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Foreword

Reciprocal diagrams: Innovative applications of past theories

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The geometric relationships between a structural configuration and its internal force distribution have not received much attention for nearly hundred years. Directly stemming from the most fundamental principles of statics, the underlying theories were brought to life by the most influential researchers of 19th-century civil engineering such as J.W.M. Rankine, J.C. Maxwell, L. Cremona, and C. Culmann. The graphical approach they proposed for the analysis of trusses soon became a favourite among engineers, offering a less error-prone and faster alternative to solving equilibrium equations by hand. Its popularity faded with the advent of portable calculators and later with the spreading of modern computers. Today, thanks to advances in computer-aided modelling and computational methods, new research tends to reverse the trend.

The recent revival, however, has other goals and challenges in mind. Indeed, recent computerised uses of graphical methods are not meant to compete with structural analysis tools. Instead, they aim at opening new horizons for 'shaping structures' – that is, the geometric exploration of structural arrangements in static equilibrium – a shift crystallised by Allen and Zalewski's eponymous book in 1997. More precisely, three main reasons articulate the new direction of research on reciprocal diagrams: (1) they provide an intimate understanding of the intrinsic geometric properties of static equilibrium and therefore its optimisation; (2) their automated construction in a computer-aided environment facilitates interactivity and therefore design opportunities, not only in the form but also the force domain; and (3) the limits of their fundamental principles, long confined to the plane, or at least hardly effective for spatial problems, are now overcome thanks to three-dimensional (3D) computer-aided design (CAD) software.

The eleven articles in this issue cover the wide spectrum of these three incentives. The first four articles display the elegant theoretical simplifications that occur when dealing with reciprocal diagrams. Mitchell *et al.* and McRobie *et al.* explore the connections between mechanisms and states of self-stress and how this can be related to properties of form and force diagrams. Mazurek *et al.* use reciprocal diagrams for topology optimisation. Williams and McRobie show how discontinuous stress functions provide a direct relationship between bending moments and reciprocal diagrams. The next articles emphasise the role of graphical computation when exploring structural shapes interactively. Fivet reviews the limits of projective transformations. Lee *et al.* propose new grammar rules for the automated construction of static equilibrium. Zastavni *et al.* approach the question of robustness at the early design stage. Ohlbrock and Schwartz develop a third diagram to control the topology of the network more explicitly. Fantin and Ciblac extend the solution space of thrust networks for masonry vaults. McRobie develops 3D reciprocal diagrams by means of Minkowski sums. And, finally, Akbarzadeh *et al.* provide construction methods for the design of spatial structures using reciprocal polyhedra.

Early versions of most articles originate from contributions presented at the Symposium of the International Association of Shell and Spatial Structures (IASS) in Amsterdam, 2015, or from the conversations that took place during the special sessions organised at the event by the guest-editors of this issue. We would like to thank all contributors for their valued articles and the many reviewers for the fruitful scientific discussion that has emerged throughout the process. Special thanks go to Noelle Paulson for her assistance with the editorial process. Finally, we are grateful to the editors of the *International Journal of Space Structures* for the opportunity to share our field of research, gathering some of the most important recent advances, through this journal.

Philippe Block
ETH Zurich, Switzerland

Corentin Fivet
École polytechnique fédérale de Lausanne (EPFL), Switzerland

Tom Van Mele
ETH Zurich, Switzerland