

DIRECTED DEPOSITION: EXPLORING THE ROLES OF SIMULATION AND DESIGN IN EROSION AND LANDSLIDE PROCESSES

James Melsom (Principal Author)

Institute of Landscape Architecture, ETH Zürich

Christophe Girot

Institute of Landscape Architecture, ETH Zürich

Ilmar Hurkxkens

Institute of Landscape Architecture, ETH Zürich

ABSTRACT

Mountainous territories are intrinsically landscapes of transformation, under the continuous in-fluence of the processes of erosion, avalanche, rockslides, and reforestation. Over centuries of settlement, techniques have been developed to mitigate and control these effects. Although such interventions are often associated with huge land-use and visual impacts, the field of intervention has been primarily the domain of the engineering and environmental science fields. This research is primarily interested in the potential and means of landscape and architectural design to interact with such processes, taking the hillsides above urbanised alpine towns as test case scenario.

In order to allow this interaction, familiar design modelling softwares such as Rhinoceros can be coupled in a direct workflow with GIS and specialised erosion simulation softwares, already in use by alpine engineers. The resulting potential is for an interdisciplinary approach in which can integrate an architectural design consideration into such erosion structures and their contexts, whether future path systems, bridges, promontories, shelters, and the surrounding urbanised landscape. An increasing urban pressure on such environments has accompanied the gradual shift in the urbanisation of these territories from agriculture and industry to recreation and short-term settlement. This shift from private productive landscapes to public recreational ones raises issues not only of physical design, but of feasibility, investment and the sustainability of such systems. In seeking new synergies between maintenance, safety, ecology, and public amenity, new opportunities for the future design of these landscapes can be proposed.

INTRODUCTION

Working with and against environmental processes, such as the movement of water, earth, and rock, and terrain, has been a perpetual challenge since the dawn of civilization. While it has been possible to gradually tame many landscapes to perform in a predictable manner, there are many circumstances where we are forced to live with and around such processes in everyday life. This research is primarily interested in the potential of landscape and architectural design to interact with and refine such transformative processes, where they intersect with socio-cultural use. In order to investigate the designed redirection of erosion and landslide processes already observable in nature, we have chosen the hillsides above the urbanised alpine town of Davos, Switzerland as test case scenario.

The research specialisation continues a research and design focus focussed on processes of material deposition within river and floodplain systems, further down the water catchment chain (Giriot 2012). This specific alpine research is compelling in the context of anthropocene processes, as we are specifically focussed in the appraisal, harnessing and redirection of existing environmental phenomena, given what can be understood as our inevitable interaction with these processes (Sijmons 2015). Within this broader research which has ecological, cultural, and formal potential, this paper explores the practical aspects of allowing the designer, and resulting design methods to enter the mixed disciplines of transforming these evolving mountain landscapes.

There is a long tradition behind the development of the discreet landscape elements which control avalanches, rock, mud, and landslides. Due to this gradual process, the cultural, functional and aesthetic role of such elements in the landscape remains relatively undiscussed, epitomising an approach that is primarily pragmatic in both engineering and expense. It is perhaps no surprise that these elements have a dominant physical and visual presence in the contemporary landscape, serving a functional and a symbolic role. Since these elements often coincide with cultural use, such as roads, paths, and crossings, the potential for design synergies with these systems, which go beyond a purely engineering and ecological background, is clear. This research proposes that the intuitive linking of common design software to direct landslide simulation and engineering solutions can provide a meaningful integration of landscape architectural design into these transforming landscapes. Through the elaboration of these methods within which design can enter the process of landscape management, the modelling processes of the landscape designer can be combined with the simulation capabilities of the specialised engineer, allowing new potential for practical collaboration.

