Evaluation and Prospects of Semi-Automatic Video Distance Measurement in Ski Jumping

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ABSTRACT: *Great competitive results of Slovenian ski jumpers in world cup and continental competitions have sparkled a lot of interest for active participation in this attractive sport. In junior levels, national competitions with considerably more than 100 jumpers are becoming the norm. However, due to lack of technologic aids for distance measurement, such competitions can last over half a day. Only at the top-level competitions (world cup, continental cup) expensive and logistically demanding commercial video distance measuring tools are used for this purpose. In a previous project we developed a video distance measuring system from low-cost commercial components, which was not suitable for real-time usage due to technological limitations, but worked great for offline measurement. We analyze the results of offline measurements for several competitions and show that measurement errors are often unacceptably high. This serves as a motivation for an ongoing project, where video measurement is performed in real time and supported by advanced computer vision and deep learning methods.*

Keywords: Ski Jumping, Video Distance Measurement, Computer Vision, Machine Learning, Deep Learning

Received: 18 August 2018, Revised 4 October 2018, Accepted 19 October 2018

1. Introduction

In recent years, we have witnessed a boom in Slovenian ski jumping, mainly as a consequence of excellent results of Slovenian competitors. There is a marked increase in interest at the primary level; the ski jumping clubs have reportedly doubled the number of younger, primary school competitors (7-10 years). This has considerably increased the burden on ski jumping coaches, as well as on organizers and professional staff in competitions, that are carried out even in the youngest categories (from 2018, up to 10 years on only as "animations").

The administrative support for small competitions is mostly covered by the information system "Spletni Smu—sko[1]", while the IT support is virtually nonexistent for style and distance umpires. Only at the highest competitive levels (world cup, continental cups), professional staff delegates, style and distance umpires | are supported by expensive commercial solutions [6, 2]. In our project, we focus primarily on supporting distance umpires who have a demanding, exposed role, and their mistakes often lead to bad will among coaches, competitors' parents and spectators, as well as in public opinion.

The aim our previous work [1] was to develop a system for supporting video distance measuring on smaller hills, with accessible hardware requirements (a single video system and a laptop). In this paper we evaluate the system results from ski jumping competitions in younger categories on small hills in regional competitions (Cockta Cup), and provide some directions for future development.

1.1 Ski Jump Distance Measurement

In ski jumping the jump distance is defined as a distance between the edge of the jumping ramp and a point where both ski jumper's legs have touched the ground with full surface [4, article 432.1]. The middle point between both legs is used when the legs are apart (e.g., Telemark landing style). There are however three exceptions [3]:

1. In one-legged landings (i.e. the second ski is longer in the air than what is typical during the normal landing routine) the correct distance is measured where the first ski touches ground with full surface.

2. In a fall (where the landing does not result on the skis as is normal), the correct distance is measured at the location where the ski jumper contacts first the landing surface with a body part.

3. In arbitrarily delayed landings (i.e. the ski jumper is positioned extremely behind thus delaying the normal landing routine and the touch down of the ski tips to the landing surface) the correct distance is measured where both feet contact rst the landing surface.

Even on the smallest competition hills (HS ≤15 m) it is difficult to measure the exact flying distance by eyes only, since landing speeds exceed 10 m/s (36 km/h), and the angle between the landing slope and landing trajectories of ski jumpers is often very small [5].

Therefore, umpire tower is often built not far from the lower end of landing slope. It allows good view, but is utilized chiefly by style-measuring umpires. During ski jumping competitions, distance-measuring umpires are stationed a few meters apart along the landing slope (Figure 1). Usually they are volunteers from the organizing ski jumping club, and often have no training and very little experience with distance measuring. With speeds exceeding 10 m/s, the umpires have less than 0.05 second (with resolution

