The purpose of this study is to analyze Abraham William Hajjar's single-family houses in State College, PA, using shape grammar as a computational design methodology. Hajjar was a member of the architecture faculty at the Pennsylvania State College (now The Pennsylvania State University), a practitioner in State College, and an influential figure in the history of architecture in the area. In this study, shape grammars are used specifically to verify and describe influences of modern architecture, as defined by Hitchcock and Johnson (1932), and influences of local traditional American architecture on Hajjar's domestic architecture. The underlying hypothesis is that Hajjar's work is the result of a hybridity phenomenon that can be traced through a computational design methodology. The first step in this endeavor and the study focus is to establish Hajjar's single-family architectural language. Future work will be concerned with verifying and describing the hybridity between modern architecture and traditional architecture expressed in Hajjar's work by comparing his grammar with grammars underlying modern and traditional architecture likewise.

Keywords: shape grammar, modern architecture, American architecture, William Hajjar, hybridity, single-family houses

Introduction
The residential architecture of A. William Hajjar, a faculty member at Penn State and a practitioner in the area in the mid-twentieth century, incorporates many of the shapes, rules, and features of both European modern architecture and traditional American architecture. In this regard, his work reflects a quality that may be unique to certain architects in certain situations, in this case, to faculty-practitioners producing residential architecture in small American college towns in the mid-century. On the basis of this hybridity, this study offers an investigation of this architectural phenomenon by comparing and contrasting it with both the modern architecture of the time and the traditional American architecture of the local context. Via computational design methodology, this comparison will provide information to identify and establish Hajjar's single-family architectural language and verify and describe its hybridity.

The theoretical outcomes of this study answer
the following central questions in regard to the methodology and context: Can shape grammars be used to verify and describe the possible hybridity between modern and traditional architecture in Hajjar’s work? And, more broadly, can shape grammars be used to describe architectural hybridity phenomena in general? And, what influence did the social and technological contexts have on the layout of the houses designed by Hajjar? Highlighting Hajjar’s architecture is a significant aspect of this study such that insights into and interpretations of his work are generated and presented herein. However, Hajjar’s work features primarily as a case study for verifying the effectiveness of the shape grammar methodology to analyze hybridity in architecture.

The notion of hybridity between modern architecture and traditional architecture, or the duality between modern and traditional, international and local, and designed and vernacular in architectural practice has already been addressed in the literature. Terms or ideas such as “high style” versus “popular” architecture in the mid-twentieth century (Dewlin & Nasar, 1989), “Brazilian popular modernism” (Lara, 2008), “critical regionalism” (Frampton, 1983), and “vernacular modernism” or the contrast between vernacular traditions and the twentieth-century built environment (King, 2016) all refer to this duality, although in various geographic locations or time periods. Furthermore, the practice of mixing elements of European modernism with elements of traditional American styles in architectural practice began much earlier in the twentieth century, although not in the context of domestic architecture. As scholars such as Leland Roth note, most skyscrapers built in the 1920s combined selected elements of the International Style with traditional revival styles such as Renaissance and Gothic typologies (Roth, 1979). In a U.S. college town such as State College, in the mid-twentieth century, a key question on this point pertains to whether this hybridity can be described accurately, and if yes, whether shape grammars as a computational design method can be used successfully for this purpose.

Methodology

This paper is part of a larger research project that includes the following steps: (1) tracing Hajjar’s life and practice to identify likely influences on his work; (2) developing a shape grammar for the houses he designed in State College; (3) identifying or developing grammars for some of his likely influences; (4) comparing Hajjar’s grammar to the grammars of such influences to determine the nature and extent of their impact on his work; and (5) identifying aspects of the social and technological context that may explain such influences—i.e., trends in regard to lifestyle and available technology. This paper focuses on describing Hajjar’s single-family architecture by developing a grammar of his work. It includes an effort to identify and account for the rules Hajjar followed in designing single-family houses, a derivation of houses he designed, and solutions generated by the grammar that he did not design. Future papers will focus on other methodological steps related to the notion of hybridity.