PROCESS

The focus of this research project has been to create a functional link and workflow between intuitive modelling software with highly specialised GIS oriented simulation packages. The research can capitalize on a broad and specialized tradition in alpine

erosion research, centered on the de-velopment of engineering typologies and implementation practicalities in extreme topographies. The simulation solution consists of several stand-alone simulation modules based around the RAMMS, Rapid Mass Movement Simulation, platform. This solution, developed by the Swiss gov-ernment research institutions SLF (Institute for Snow and Avalanche Research), WSL (Swiss Fed-eral Institute for Forest, Snow and Landscape Research), and the ETH Zurich, is directed at real-world applications in the prediction and adaptation of major terrain movement and erosion proces-ses in mountainous landscapes. Its simulation results have been supported and improved with ex-tensive testing in the Alps, specifically to test the placement and effectiveness of dam and netting structures to alleviate the negative impacts of these inevitable phenomena. (Bühler et al. 2011/12).

In order to ensure relative accuracy of the research outcome, and to control the results, the local site was chosen as an urbanised environment (the well-known Swiss town of Davos) in the near vicinity of existing published RAMMS simulation research sites, with similar weather, geology and vegetation characteristics (Christen 2010). While the verification and detailed accuracy of the first design intervention hypotheses is not the focus of the study, it is nevertheless feasible to supple-ment the data in order to create a highly accurate result.

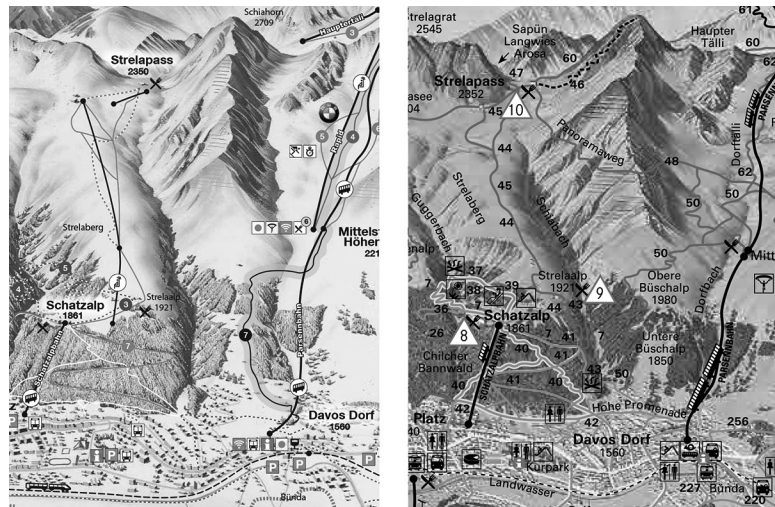


Figure 1
Comparison of program and path network of the 2014 summer and winter season maps (Source: Davos Klosters Tourism Authority 2012).

SITE APPROACH

The town of Davos is characterised by diverse seasonal activities, with extreme contrasts in landscape program between summer and winter months, as it transforms from summer hiking destination and popular skiing and wintersport destination (*Figure 1*). It lends itself well to such a study, as it combines areas of natural hazard with a dense network of programs and landscape use, with social program running almost uninterrupted throughout the seasons.

While there are many variations on the implementation of structures built for the control of such terrain-movement phenomena, they tend to fall into three main categories: dam-walls, steel/wooden grids, and netting solutions (*Figure 2*). The choice of and implementation of such structures depends on the local topography, neighbouring paths/structures, and nature of the material to be caught or diverted.



Figure 2

Various barriers concrete, steel screens and hanging net barriers, Switzerland (Sources: Stager 2013; Roffler 2012; Lässig 2009).

The chosen interventions which are most of interest to this study is a series of concrete walls, which would partially direct, and collect, avalanche and rockfall debris. These would be placed into the valley of the Schiabach watercourse, which also features several summer path crossings, and closely neighbouring winter activities. Such concrete structures are typical in such alpine settings, however often used in less steep inclines, due to construction considerations. For the purposes of this research, the test geometries of the structures, three concrete dam-walls, can be considered as a first iteration in this possible design process, potentially incorporating design program and public use. As the research continues, we look forward to working with variations and iterations, as has become key to the landscape design method (Giriot 2010).

PROCESS AND ENCOUNTERED ISSUES

The typical RAMMS simulation workflow involves manual editing of barrier structures in the soft-ware, or the need to create these elements in a GIS platform. In order to facilitate the most flexible link between designer and simulation software, flexible design applications were chosen which are intuitive for the designer, yet allow large scale precision. Rhinoceros 3D was chosen as modelling interface, as a flexible platform which also allows scripting and deals well with global position data, via plugins such as with Grasshopper, GHowl, and custom C# components.

