PILOT

Predicting Interior Layouts Over building Types

Ramesh Krishnamurti, Principal Investigator
Kui Yue & Casey R Hickerson, Graduate Students

Problem Statement

A problem of tactical significance in urban operational situations is target location within a building prior to human intervention. There are two essential aspects to this problem: firstly, the spatial dimension–generating possible layouts; and secondly, the reasoning dimension–estimating the likelihood of any particular layout. We concentrate, in this project, on the first of these two aspects, although, we note that due consideration must and will be given, incrementally, at increasing levels of technical detail, on the relationship and feedback between the spatial and reasoning components.

We are developing a method for rule-based generation of possible layouts for the interior of a building and implementing the method as a prototype for layout generation. We formulate this problem as two major sub-tasks; i) developing the mechanism to convert prior knowledge into sets of rules, recorded in a database; ii) generating possible interior layouts using these rules by additionally inputting known features. The short-term assumption, at a minimum, is the availability of a 2.5D model, presumed derived from image data, augmented with associated external features, which include building footprint plus height, and other obtainable building features, such as number, size, and position of windows, paths, etc. The longer-term goal is to automate the system by extracting both the 2.5D model and building features from photo images of the target building.

Background

Buildings are characterized in a number of different ways — by type: house, office, hospital, etc.; by architect or designer: Frank Lloyd Wright's Prairie and Usonian houses, Christopher Wren's churches, Alvaro Siza's Malagueira development, etc.; by urban city: bungalows of Buffalo, Queen Anne houses of Pittsburgh, etc; by style: Victorian, Georgian, Bauhaus, etc.; by construction: stone, brick, stick-built, pre-cast concrete, adobe, etc.; by culture: vernacular Taiwanese dwellings, vernacular Hayat house; and so on. Buildings usually share several characteristics, which translate into spatial features. Based on such characterizations, we can formulate spatial rules in a systemic fashion by means which building designs and layouts can be generated. Shape grammars have been shown to be extremely useful and adept in these endeavors.

A shape grammar is a system of rewriting shape rules. A design is generated as a sequence of shapes; each shape in the sequence produces the next shape in the sequence by substituting a part of the shape for another part. The two parts constitute a shape rule. Shapes can be tagged with markers, to deal with functional and other non-spatial features. Markers can be erased and added during layout generation. Markers can be specified in the shape rules. Shape rules are usually further classified into stages; in this way, layout generation can be broken down into phases. A shape grammar is developed from a methodological examination of corpora of building designs specified by a set of building characteristics. A general paradigm for shape grammar development is documented in the published literature.