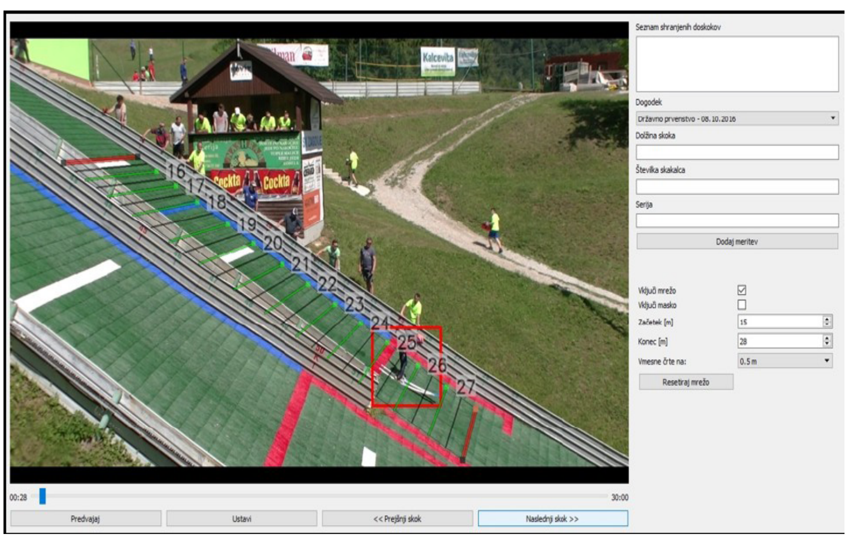

Figure 1. Offline video distance measuring system. A calibrated measuring grid is overlaid over video stream. Eight distance-measuring umpires can be seen standing along the landing slope

[1]http://smusko.adamsoft.si

of 0.5 m) to decide on a particular distance. Also, as declared by ski jumpers, they are almost never able to determine their flying distance with a reasonable accuracy. As a consequence, ski jumpers and their coaches are challenged when evaluating the progress in terms of jump/flight distance. A reasonably automated video distance measuring system therefore has the potential to become an important coaching aid in everyday practice.

2. OFFLINE Video Distance Measuring

In a recent project cooperation with the Ski Association of Slovenia[2] (SAS) we developed a system for offline video measurement [1]. The aim of the project was to develop a reasonably priced system for video distance measurement based on commercially available components. It utilized a JVC GCPX100 camcorder[3] that allows recording of up to 600 frames per second (FPS). While the camcorder was great for offline video measurement due to standalone video recording, it was impossible to use it in an online setting due to it's incapability of live video streaming to the computer.

In the offline setting we recorded several competitions on small hills (HS up to 25 m). Two professional ski-jumping coaches utilized specially developed software developed with- in the project (see [1] and Figure 1) to facilitate offline video measurement. In total, more than 200 ski jumps were video measured. For 86 we identified the jumpers and obtained officially measured distances, that were used for further evaluation. All jumps were either successful or with the ski jumper touching the landing slope with his/her hands. No spectacular falls were included.

	Official distance	**Video distance**	**Abs. diff.**	**Abs. diff. (centered)**
count	86	86	86	86
mean	22.52	21.99	0.62	0.33
st. dev.	2.11	2.23	0.37	0.35
min	17.00	15.50	0.00	0.00
max	26.00	25.50	1.50	1.50

Table 1. Basic statistic of ocial and video measurements

3. Evaluation of Official Distance Measurement Results

For 86 jumps we compared the official results (measured by eyes only) and offline video measurements, performed by two professional ski jumping coaches. Figure 2 depicts a scatter plot of official measurements vs. video measurements. From the placement of measurement pairs (almost all are below the diagonal) it is obvious that manually measured distances are bigger than video measured ones. This bias is a result of different positioning of umpires and video camera, resulting in different parallax errors (the camera was mostly positioned slightly higher than umpires and more towards the outrun). In Figure 3 this bias can be clearly seen as nonnegative differences in distances for all but five jumps.

Table 1 shows basic statistics of official and video measurements. The difference in means (0.53 m) indicates the need to account for different biases for each method. For this reason we compare the two distance measuring approaches with their values centered around their means (Eq. 1).

$$center_j^{(m)} = d_j^{(m)} - \overline{d}^{(m)} \qquad (1)$$

where $\overline{d}^{(m)}$ is the mean value of all measured distance for a particular measuring method m, and $d_j^{(m)}$ is the measured distance for the jump j (again for a particular measuring method m). This allows us to contain the bias within the $\overline{d}^{(m)}$ and focus only on the differences dif_j (Eq. 2).

