Non-manifold Topology for Architectural and Engineering Modelling

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Non-manifold topology (NMT) allows the user to construct light-weight conceptual spatial architectural models which define the overall enclosure and the internal cellular division within that enclosure. The objective of this workshop is to give participants hands-on opportunities with a new software library that we have been developing under a research grant from the Leverhulme Trust. On the first day, the concepts of non-manifold topology will be introduced, including non-regular modelling operations. On the second day, we will introduce two plug-ins, which have been interfaced to our NMT tools: a) building energy simulation using OpenStudio and EnergyPlus and b) structural analysis software.

Keywords: Non-manifold topology, Visual data flow programming, Building performance simulation, Computational design

WORKSHOP ORGANIZERS

Wassim Jabi is Reader of Computational Methods in Architecture at the Welsh School of Architecture, Cardiff University. His current research into non-manifold topology, parametric design, building performance simulation, and robotic fabrication in architecture is supported by the Leverhulme Trust and EPSRC. Dr. Jabi has written extensively on architectural computation including the recent book “Parametric Design for Architecture”, published by Laurence King Publishing. He is a former president of ACADIA and a member of the editorial board of the International Journal of Architectural Computing (IJAC). He studied architecture at the American University of Beirut and his MArch and PhD are from the University of Michigan.

Robert Aish is Visiting Professor of Design Computation at the Bartlett School of Architecture, where his research into the use of non-manifold topology to represent architectural space is supported by the Leverhulme Trust. Previously he was Director of Research at Bentley where he led the development of GenerativeComponents and Director of Software Development at Autodesk where he led the development of DesignScript. He is also a cofounder of the SmartGeometry group. He studied Industrial Design at the Royal College of Art and has a PhD in Human Computer Interaction from the University of Essex.

INTRODUCTION

Non-manifold topology (NMT) allows the user to construct light-weight conceptual spatial architectural models which define the overall enclosure and the internal cellular division within that enclosure. The objective of this workshop is to give participants hands-on opportunities to build spatial models using NMT and use these models for various tasks such as building energy simulation (using EnergyPlus). The work-
shop will consist of formal instruction, practical exercises and opportunities for the participants to use NMT modelling with their own architectural projects and research.

On the first day, the concepts of non-manifold topology will be introduced, including non-regular modelling operations. It is assumed that participants are already familiar with conventional solid modelling using manifold topology and regular Boolean operations. Some formal exercises will be presented to help the participants acquire the appropriate hands-on modelling skills before exploring their own projects, guided by the workshop tutors.

On the second day, we will introduce connections from the NMT tools to building performance simulation using a plug-in for energy analysis (using OpenStudio/EnergyPlus). The formal instruction on the second day will address the special modelling constraints required by this plug-in. The workshop will allow time for the participants to build and test different non-manifold models, guided by the workshop tutors.

**BACKGROUND**

Designing, representing and reasoning about architectural space is one of the unique and defining properties of architecture (Ching 2004). Accounts from the literature indicate that buildings are often first conceptualised as a hierarchical sequence of related spaces (Curtis 1996). Only once this spatial arrangement has been defined does the focus shift to how these spaces will be realised by the use of physical building components. However, in BIM systems, the most prevalent approach is to represent a building as a collection of 3D solid models with each solid representing an individual physical building component (Attia et al. 2011). Modern BIM systems do not require nor advocate the creation of a conceptual spatial model as the basis of the building fabric model. Therefore, one of the primary motivations for the development of the tool to be used in this workshop is to rethink the BIM design process to focus first on building a conceptual model that can act as an ordering framework and support for further design development. In this process, an NMT conceptual model would serve as a defining model for a derived building fabric model. The NMT conceptual model would define both the spatial configuration and topology as well as provide a skeletal framework that can be ‘thickened’, either manually or using computational algorithms and rules, into actual building fabric components (Aish and Pratap 2012).