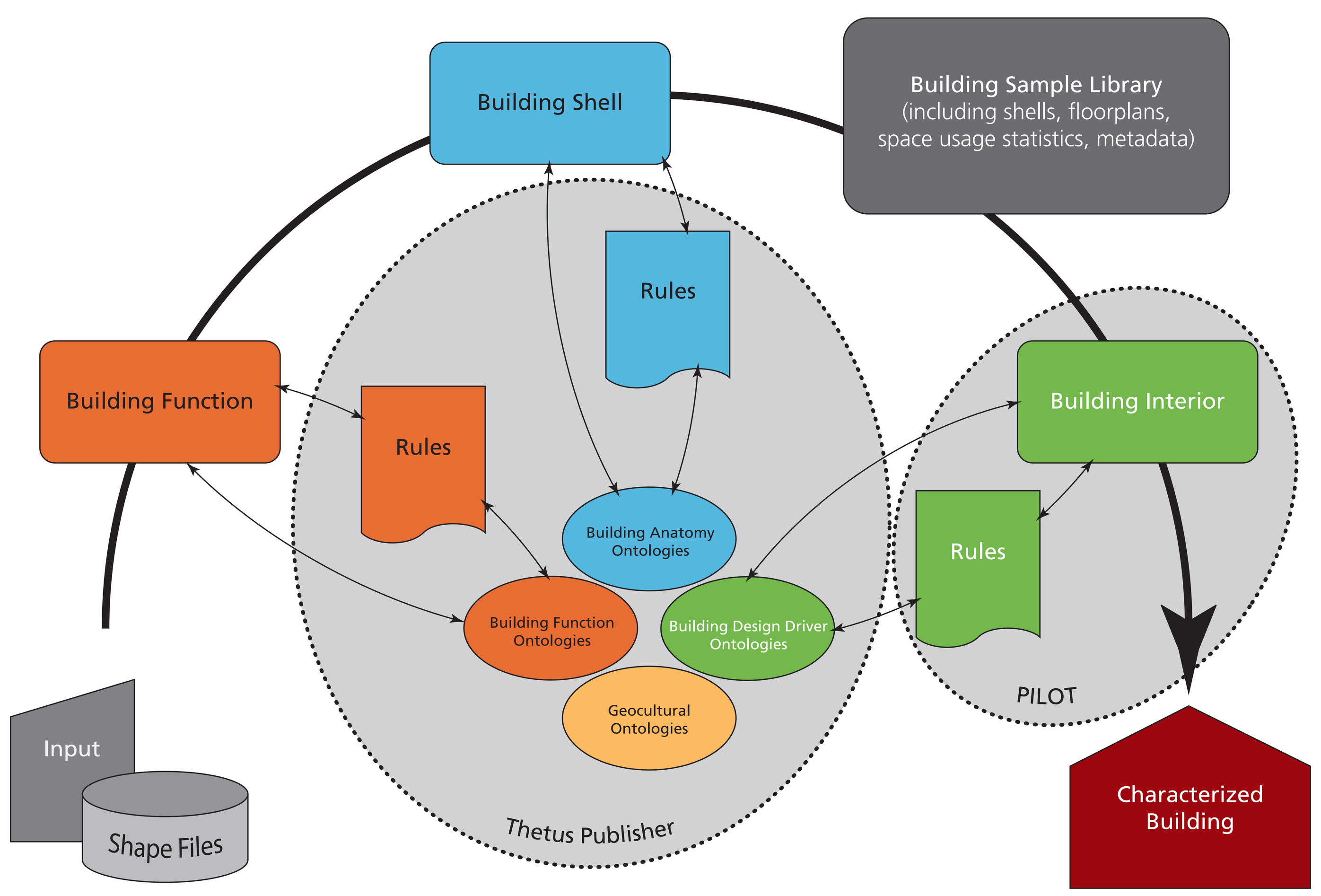


Diagram of CERL Building Characterization System

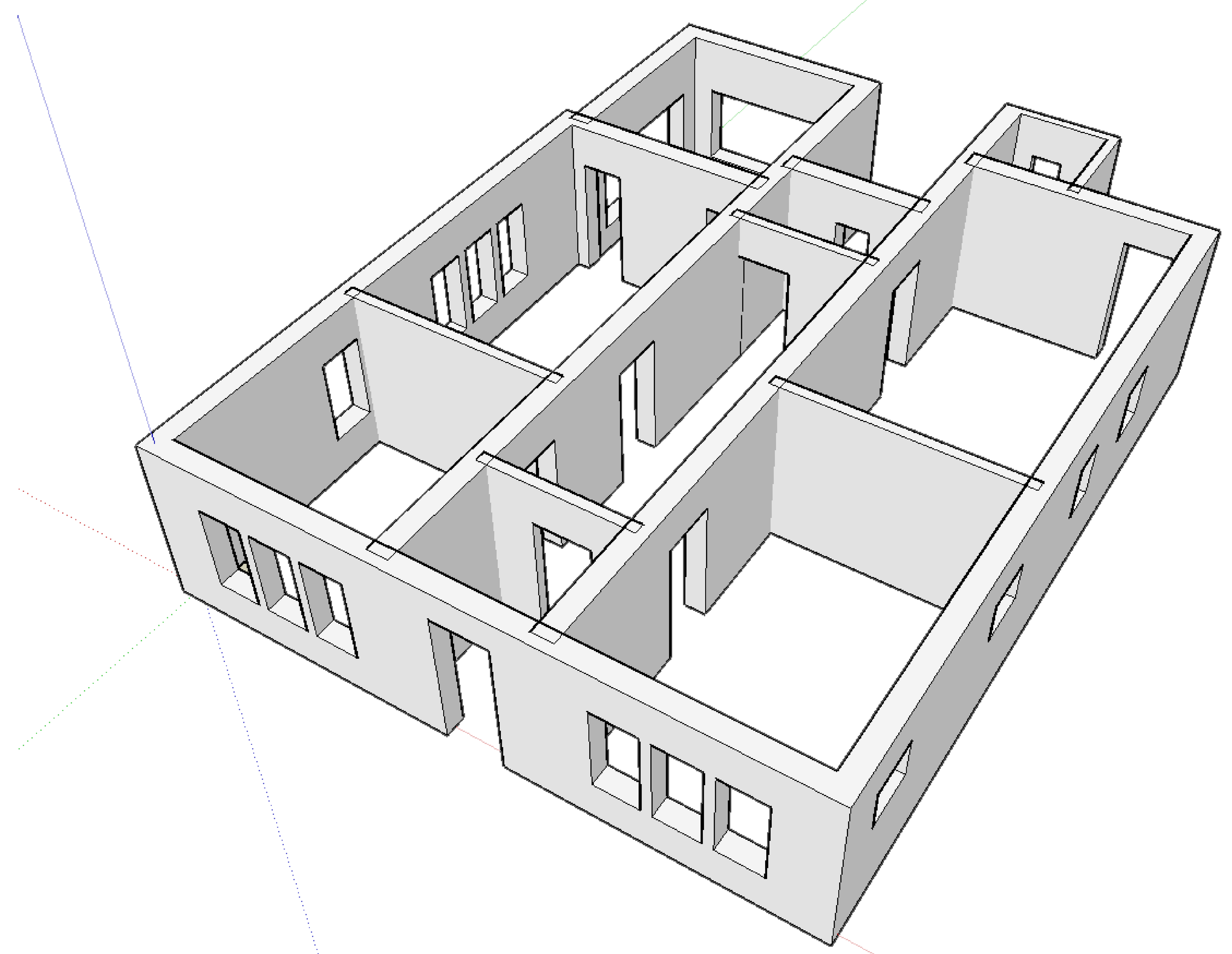
Approach

We have adopted a two-part approach with certain tasks conducted in parallel: The first part relies on developing the methodology and prototype on a control environment using a known grammar for buildings with known layouts. This part involves analytical work, modifying existing rules to incorporate those building features that are considered strategic by CERL. This step is also necessary to obtain rules specified at an appropriate level of granularity for the layout reconstruction problem. The original rules were targeted at many of the design features of Queen Anne houses, and not solely at layout. The original rules did not consider terrain and environment features. The second part is to test the efficacy of the prototype on a target environment with partially known layouts but no known rules. In this task, shape rules have to be developed from corpora of buildings using the aforementioned paradigm, fine-tuned to accommodate given building features using the analytical approach developed in the first part. For the first part, as the starting point, we plan to use Queen Anne houses in Pittsburgh, PA as the control case study (near right). The main reasons are geographical convenience in collecting the data necessary for the methodology and prototype developments, and the significant amount of prior work on Queen Anne houses conducted by Carnegie Mellon University. It should be noted that the proposed work is new, and the approach is basic research. For the second part, we have used the vernacular rowhouses of Baltimore, MD as the target environment (far right). The advantages of Baltimore rowhouses are threefold: tight variability among instances of the type, availability of high quality layout information, and the limitation imposed by having two hidden sides.