[2] https://www.szs.si

[3] https://eu.jvc.com/microsite/eu/gc-px100/index.html

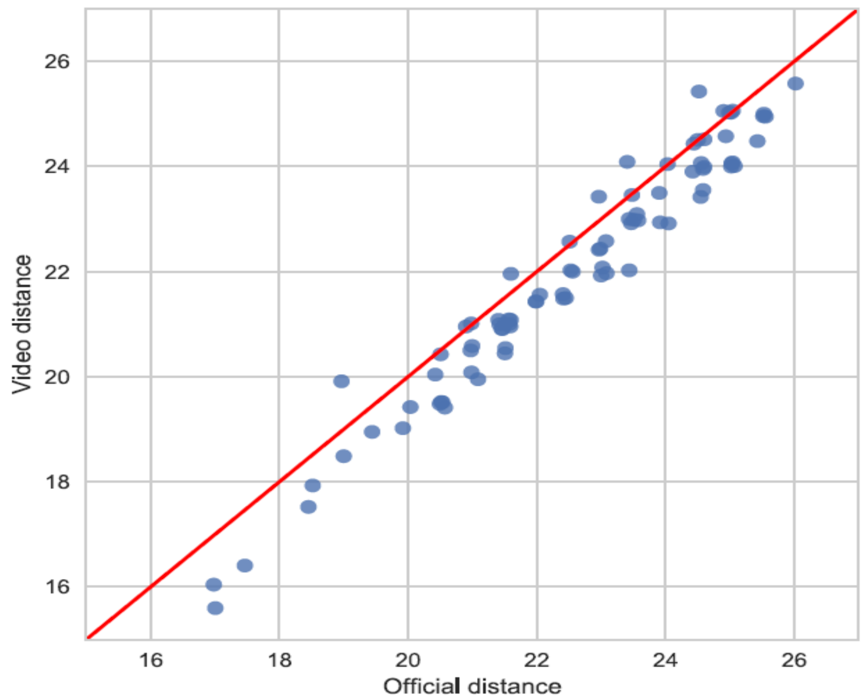

Figure 2. Scatter plot of official vs. video measurements

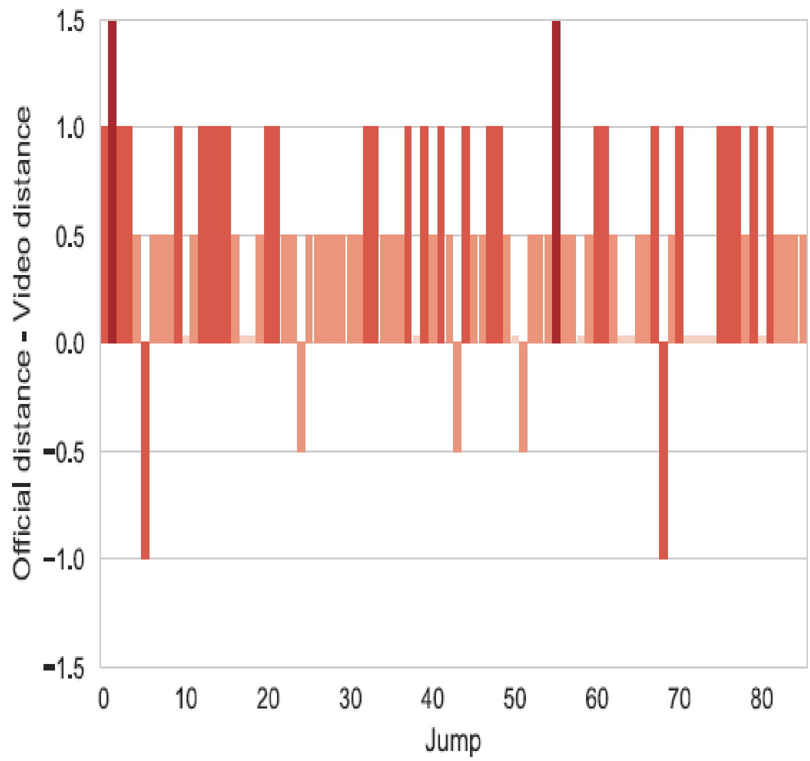

Figure 3. Dierences between original official and video measurements

Difference (centered)	Count	%
0.0	39	45
0.5	40	47
1.0	5	6
1.5	2	2

Table 2. Frequencies and percentages of absolute dierences between centered ocial and video measurements

$$dif_j = \Big(\underbrace{d_j^{(manual)} - \bar{d}^{(manual)}}_{\text{centered manual distance}} \Big) - \Big(\underbrace{d_j^{(video)} - \bar{d}^{(video)}}_{\text{centered video distance}} \Big) \tag{2}$$