Shape grammars are a specific class of production systems where transformational shape rules are applied recursively from an initial shape (Stiny & Gips, 1971). Since the 1970s, the concept of shape grammar has been used in architectural analysis when a pattern of design characteristics or a stylistic repetition of shapes in architecture is evident. This method has been used to analyze examples of historical architecture, such as the Palladian Villas (Stiny and Mitchell, 1978), Frank Lloyd Wright’s Prairie houses (Koning and Eizenberg, 1981), Queen Anne houses (Flemming, 1987), and Alvar Siza’s houses at Malagueira (Duarte, 2005). Given that the houses created by the study’s focal architect show evidence of shared shapes and transformation rules, the shape grammar methodology is appropriate for testing the hypothesis. For example, many of the houses designed by Hajjar include a wing (i.e., a garage) connected through a breezeway to the main volume. This main volume in his early work is a simple shoe box, which regardless of size and orientation usually has a low-pitched roof. This volume sometimes com-
prises two stories, usually with the bottom one hosting the main living area (living room, dining room, and kitchen) and the top one the sleeping area.

This study owes a debt to the work of other authors. In 1983, taking the transformation of Frank Lloyd Wright’s Prairie houses into Usonian houses as her focal case, Knight showed how stylistic evolution in art and design can be explained by the evolution of the underlying grammars. In 2001, Çağlakoğlu used this idea to propose a methodology to design contemporary houses from vernacular Turkish Hayat houses. Four years later, Chase and Ahmad used grammatical transformations to understand hybridity in design. Then, in 2011, Eloy and Duarte proposed the concept of transformation grammar to adapt an existing house type to contemporary living needs. In the same year, Kruger et al. (2011) advocated the use of transformations to study Alberti’s influence on Portuguese classical architecture. More recently, Benrós (2018) used transformations in design to study the phenomenon of hybridity in architectural languages. Against this background, the present paper is principally concerned with developing a shape grammar for Hajjar’s architecture as the initial step, but the ultimate purpose is to contrast Hajjar’s grammar with grammars of traditional American architecture and modern architecture.

William Hajjar

Abraham William Hajjar (1917-2000) was born on February 11, 1917, in Lawrence, MA, the youngest of a large immigrant Lebanese family. He received his bachelor’s degree in architecture from the Carnegie Institute of Technology (now Carnegie Mellon) in 1940 and his master’s degree from MIT in 1941 (Hadighi et al., 2016). In 1942, Hajjar joined the Department of Architecture at the State College of Washington, and in 1946, he moved to State Colleg to teach at the Pennsylvania State College. When Hajjar moved to State College, most single-family residences in the area were in the Georgian revival, Colonial revival, Tudor, and Cape Cod styles, although ranch and split-level houses were also starting to appear. Given that he designed and built thirty-two single-family houses in the area, Hajjar had a significant influence on the architectural language of the houses built in the area afterwards, especially in neighborhoods adjacent to university campus, like College Heights. In doing so, he contributed to the stability and popularity of localized/Americanized modern architecture by reshaping mid-twentieth century modernism in the area and, to some extent, in the United States.

While Hajjar was at Carnegie, the school’s philosophy of design was dominated by the Beaux-Arts, in line with most of the architecture programs in the US. It was probably at MIT that Hajjar was introduced to modernist architecture by proponents of modernism, such as Lawrence Anderson, who was Hajjar’s supervisor. Anderson not only designed the first modernist building on an American campus (MIT Alumni Pool-1939), but he also tried to bring a modern outlook to MIT’s program in the late 1930s. He advocated for Alvaro Aalto’s appointment as a research professor in architecture at the school in 1940. More importantly, it is likely that Hajjar was influenced by modernist ideas propagated by the German émigrés: He was at MIT when Gropius and Breuer were at Harvard, a time when students from the two schools attended lectures together and when Anderson would often invite Gropius, Breuer, and other outside critics to MIT to review the students’ work (Anderson, 1992).

