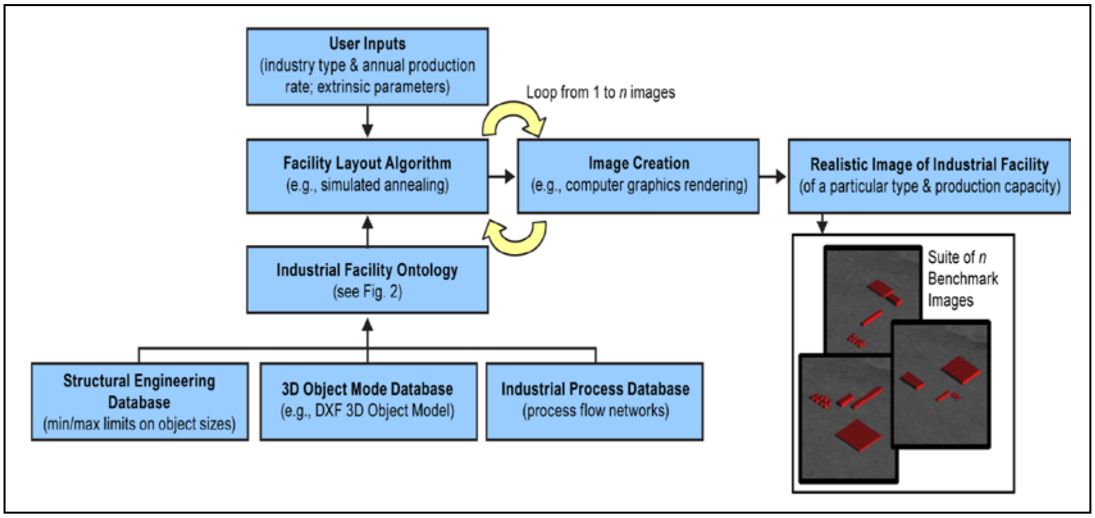

Figure 1. Illustration of the proposed system to synthesize imagery of industrial facilities.

It is possible for a multitude of layouts to be generated, even though the process flow and the type, number, and size of objects remains the same. This means that variation in facility layout is provided at this point in the process.

Therefore, a for loop is utilized such that a number of images can be output while still holding fixed the type of industry and its annual production output.

Once the object arrangement has been computed, an image of the industrial facility is created via rendering, either through a physics-based method [10] or through computer graphics methods [11]. On exit from the loop over the number of images desired, the required suite of benchmark imagery will have been produced.

III. INDUSTRIAL FACILITY ONTOLOGIES

Ontologies would be leveraged at two places within this process framework (Fig. 2). First, the industry type would be selected from an ontology of industrial types (top half of Fig. 2). Second, the object types would be selected from an ontology of industrial process object types (bottom half of Fig. 2). These ontologies would either be created by information gleaned from subject matter experts via knowledge elicitation and a review of the relevant literature, or leveraged from existing ontologies, or a combination of both [12]. An initial review of ontologies which capture industrial processes reveals that they appear to be quite specialized and are generally rare. Examples are the MAnufacturing Semantics Ontology (MASON) [13] and OntoCAPE [14]. Creation of an ontology designed for our particular purpose (i.e., containing only the objects which are "relevant" within our "reality") will most likely be required [15]. Also, considering the fact that we will have to account for industrial parts and wholes, their spatial relations, as well as geographic "things", then insights into mereotopology [16] and geo-ontology [17] will most likely be required and should prove useful.

IV. CONCLUSIONS AND FUTURE WORK

A system to create synthetic imagery of industrial facilities for the purpose of conducting V&V of auto-annotation algorithms has been proposed herein. Central to our design is an industrial facility ontology which guides the selection of the object types and their number to re-create the industrial process desired and its production rate.

Realism is achieved both by leveraging the industrial facility expertise captured by the ontology as well as the impressive realism available via modern computer graphics techniques and technology.

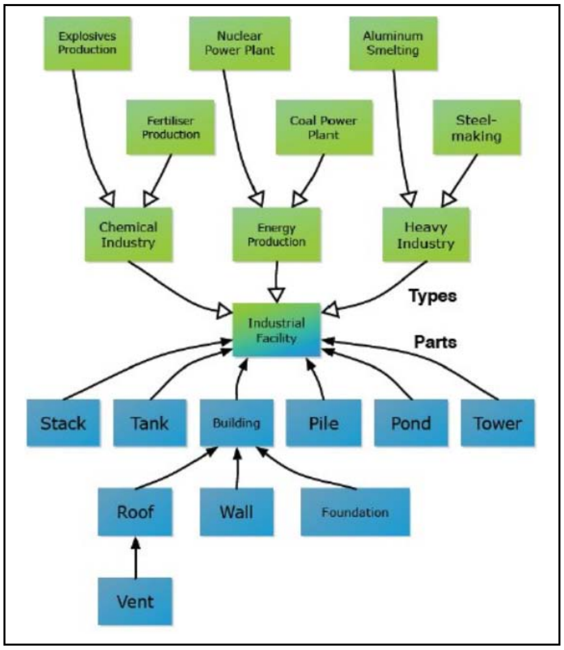

Figure 2. Illustration of an industrial facility ontology to support the proposed system. The upper relationships indicate industry types, while the lower relationships indicate parts (objects) that comprise an industrial facility. This ontology was derived in part by analysis of the nouns put forth as salient by Chisnell and Cole [18].

This overall sketch is an important first step in achieving such a capability; however, much work remains to be done. Our current aim is to realize a first version of such a system. We expect that substantial improvements will occur as this nascent version is utilized for V&V of auto-annotation algorithms.

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