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Discussion of "Application of AI Approaches to Estimate Discharge Coefficient of Novel Kind of Sharp-Crested V-Notch Weirs" by Amin Gharehbaghi and Redvan Ghasemlounia

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The authors apply several artificial intelligence (AI) approaches to modeling the performance of a weir device with multiple, linked V-notch openings that they describe as a "novel type of sharp-crested V-notch weir", or SCVW. They use AI methods to find relationships between the discharge coefficient and dimensionless ratios involving the upstream head, weir height, and channel width. The AI methods are applied to an experimental data set comprising tests by the authors and by Saadatnejadgharahassanlou et al. (2017). Results are comparable to traditional hydraulic analyses applied by Saadatnejadgharahassanlou et al. (2017), with computed discharge coefficients within 10% of experimentally determined values, a larger range than that of most devices intended to provide accurate flow measurement (Bos 1989). The authors focus on how the AI methods were combined, adjusted, trained, and evaluated but do not provide irrigation and drainage engineers with practical information needed to apply the techniques and results to real-world devices or adapt the methods to other weirs that may be of interest to the irrigation and drainage community. Notably missing are the discharge equations that define the coefficient that is the subject of this work, which greatly hinders practical application. Some awkward wording also needs clarification, such as the reference to the *tripping salesman dilemma*. A common benchmark for evaluating optimization methods is the *traveling salesman problem* which does not concern a salesman tripping over obstacles but rather one who wishes to travel the shortest distance to reach multiple clients in different locations.

The missing discharge equations are especially important because the equations incorporated by reference to Saadatnejadgharahassanlou et al. (2017) are incorrect for the case in which the upstream head, h, exceeds the P_2 dimension of the weir opening (Fig. 1). Discharges calculated by the incorrect equations differ from correct values by the factor 11/3 at the transition between $h \le P_2$ and $h > P_2$. The correct equations are,

for $h \le P_2$:
$$Q = N\left(C_{dSCVW}\frac{8}{15}\tan\frac{\theta}{2}\sqrt{2g}\right)h^{5/2} \quad (1)$$

and for $h > P_2$:
$$Q = N\left(C_{dSCVW}\frac{8}{15}\tan\frac{\theta}{2}\sqrt{2g}\right)\left[h^{5/2} - (h - P_2)^{5/2}\right] \quad (2)$$

where Q is the discharge, N is the number of V-shaped weir openings, θ is the included angle of each V-shaped opening, g is the acceleration due to gravity, P_2 is the depth of the V-shaped openings, and C_{dSCVW} is the discharge coefficient, which varies with h. The distinguishing condition for the use of eq. (1) or eq. (2) as stated by Saadatnejadgharahassanlou et al. (2017) is only approximate; in reality, the shift should occur when the contracted flow at the weir face begins to exceed the P_2 height, which due to local drawdown of the water surface will occur at an upstream head condition somewhat greater than $h = P_2$.

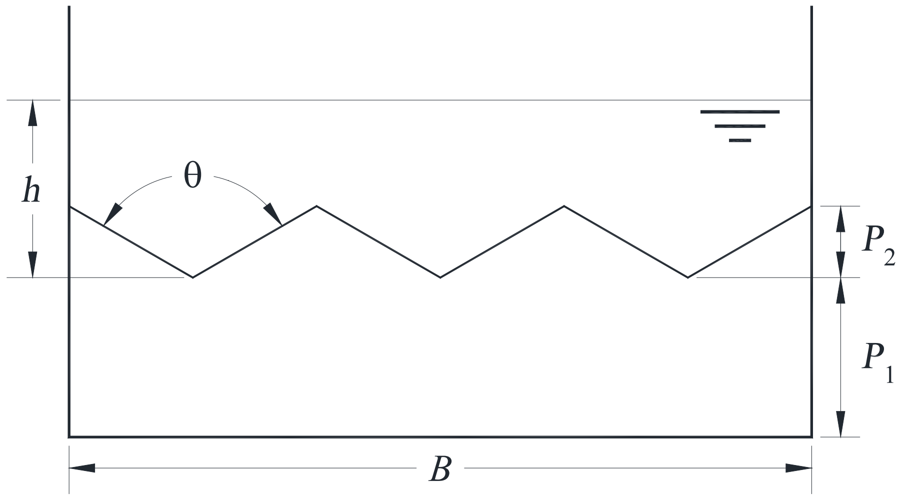

Figure 1. Elevation view of V-notch weir with multiple openings linked continuously together.