Hajjar designed and built his thirty-two single-family houses in State College in two neighborhoods close to the Penn State campus. Many of his houses blend into the traditional houses in the neighborhood in terms of exterior building materials, volumes, and roof shapes. However, Hajjar’s houses have an internal organizational structure that is both modern for the time and unique to his work.

After a few years at Penn State, Hajjar built his first residential design in the area—his own family home. The house consists of a simple shoebox and a garage connected to the main house via a breezeway. With cement blocks for the base and wood cladding for the top part, together with a sloped roof,
Hajjar’s design is similar to other houses already built in the area. However, there is no front porch and no entrance in the front façade. In fact, the front façade seems to be a side façade when compared to those of other houses in the area. In addition, most of the local Colonial revival houses had a garage at the back of the building, whereas Hajjar rotated the organization of the house to include the garage at the front with the main entrance to the house hidden in the breezeway. Many of his later designs, are similar to his first family house.

Hajjar took advantage of the sloped sites of the College Heights neighborhood by situating the entryway between the two main levels of the houses—a feature that can be read as an adaptation of the mid-century split-level effect. Although in section and façade there are similarities between Hajjar’s architecture and mid-century split-level houses, in terms of the interior planning, the organization of the fenestration, and the slope of the roof, there are noteworthy differences. Hajjar’s interior planning leans toward a modernist idea of open plan, especially in the public part of the house (living room-dining room-kitchen). Specifically, typical mid-century split-level houses were still organized so that the living room faced the street, whereas Hajjar’s designs are open with the kitchen facing the street and the living room at the back of the house.

In the plans, the entryways to Hajjar’s houses are generally in the middle open space, which could include a hall and a family/sitting room. Hajjar’s typical plan can be read as a modern plan with an open space in the center, rooms organized on both sides, and the service spaces, including the bathroom, staircase, and hallway in the middle. However, it can also be read as a very traditional plan as used in the Georgian period and the Georgian Revival, i.e., a developed hall-parlor organization or as a developed foursquare design (Figure 1).

Considering the spatial relationships in Hajjar’s houses it is possible to identify five subtypes of floor-plans (Figure 2): (1) tri-partite organization, where a breezeway connects the garage to the inhabitable space, the lower floor hosts the living areas, and the upper floor the sleeping area; (2) split-level organization, where the sleeping area is a half floor above the living area; (3) butterfly or cross-shape organization; (4) compact organization, where a square-shaped plan reflects Hajjar’s idea of a core area; and (5) linear organization.

**Hajjar’s Grammar**

The grammar of Hajjar’s single-family houses was developed based on the five subtypes described above. The grammar encompasses four phases or groups of rules: (1) Rules that capture the way in which Hajjar situated his houses on the lots (Rules 1-2, Figure 3); (2) Rules that describe the formal relationships between...
Figure 3
Selected rules of Hajjar's grammar: locate house on plot and define relationship between volumes.

R1: L1
   W1 → L1
   W2 L2

DA = Design Area
S = Setback

R2: W → L
   DA

-10° <= a <= 10°
Wd >= 3'
BA= Buildable Area

R3: W → L
   BA

W1 = W
W1 <= L
W1 x L = In.S Area
1.020 SF <= In.S Area
If W1>L then W1/L = 3/2
If W1<L then W1/L = 2/3

R4: L1 → L1
   In.S
   W1

0 <= a <= L1 - L2
7' <= b <= 24'
G can be garage or inhabitable space

R5-a: L1
   In.S
   W1
   L2
   G
   W2

R5-b: L1
   In.S
   W1
   L2
   Con.
   L3
   In.S
   W3

R5-c: L1
   In.S
   W1
   L2
   Con.
   L3
   In.S
   L4
mass volumes (Rules 3-5, Figure 3); (3) Rules that describe the way in which the interior space is divided into smaller rooms or spaces (Rules 6-29, Figures 3, 4 and 5); and (4) Rules that generate details such as the placement of closets and wall thicknesses.