According to the involved ski jumping coaches, our video measurements are much more reliable than the official manual ones, and can be considered as correct. Figure 4 and Table 2 show a much clearer picture of official measurement errors. 45% of measurements are deemed to be exact (within 0.5 m), 47% are off by ±0.5 m, while additional 8% errors are in the range of 1-1.5 m. For distances around 15 m this means a whopping 10%! To put this in perspective, for a world record jump (253.5 m) this would translate to 25 m! On small hills, 1 m is worth 4.5-6 points, and such errors can easily influence podium places, especially in closely fought competitions. With introduction if video distance measuring system would therefore benefit both umpires (less demanding work) competitors and spectators (less distance measuring errors).

4. Beyond Offline Measuring

In the ongoing —SIPK project we are partnered with the Technix[4] d.o.o company, the biggest provider of trac surveillance network cameras in Slovenia. They kindly provided various camera models, produced by Axis Communications. We settled for the high frame rate model Q1645[5], that connects to the computer via 100 Mbit Ethernet connection, allows frame rates up to 120 FPS with full HD resolution, and supports low light recording. At the time of paper submission the project is still in progress, therefore we are reporting only partial results. Figure 5 shows the video distance measuring system (camera and laptop) in action.

One of the main drawbacks of our original system [1] was the lack of online distance measuring. This is now effectively solved by utilizing the network camera. The video processing pipeline consists of several steps:

- A frame is acquired from the camera (MJPEG or H.264 stream)
- Gaussian blur is used to get rid of noise
- Background is subtracted by using the MOG2 algorithm [7], and the image is converted to black (back- ground) and white (moving) pixels, based on the last five frames
- Of all the moving contours, the largest is selected as the ski jumper, and the corresponding bounding box is superimposed to the frame (Figure 6).
- Once detected, the ski jumper is tracked until he/she has left the camera view

According to [3] and [4, article 432.1], video distance measurement is performed in two steps:

[4]https://www.technix.si

[5]https://www.axis.com/products/axis-q1645

1. Determining the correct landing frame

2. Determining the correct landing point corresponding to the ski jumper’s foot positions.

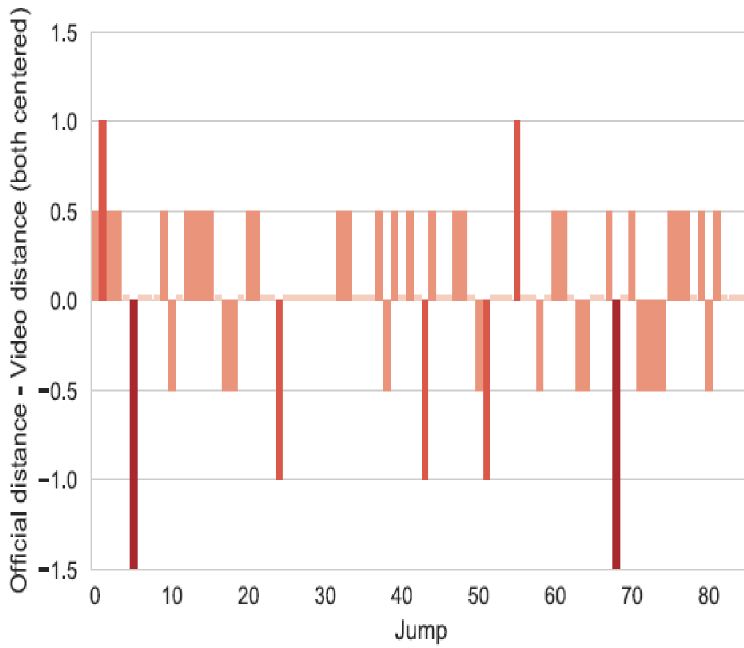

Figure 4. Differences between centered official and video measurements

Figure 5. An online video distance measuring system consisting of a network camera (left) and a laptop computer

Figure 6. Trained operator determines the distance by using the calibrated measuring grid in 5-8

A heuristic approach based on the flight curve derivatives is used to approximately detect the landing frame. It works with accuracy of approximately 1 m (on small hills). The human operator is still needed to determine the correct landing frame, and determine the distance based on the super- imposed measuring grid (Figure 6).