To provide a basis for comparing the AI methods, the authors initially relate the discharge coefficient C_{dSCVW} to the ratio h/P_1 as suggested by Rehbock (1929), where h is the upstream head on the weir and P_1 is the height of the invert of the V-shaped weir opening above the approach channel floor. (The reference elevation for the upstream head h is not defined but is presumed to be the invert of the V-notched weir opening.) Four regression relations (authors' eqs. 7-10) are determined for the common weir vertex angle θ = 60° at four different ratios of P_1/B, where B is the channel width. The regression relations have the form $C_{dSCVW} = A_1+A_2(h/P_1)$, with A_1 and A_2 being fitted constants. (Notation for the constants is changed here from that used by the authors to avoid confusion with the channel width, B.) With four values of A_1 and A_2 determined, the authors then develop two 3rd order polynomial equations for curves relating A_1 and A_2 to P_1/B (authors' eqs. 11 and 12) and combine these to produce a single equation (authors' eq. 13) that predicts the discharge coefficient as a function of h/P_1 and P_1/B. However, readers should be aware that the two 3rd order polynomial equations fitted to four data points have no practical purpose or value, since it is trivial to perfectly fit an n-th order model to n+1 data points. For example, a straight line (1st order polynomial) fit through two data points defines a line between them but does not provide any experimental evidence that intervening points in the domain can be expected to follow that linear relationship. Similarly, the 3rd order polynomials are being fitted to match experimental variability associated with the observed data points but do not indicate that a 3rd order polynomial relationship exists between A_1 or A_2 and P_1/B. The resulting equation for C_{dSCVW} is only meaningful at the four tested values of P_1/B, which the authors acknowledge. The purpose for developing the equation is not apparent, since the values of C_{dSCVW} at these values of P_1/B were already known, so nothing has been gained. A lower order polynomial (linear or 2nd order) would fit the individual points less accurately but would be more useful, since it would use the trend exhibited by the available data to model the potential behavior at intermediate values of P_1/B, with recognition that experimental uncertainty affects the four measured values. Saadatnejadgharahassanlou et al. (2017) performed a similar analysis to develop an equation for discharge coefficients of a weir with vertex angle $\theta = 128°$, but again the relation has no predictive worth for other values of P_1/B.

The bulk of the article following the introduction presents statistics and figures that compare the performance of several AI data analysis approaches. Unfortunately, the authors use a plethora of AI terms that are not defined, explained, or related to concepts familiar to readers of the *Journal of Irrigation & Drainage Engineering*. These include chromosomes, genes, ciphers, species, kernel functions and parameters, expression trees, genetic operators, mutations, pheromones, daemons, gene expression programs, support vector regression, ant-colony optimization, evaporation, inversion, gene transposition, one and two-point recombination, root transposition, gene recombination, extreme learning machines, multiple-layer perceptron neural networks and others. While the meaning and significance of these terms to AI data analysis can be researched in cited publications, the authors do readers a disservice by failing to provide basic explanations within the article.