Figures 6 and 7 show derivations of designs in the corpus used to infer the grammar. In addition to all the houses designed by Hajjar included in the corpus, the grammar can generate Hajjar-inspired houses—solutions generated by the grammar that were not designed by Hajjar (Figure 8). To facilitate the generation of designs and eliminate human input while applying rules to generate houses, a computer program has been developed. The code was written in the Python scripting language for Rhino.

**Discussion**

As noted earlier, this paper is part of a larger study undertaken with the purpose of analyzing Hajjar’s hybrid architecture by developing a grammar of his work and comparing its shape rules with grammars for works of modernist and traditional American architecture. The selection of works with which to compare Hajjar’s work was based on the analysis of his personal and professional life, through which likely influences were identified. Among them are the works of immigrants including Gropius and Breuer, with whom Hajjar was in contact while at MIT, and of Frank Lloyd Wright, whom Hajjar’s son referenced as an important influence on his father’s work (personal interview, 2016). It is important to note that a shape grammar of Wright’s Usonian houses has already been created (Knight, 1983) based on a transformation grammar of his Prairie Style houses (Koning & Eizenberg, 1981). The grammar of Gropius and Breuer’s architecture in the United States needs to be developed, though. In terms of traditional American architecture, it is necessary to identify house types or styles that might have influenced Hajjar’s architecture and develop the corresponding shape grammars. Preliminary analysis suggests some possibilities in this regard but further work is needed to con-
firm them. In any case, a grammar for the Buffalo Bungalow houses developed by Downing and Flemming (1981) will be considered in the analysis.

An important question in comparing shape grammars pertains to the level of detail needed. This question can be answered by finding where hybridity exists, whether in the functional organization, the building system, or in the decoration, following Habraken's definition of house type (1988). At this stage, Hajjar's grammar is used to describe the spatial relationships in his interior layout and the volumetric relationships in his overall design, mainly because the preliminary analysis suggests that hybridity might be most important at this level. The next step is to determine the extent to which the rules of the respective grammars are similar or different. By comparing the rules of Hajjar's grammar to those of other grammars, we may be able to determine which rules have been maintained, changed, deleted, or added. In this regard, it is important to note that the grammars must be developed in a way that enables comparison, as noted by Benrós in her comparison of Palladian Villas, Wright's houses and Siza's homes (2018).

Figure 5
Selected rules of Hajjar's grammar: divide interior space into smaller spaces (continued).
Figure 6
Derivation of the Snowdon House, designed by Hajjar in 1959.

Figure 7
Derivation of Eisenstein House, designed by Hajjar in 1954.
Future Possibilities

In the present paper, Hajjar's single-family houses were analyzed via a shape grammar. Although College Heights is designated as a historic district, mid-twentieth-century houses added to the neighborhood are not considered historic features of the neighborhood. At present, the authors of this paper are in negotiation with the Borough of State College and the Pennsylvania State Historic Preservation Office to determine whether a “new” College Heights historic district with modern houses can be designated. Should this effort meet with success, any new house built in the neighborhood would be required to conform to certain regulations and design guidelines. In this context, the grammar of Hajjar’s houses might be helpful.

Contributions

The proposed study makes a contribution to the field of architecture not only by presenting shape grammars as a tool for verifying and describing hybridity between modern and traditional architecture, but also by describing the work of Hajjar, a local architect who contributed to the stability and popularity of modern architecture in the United States. Furthermore, it is our hope that the study will show the potential of shape grammars as a complementary tool that architectural historians can use to verify formal and functional similarities between styles in a rigorous way.

REFERENCES


Habraken, J 1988 ‘Types as a Social Agreement’, Third Asian Congress of Architects, Seoul, Korea