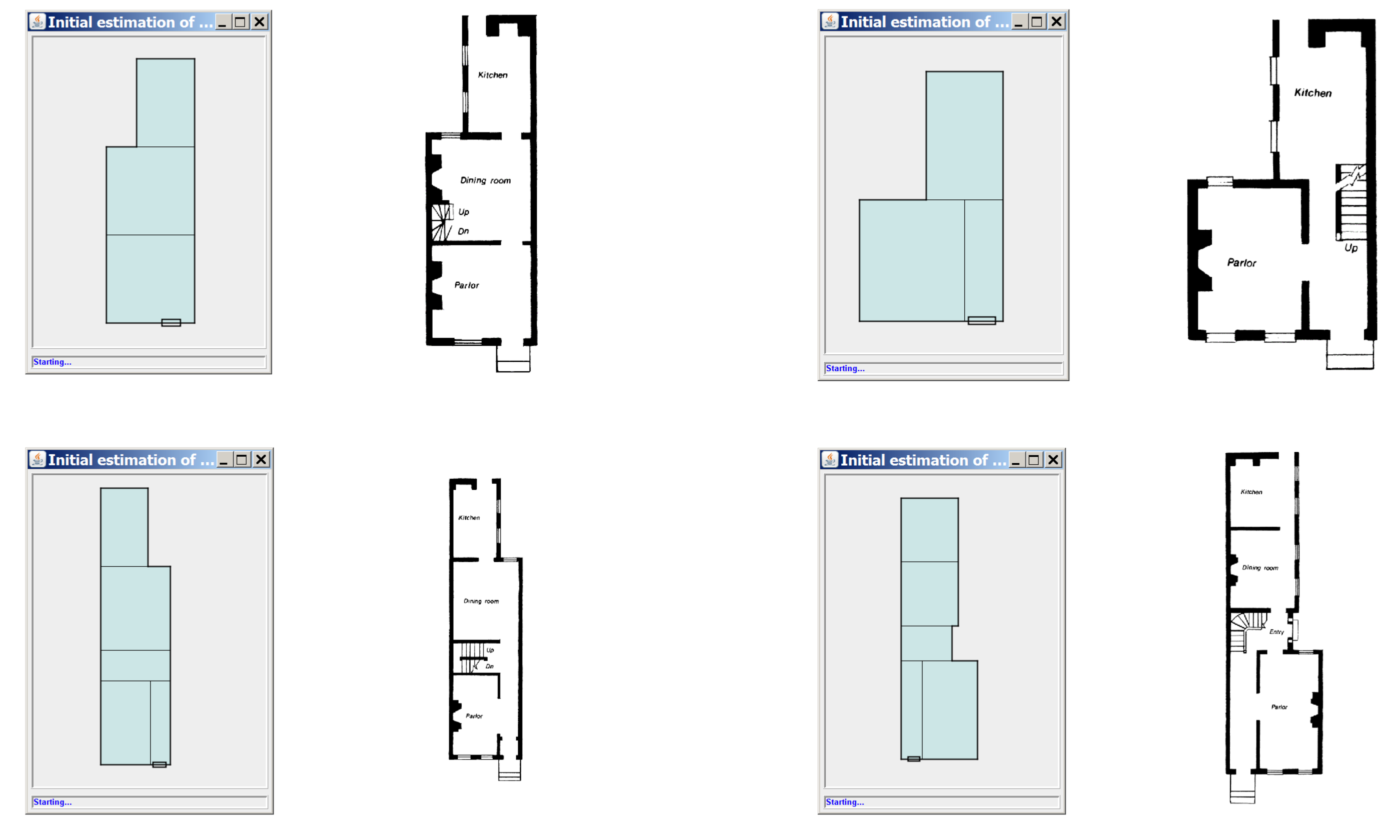
Knowledge used to predict the building interior layout is two fold: topological, e.g. the relationship between the different rooms in a building, as well as geometrical. Traditional shape grammars tend to consider shapes essentially in topological terms with rudimentary geometry thrown in, e.g., triangle, rectangle, square, etc. Parameterization is left to human resolution. Often little or no consideration is paid to geometry or more precisely, geometrical measurements. To predict the interior layout of real buildings, we are forced to consider their topology, measured geometry, and any additional local site/context-related inferences that may become forthcoming. The approach formulated above provides the opportunity, to examine the interaction between topology, exact geometry and context, in turn, to develop a mechanism to transform back and forth amongst these in the context of buildings.