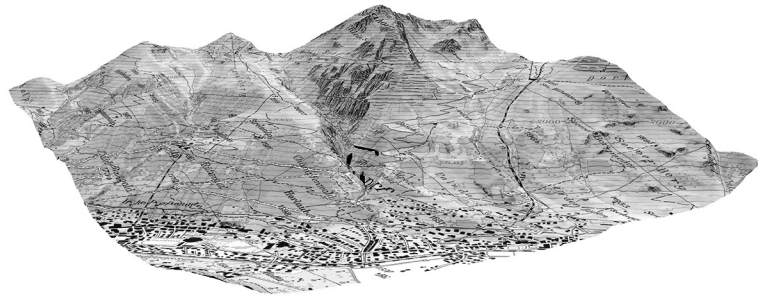


Figure 3

DEM terrain in Rhinoceros, 4x3km in a resolution of 5m. This un-edited textured landscape model was generated from LIDAR aerial laserscan data, and demonstrates simple wall barrier elements, forest edges, and urbanisation (Source: authors/ Swisstopo).

The RAMMS simulation platform lends itself well to automation, as it provides both GUI and com-mand line batch processing to begin simulation tasks. The basic requirements for an avalanche or rockfall simulation are terrain, forest, surface characteristics, release area, and barrier structures. In order to feed each of these formats from Rhinoceros into RAMMS, typical GIS formats DEM ASC (a Digital Elevation Model grid), and Shape files are required.

In this example, a Rhinoceros terrain file was generated from DEM data using standard grasshopper components, with a custom C# component converting to and from the local swiss coordinate system from WGS 84, as recognised by GHowl, for export (*Figure 3*). The resolution of the resulting working area depends on the simulation area and impact; as can be expected in such computation intensive simulations, refining the simulation area and resolution for an op-timal processing overhead is necessary, particularly within an iterative design process.

All Shape information, whether forest, release area, or barrier structures can be converted with a custom Python component from standard curve geometry to SHP files, which required by RAMMS.

Remaining factors can be either adjusted in the RAMMS GUI or added to a batch command line operation, allowing for additional landscape characteristics to be visualised in Rhinoceros before simulation.

The resulting simulation, based on height data assembled in Rhinoceros, demonstrates a satisfactory result, the simulation generating depth, speed, and acceleration data both as numerical data (ASC grid GIS format) and images. The various modules deliver varied results and data formats, whether avalanche, mudslide or rockfall event. For this reason the key workflow module within the scope of this research remained the avalanche simulation (*Figure 4*).

In the case of this simulation, an exaggerated quantity of avalanche material was simulated, since the initial tests centre around the feasibility of the workflow, and comparison of data for feedback within Rhinoceros, rather than the accurate avalanche event, which has been satisfactorily proven in other studies (Bühler 2011).

Either the resulting texture files or the output ASC grid value data can also be loaded into Rhinoceros, allowing sufficient feedback to refine the design scenario. The use of image texture until the current research level has maintained a fast and workable modelling environment in Rhinoceros, which which to adjust the design solution (*Figure 5*).

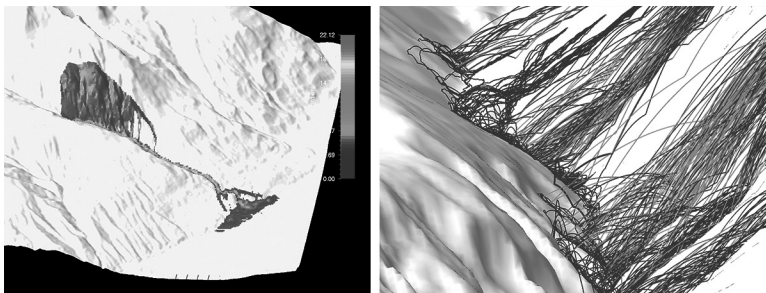


Figure 4

The Davos simulation without barriers or intervention, showing the large scale avalanche depth scenario (left). The alternative RAMMS module for detailed rockfall simulation shows individual trajectories, although it is restricted in use to specific sites where loose rock formations occur and can be characterized (right) (Source: authors/Swisstopo/WSL).