The term ‘topology’ is derived directly from the Greek τόπος (place), and λόγος (study), and therefore can be defined as the study of place - or the study of space. This is precisely our aim - mainly to enhance the representation of space in computational design systems through the use of topological concepts. Topology defines the relationships between entities and is concerned with the properties of space that remain constant when it is subjected to deformations. NMT is well-suited to create a lightweight representation of a building as an external envelope and the subdivision of the enclosed space into separate spaces and zones using zero-thickness internal surfaces. In addition, NMT allows entities with mixed dimensionalities to co-exist in the same entity. Because NMT maintains topological consistency, a user can query these cellular spaces and surfaces regard-
ing their topological data and thus conduct various analyses. Prior publications by the authors suggest a strong potential of using geometrical entities with NMT as a representation of architectural space that is also highly compatible with the input requirements of building performance simulation (BPS) engines (El-lis et al. 2008; Jabi 2015; Chatzivasileiadi et al. 2018; Wardhana et al. 2018), structural design, fabrication planning (Jabi et al. 2017) and spatial reasoning (Jabi 2016; Jabi et al. 2017; Al-Jokhadar and Jabi 2017). The approach afforded by NMT provides topological clarity that has the potential to allow architects to better design, analyse, reason about, and produce their buildings.

In this workshop participants will use Topologic, an open-source software modelling library enabling hierarchical and topological representations of architectural spaces, buildings and artefacts through NMT. Topologic is designed as a core library and additional plugins to visual data flow programming (VDFP) applications and parametric modelling platforms commonly used in architectural design practice. This workshop is part of the Non-Manifold Research project funded by the Leverhulme Trust (Research Project Grant Number RPG2106-16) at the Welsh School of Architecture, Cardiff University and at the Bartlett School of Architecture, UCL. The building performance analysis tools introduced at the workshop have been developed in collaboration with our industrial partners: The National Renewable Energy Laboratory (NREL) and BuroHappold Engineering. For more information, please visit non-manifold.net or contact Dr. Wassim Jabi (jabiw@cardiff.ac.uk).

WORKSHOP SCHEDULE

Day 1

- 9:00 - 10:00 Welcome and software installation
- 10:00 - 12:00 Introduction to Non-manifold Topology
- 12:00 - 13:00 Hands-on initial experimentation with NMT
- 13:00 - 14:00 Lunch
- 14:00 - 16:00 Build and analyse a simple office building (energy and structure)

Day 2

- 9:00 - 10:00 Discussions regarding own project
- 10:00 - 13:00 Individual development of project using NMT tools
- 13:00 - 14:00 Lunch
- 14:00 - 15:00 Analysis using OpenStudio/EnergyPlus and/or Autodesk Robot
- 15:00 - 16:00 Presentation of results

PREREQUISITE SKILLS AND KNOWLEDGE OF PARTICIPANTS

The non-manifold topology library, Topologic, written in C++, will be available as a Dynamo plugin. Participants should be familiar with the basics of Dynamo visual programming. They should also have knowledge of and an interest in building performance simulation including energy analysis (OpenStudio/EnergyPlus).
REQUIRED INFRASTRUCTURE OF THE PARTICIPANTS
Participants are required to have a modern Windows 10 64bit laptop with Dynamo installed. There should be 3 GB available storage space for software installation.

SKILLS ACQUIRED BY PARTICIPANTS
At the end of this workshop, participants will be able to:

- Understand non-manifold topology and related concepts
- Explore the benefits of the use of non-manifold topology in the representation of buildings
- Represent their buildings appropriately for building performance analysis

EXPECTED OUTCOMES
The expected outcomes of the proposed workshop are the following

- Parametric Dynamo definitions
- Non-manifold 3D models
- Building performance analysis visuals

REFERENCES
Ching, FDK 2014, Architecture: Form, Space, John Wiley & Sons
Curtis, WJR 1996, Modern Architecture Since 1900, Prentice Hall