Objective

We are currently producing a proof-of-concept storyboarded prototype for rule based prediction of interior layouts of buildings given a 2.5D model and a set of associated external features. The objective of this prototype is to provide an essential component of CERL's Building Characterization system (below). The core of this system consists of ontologies, implemented in Thetus Publisher, that formalize knowledge about various aspects of building design, e.g., function, anatomy, design drivers, and geocultural factors. Given raw data about a particular building, the system discovers knowledge about the building. PILOT provides the spatial reasoning necessary to completely characterize the building.



Perspective Representation of Ground Floor
5816 Walnut Street, Pittsburgh PA



Screenshots of Layout Prediction System
Baltimore Rowhouses

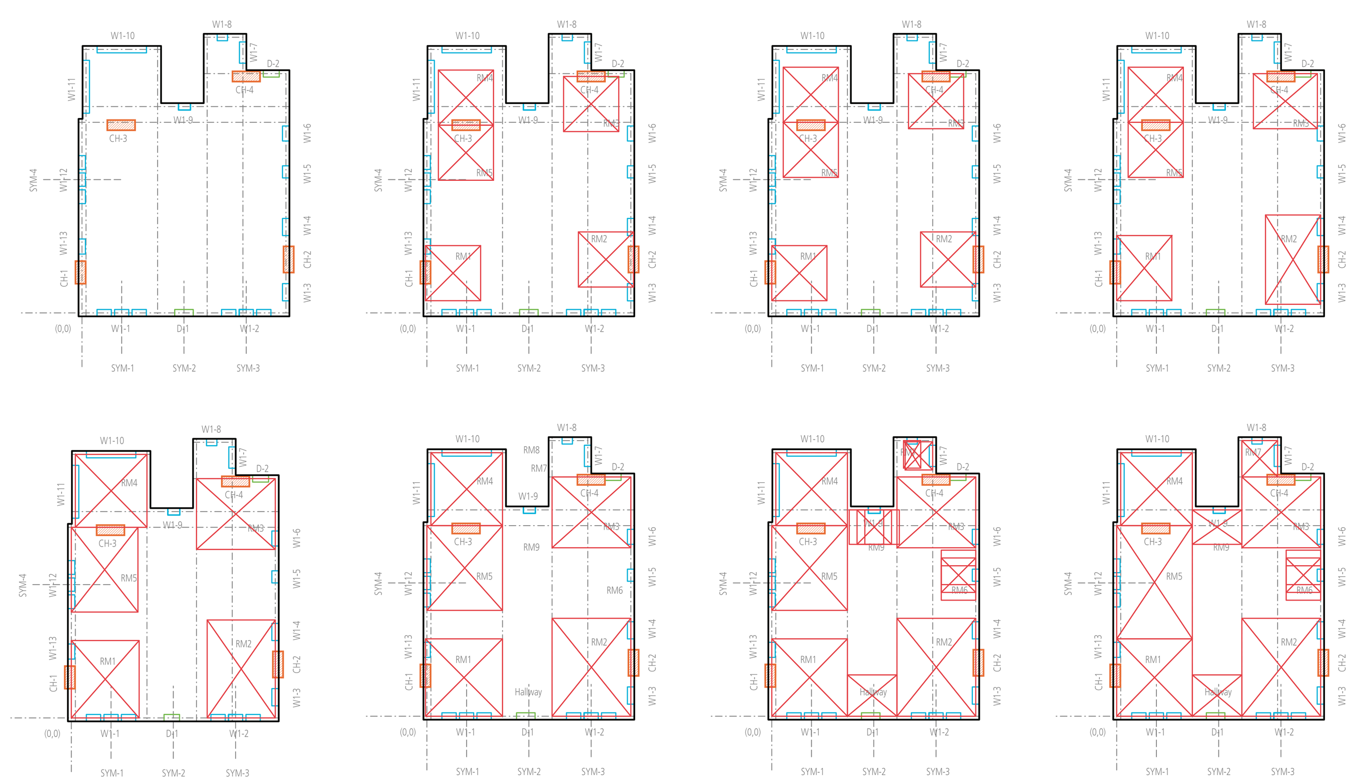
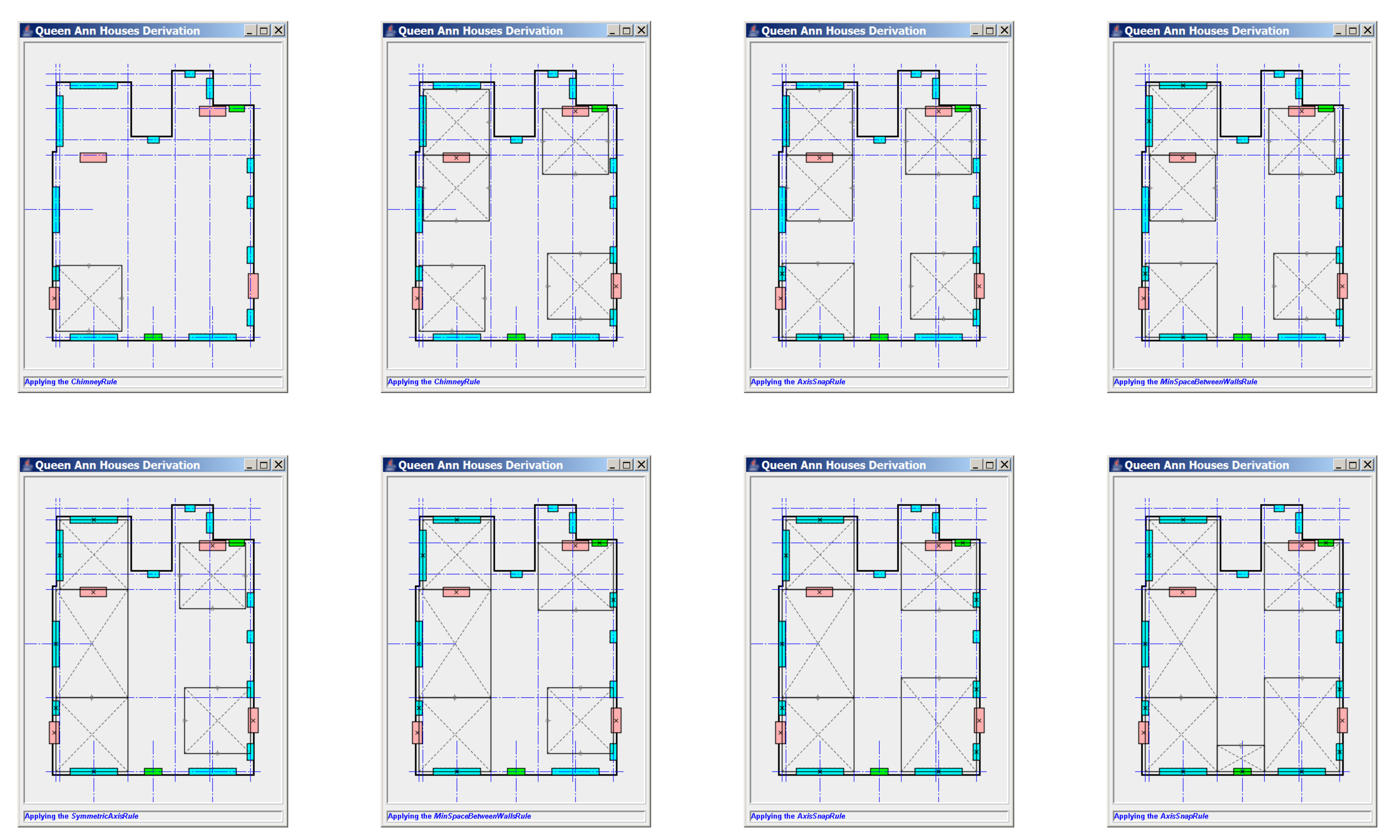