4.1 Automatic Detection of Landing Point with Deep Learning

We are currently experimenting with two approaches to automate and speed up video distance measuring. The rst approach is using a deep convolutional neural network with 10 hidden layers in order to automatically detect the correct landing frame. Its input is a framed ski jumper in resolution 150 × 150 color pixels. Each frame is classified either as “air” or “ground”. Due to real time processing requirement (net- work executes on CPU only) the current topology it is relatively shallow. It consists of two 2D convolutional (C), two pooling (P), four dropout (D), one attening (F), and three dense layers (De) as follows: C-P-D-C-P-D-F-De-D-De-D- De. A sequence of frames can be classied as shown in Figure 7. The sequence always starts with “air” and ends with “ground”. When at least two subsequent “ground” frames are detected, the first is selected as the landing frame. This approach currently achieves 96% classification accuracy for determining the type of frame. However, as the errors always occur near the correct landing frame, human intervention is still necessary. The second approach utilizes classic computer vision image segmentation techniques to acquire positions of ski jumper’s skis and legs in order to determine the correct landing point within the frame, and therefore the distance based on the measuring grid (currently with accuracy of 0.5-1 m). Regarding the processing speed, for small hills 30 FPS are sufficient to achieve 0.5 m accuracy, however the process works well even for 100 FPS video stream (tested in laboratory conditions). For deeper neural networks, a gaming laptop with a discrete GPU will be required.

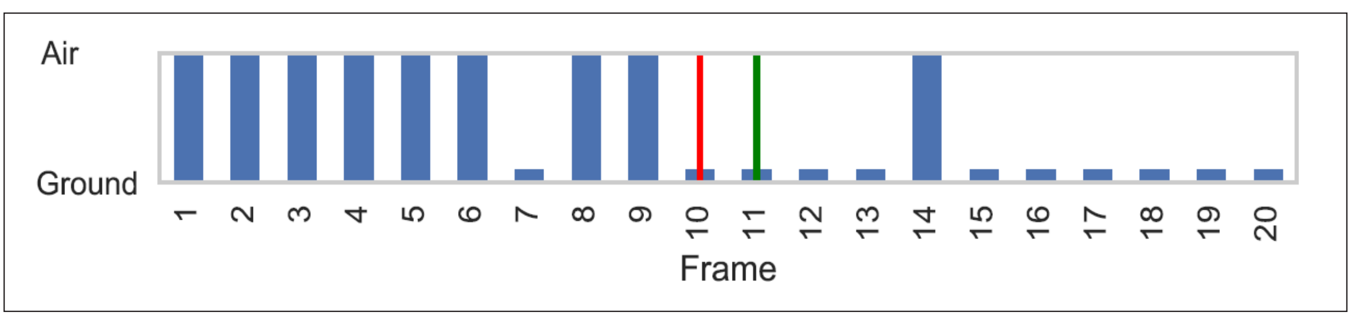

Figure 7. A sequence of frames classified as “air” and “ground”. The green line marks the correct landing frame, and the red line the predicted landing frame. Frames 7, 10 and 14 are incorrectly classified

5. Conclusions

Our evaluation has shown that there is great need for improvement in ski jumping distance measuring, especially for small hills. In order to achieve objective results and reduce errors, video distance measurement is highly advisable. There is considerable interest from ski jumping clubs and SAS for widespread testing. For use on larger hills, slight modification of software will be needed in order to allow for two, three or four network cameras. The system still needs further testing (especially the automated components) under artificial lighting conditions (night competitions).

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6. Acknowledgments

Original software for video distance measurement was developed within the PKP project \Video meritve dol—zin smu—car- skih skokov" by T. Ciglari—c, K. Gosti—sa, T. Kova—c, D. Peternel, M. Pograjc, N. Stoklas, B. —Stempelj and G. Vodan [1]. Advanced automatization is developed within an ongoing —SIPK project VIDEOMEN in the ski jumping center Menge—s, Slovenia.

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