The AI analysis using gene expression programming (GEP) yields Eq. (14) of the original paper, which relates the discharge coefficient to θ, P_1/B and h/P_1. The authors observe that the equation has "a high degree of intricacy", although some of the intricacy can be easily eliminated. First, the argument of the sech function in the last term can be reduced from $|-h/P_1| - (\theta + 3\,P_1/B)/4 - h/P_1$ to simply $-(\theta + 3\,P_1/B)/4$; since h/P_1 is always positive for meaningful applications, $|-h/P_1|$ is equivalent to h/P_1 and is thus cancelled by the last $-h/P_1$ term. Second, the expression $\mathrm{sech}(\mathrm{sech}(\log_{10}(P_1/B)))$ in the second term is unnecessarily complex for what it accomplishes, since the curve it defines in the range of P_1/B studied by the authors (0.25 to 0.40) is a nearly straight line (R^2=0.99 for a linear regression using the four values of P_1/B = 0.25, 0.30, 0.35, and 0.40). Even after simplification, Eq. (14) remains a complex way to describe a family of nearly parallel and nearly linear relationships between the discharge coefficient and h/P_1 for the tested values of P_1/B. This demonstrates a trend that the discusser finds distressing in the recent scientific literature. While AI-based optimization can be theoretically effective, it often fails to provide insight and even obscures understanding of the fundamental mechanics of a process. The discusser also finds that Eq. (14) does not reproduce the significant variation with θ illustrated by the experimental data shown in the authors' Fig. 8 for P_1/B = 0.25. Eq. (14) predicts almost identical discharge coefficients for different values of θ. Correspondence with the authors indicates that this is due to Eq. (14) being developed from a limited subset of experimental data, and the authors discouraged the discusser from applying Eq. (14) for general use. This point was not made clear in the original article.

Readers of the journal may be interested in established engineering applications of these devices. The name Sharp-Crested V-Notch Weir and acronym SCVW give no indication of what is novel about the device, but a comparison to the devices described in articles cited in the authors' literature review (e.g., Rehbock 1929; Kandaswamy & Rouse 1957; Rajaratnam & Muralidhar 1971; Ramamurthy et al. 1987; Bos 1989; Bagheri & Heidarpour 2010; Aydin et al. 2011) shows that the difference is flow through multiple adjacent V-notched openings vs. flow through a single weir opening. Such multiple-notch devices are known in some industries as "sawtooth weirs", a more descriptive and memorable name than SCVW (Fuchs 2014).

Sawtooth weirs provide a reliable means of withdrawing fluids from the surface layer of tanks involved in such industrial applications as water treatment (Brenntag 2022) and parts washing (cleansing of automotive or other industrial parts using solvents and other agents) (Fuchs 2014). In these applications the advantage of sawtooth weirs over straight-bladed weirs is that flow skimming can be distributed more uniformly over the full extent of a weir that spans most of the width or length of a tank, even if the tank and weir are slightly off-level or if the flow rate is so low that surface tension would stop the flow over significant lengths of a straight weir when the flow rate is small. Surface tension is especially important with some industrial fluids that exhibit strong surface tension, such as deionized water (Fuchs 2014).

Sawtooth weirs are effective for this application due to the diminishing open width of the weir at low heads, which maintains more head for a given flow than would occur over a straight-bladed weir. This allows the lower portions of the V-shaped openings to continue to withdraw significant amounts of fluid from the tank along the length of the weir over a wide range of upstream head conditions (Fuchs 2014), producing effective skimming of the tank surface for a wide range of flow rates. This prevents short-circuiting of the flow and the loss of effectiveness of significant portions of the tank volume. The discharge coefficient of such weirs is of relatively minor importance to their function. As a result, the weir blades can be constructed with little attention paid to the sharpness of the edge, whereas single weir devices meant to provide accurate flow measurement (discharge coefficients with variability in the range of 2-3% or better) have tight specifications for the geometry and sharpness of the weir blade, since these factors significantly affect the discharge coefficient (e.g., Bos 1989, p. 159). Baddour (2020) provides an excellent analysis of the skimming properties of single sharp-crested weir openings with a wide range of shapes including rectangular, triangular, trapezoidal, elliptical, and 1st through 5th order polynomial profiles. The skimming flow effectiveness is sensitive to the shape of the weir opening but generally independent of the discharge coefficient. These shapes could readily be incorporated into a sawtooth weir.

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