Diagram of the Layout Prediction Process
5816 Walnut Street, Pittsburgh PA



Screenshots of Layout Prediction System
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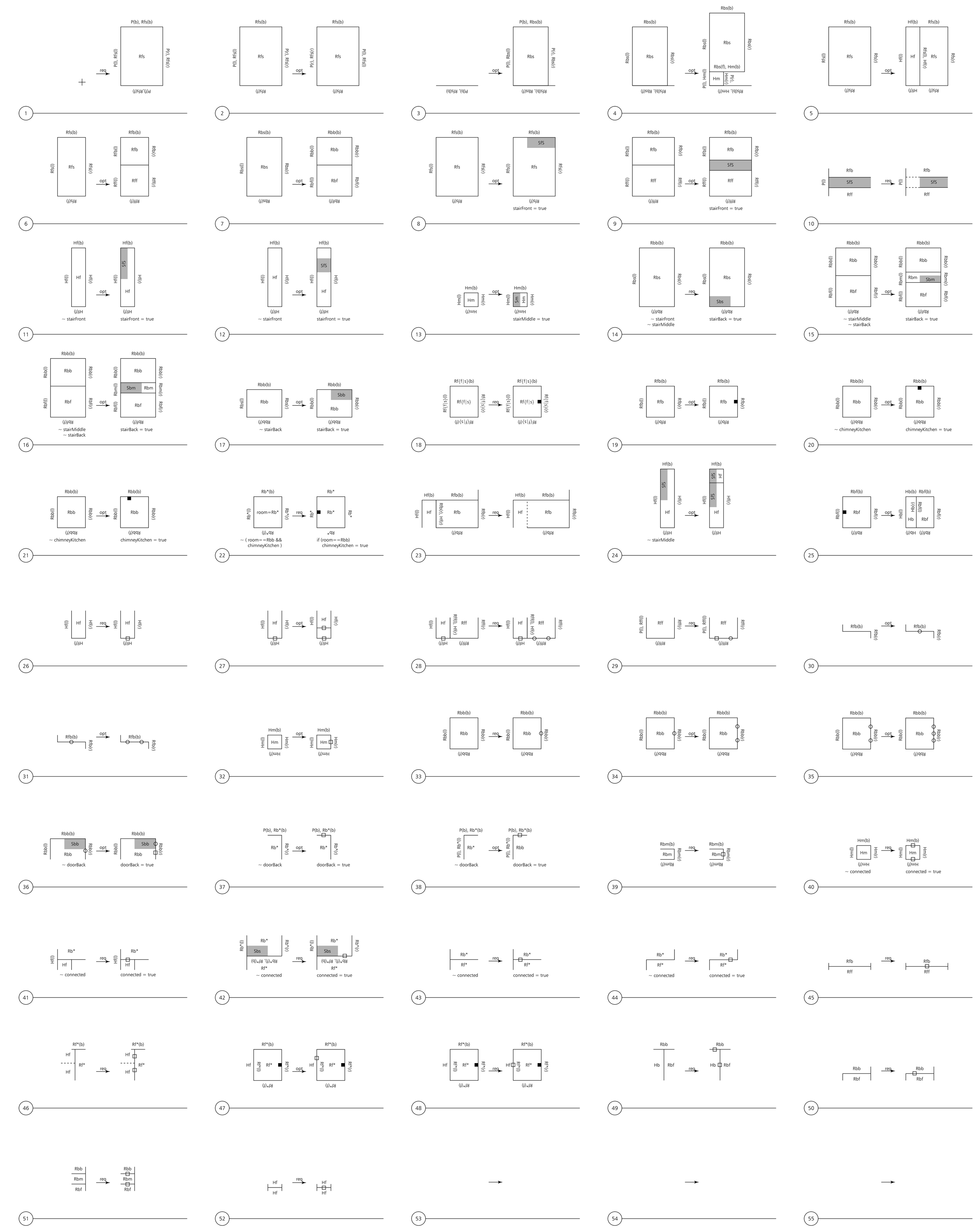

Original Shape Grammar for
Baltimore Rowhouses

Carnegie Mellon

US Army Corps of Engineers
ERDC Construction Engineering Research Laboratory [CERL]