

ACCESSIBLE, OPEN-SOURCE COMPUTATIONAL ANALYSIS AND DESIGN OF TERRAIN PARK SKI JUMPS

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INTRODUCTION. An evolution has occurred over several decades in US recreational skiing toward freestyle aerials and jumping features. Presently more than 95% of US ski resorts have these but rarely use formal quantitative or engineering methods in design. Rather jumps are simply iteratively constructed and tested based on builders' previous experience before allowing public access. References listed in Hubbard (2007), McNeil et al. (2012) and Levy et al. (2015) document that increased jump use has resulted in a concomitant increase in injuries, sometimes involving the spinal cord and consequent high social costs. Because the jumper velocity component orthogonal to the snow surface must be dissipated in landings, likelihood and severity of injury are increasing functions of the kinetic energy associated with this component. The injury energy is itself proportional to equivalent fall height (EFH) h , defined as the kinetic energy divided by the product of jumper mass and acceleration of gravity, $h=E/mg$. Previous research (Hubbard, 2007; McNeil et al., 2012; Levy et al., 2015) has provided a theoretical approach for jump design based on creating a landing surface shape that ensures the perpendicular component of landing velocity (and EFH) is relatively small everywhere that landing is possible. More recent experimental research (Petrone et al., 2017) has shown these designs are practical to build and do indeed control landing impact as theoretically predicted. Ski resorts have hesitated to adopt engineering-based design methods partly due to the somewhat weighty and complex calculations required. Levy et al. (2015) reported the development of a graphical user interface (GUI) that subsumed equations and automated calculations, but required that the user have a MATLAB license. Moore and Hubbard (2018) described an online approach that made these design methods available to any user at no cost. This paper describes a related online *analysis* tool that calculates the EFH given the provided shape $y(x)$ of an existing or proposed jump.

METHODS. The safe slope differential equation (Levy et al., 2015) expresses EFH $h(x)$ as a function of horizontal distance x from the takeoff point, landing surface shape $y(x)$, and takeoff angle θ ,

$$h(x) = \left[\frac{x^2}{4(x \tan \theta - y(x)) \cos^2 \theta} - y(x) \right] \sin^2 \left[\tan^{-1} \left(\frac{2y(x)}{x} - \tan \theta \right) - \tan^{-1} y'(x) \right], \quad \text{where } y'(x) = \frac{dy}{dx}.$$

RESULTS. The analysis tool can be accessed at the url www.skijumpdesign.info where it is required to provide takeoff angle θ and a tabular file characterizing the landing surface shape $y(x)$. Program output is the equivalent fall height $h(x)$ everywhere on the landing surface.

DISCUSSION AND CONCLUSIONS. It is now possible to have online access not only to methods that allow *design* of landing surface shape to limit EFH, but also to related *analysis* tools that calculate EFH associated with a proposed or existing landing surface shape. The code is open source and available at the above url.

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