Several issues were encountered which can be addressed within the course of this continuing re-search:

As with many such processes which rely on computation intensive simulation, a suitable workflow must be refined to allow for a truly iterative design process. The ability to update the model from within Rhinoceros can also allow the resolution of the model, and the simulation, to be gradually improved as the design progresses, or individual design hypotheses are tested. There is adequate research into the impact of terrain resolution on the resulting simulations (Bühler 2011), which could allow a predictive approach to the refinement of the design simulations, gradually raising the resolution of the simulation as the design progresses.

It is perhaps advisable to encapsulate several of the steps into discrete Grasshopper components, to simplify the process to assemble a complete simulation scenario, given the inherent complexities in preparing the initial site.

In a truly iterative design process, the necessity to compare and evaluate the success of the various simulations is crucial. The most promising method with which to accomplish such a comparative workflow would be the application of the original numerical simulation data (ASC), rather than the direct image output from RAMMS.

The key strength of the RAMMS simulation platform is its ability to produce an animated demonstration of the landslide process, demonstrating the peak values of depth, speed and pressure. While these cycled animations have been implemented within Grasshopper, the ASC data would provide deeper understanding of the impact of the implemented design.

In order to construct a relatively accurate simulation, a minimum understanding of the nature of the processes, the site morphology, and the simulation assumptions is required by the user. The interdisciplinary nature of this process cannot be underestimated, as specialist, and often local knowledge is required to establish a reliable simulation environment.

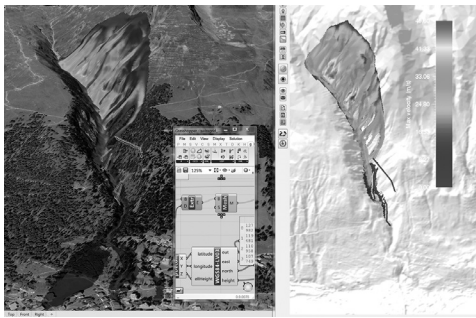


Figure 5
The DEM model and wall obstacle elements in Rhinoceros, showing the max. avalanche pressure and unrestricted flow (in red), and the RAMMS GUI showing the maximum velocity and obstacle impact (Source: authors/Swisstopo/WSL).

ADDITIONAL DEVELOPMENT

There are many potential areas for further development, and for the refinement of design applications, particularly in the detailed characterisation of local conditions, notably soil, rock, and forest. A truly comparative workflow may compare and contrast a minimal engineering solution, and a programmatically designed proposal. We are interested in investigating further the direct, practical considerations of such an approach - the simulation platform is flexible in scale, and can be scaled to investigate large areas or detailed situations. The relationship of the human movement and program patterns

in and around such structures, and the investigation of additional design potentials, remains of key interest, as being well within the means of the current workflow.

The potential of combining the design, construction, and maintenance of path, observation, and recreational structures with hazard prevention creates entirely new possibilities for form, function, as well as the investment in such structures. Such synergies are certainly advisable in many areas of future infrastructure development, and the continuation of this research project shall require several test sites with which to develop the potential of such interdisciplinary workflows.

For practical reasons, the current study has limited itself to a catalogue of officially funded design elements, which are recognised by the Swiss government (Bauman 2012). Simulations to date have focussed primarily on concrete wall structures, however additional structures can feasibly be added to the same processes, and design paradigm.

The RAMMS software has been applied in various scenarios worldwide, such as New Zealand and Peru (Schneider 2014), so it is absolutely feasible that the process can be adapted for other geo-graphical coordinate systems and applications. Beyond historical documentation, such as "Gefahrenkarte" (hazard maps), suitable sites can also be ascertained through computational methods. Such inaccessible or unpopulated sites often coincide with low data density, in terms of DEM, terrain characteristics, erosion, and vegetation, so the analysis of the terrain through other means within Rhinoceros is also possible (Fraguada 2013). Through the combination of Photogrammetry, laser scan data, and terrain surface analysis, the nature of the ground material can be ascertained, and even the size of the rock material automatically detected (Klein 2010), so as to allow further detailed analysis within Grasshopper, regarding Forest typologies, resistance, and predicted deposition over time. In such cases, even in data poor areas local data collection would suffice to create suitable RAMMS simulation data.

OUTLOOK

The gradual yet continuous increase in computation power of simulation platforms and infrastructure over recent years allows iterative, and comparative workflows to enter entirely new fields of design and planning. Such methods also generate through their nature a trajectory of logic and re-refinement, which can only support true interdisciplinary collaboration, allowing teams with varied objectives to find complementary solutions. This research does not suggest the replacement of the engineer or hazard specialist by the designer, but rather an opportunity for these various specialised fields to work with the same tools of concept and verification. Through robustly prepared simulation modelling, differences in specialised knowledge and language may be alleviated, allowing novel and unexpected solutions to such endemic problems. Due to the gradual reduction of traditional landscape management in mountainous areas, especially evident in Switzerland (Herzog et al. 2006), the shift from functional to recreational

landscapes has created additional and often conflicting pressures on landscapes which need to be managed, and designed. The implications for the future development of alpine infrastructures, and a clear requirement for rethinking the future maintenance of such dynamic landscapes has been discussed widely by ecologists, engineers, and designers alike. As postulated in the 2006 books 'An Urban Portrait', the sustainability of future mountain settlements is strongly under question, and will require new models of sustainable alpine habitation.

The future placement of pathways, design of mountain climb routes, positioning of bridges, promontories, and recreational functions must work within a landscape that can change its form and consistency. The associated influence on neighbouring urban infrastructures holds huge potential for the future development of alpine settlement and planning. It is through the considered synergy of design, engineering, land-use, and ecology that a new, evolving balance can be established, which permits the co-incidence of a cultural and shifting terrain.

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CHRISTOPHE GIROT

Christophe Girot was born in Paris in 1957 and is Professor and Chair of Landscape Architecture at the Architecture Department of the ETH in Zurich. He received a dual Masters in Architecture and Landscape Architecture from UC Berkeley, and was Chair of Design at the Versailles School of Landscape Architecture. His teaching and research interests span new topological methods in landscape design, landscape perception and analysis through new media, and contemporary theory and history of landscape architecture. At the ETH he co-founded the Landscape Visualising and Modelling Laboratory (LVML) with Professor Adrienne Gret-Regamey in 2010. His professional practice focuses on large-scale landscape projects, using advanced 3D GIS techniques that contribute to the design of more sustainable landscape environments such as the Alp-transit Deposit in Sigrino and the Third Rhône River Correction in the Canton of Valais.

ILMAR HURKXKENS

Ilmar Hurkkens studied architecture at the Delft University of Technology, graduating in 2009 with honourable mention for the design of a linear city and sea dike that combines architecture with flood control. He previously studied abroad at the ETH Zurich, served as an editorial assistant for journals OASE and Footprint, and was a member of the organizing committee of the EAAE's The Urban Project conference held in 2008. He is currently working as an architect in Zurich and is an assistant in the Design lab and at the Landscape Visualization and Modeling Lab LVML at the Landscape Architecture Chair of Christophe Girot at the ETH in Zürich.

JAMES MELSON

James Melson works in teaching and research at the Institute of Landscape Architecture Chair of Christophe Girot at the ETH Zürich since 2007. He coordinates the Design Lab and the Landscape Visualization and Modeling Lab (LVML), and teaches landscape design at both undergraduate and postgraduate levels. Since 2013 he coordinates the Landscape Architecture theme of the Master thesis projects of the Department of Architecture, ETHZ. James completed Architecture at the University of Western Australia in 2001, and later completed the MAS in Landscape Architecture at the ETH, Zürich in 2005. From 2001-03 he played a key design role in Landscape Architecture projects in Australia and throughout Southeast Asia and China. Since 2003 he has worked with several landscape architecture and urban design bureaus in Western Europe, working on major projects in the Switzerland, the UK, France, Germany and the Netherlands, and as a registered Landscape Architect, BSLA.