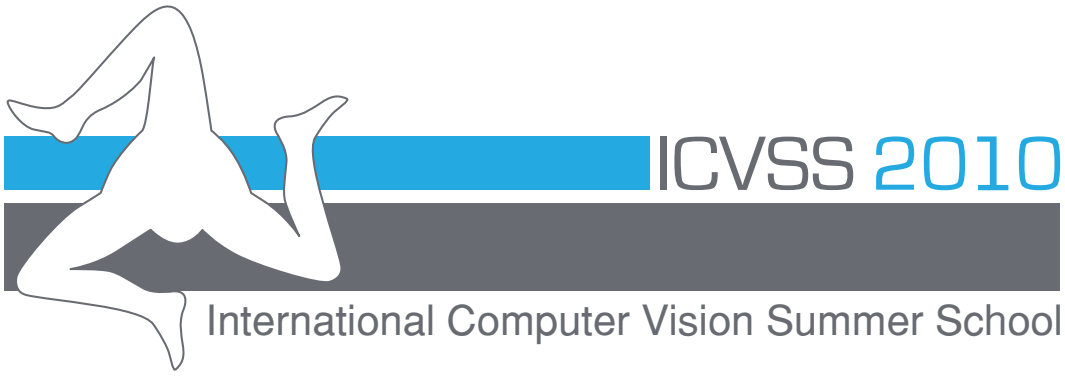

Reading Group

"Secrets of Optical Flow and Their Principles"

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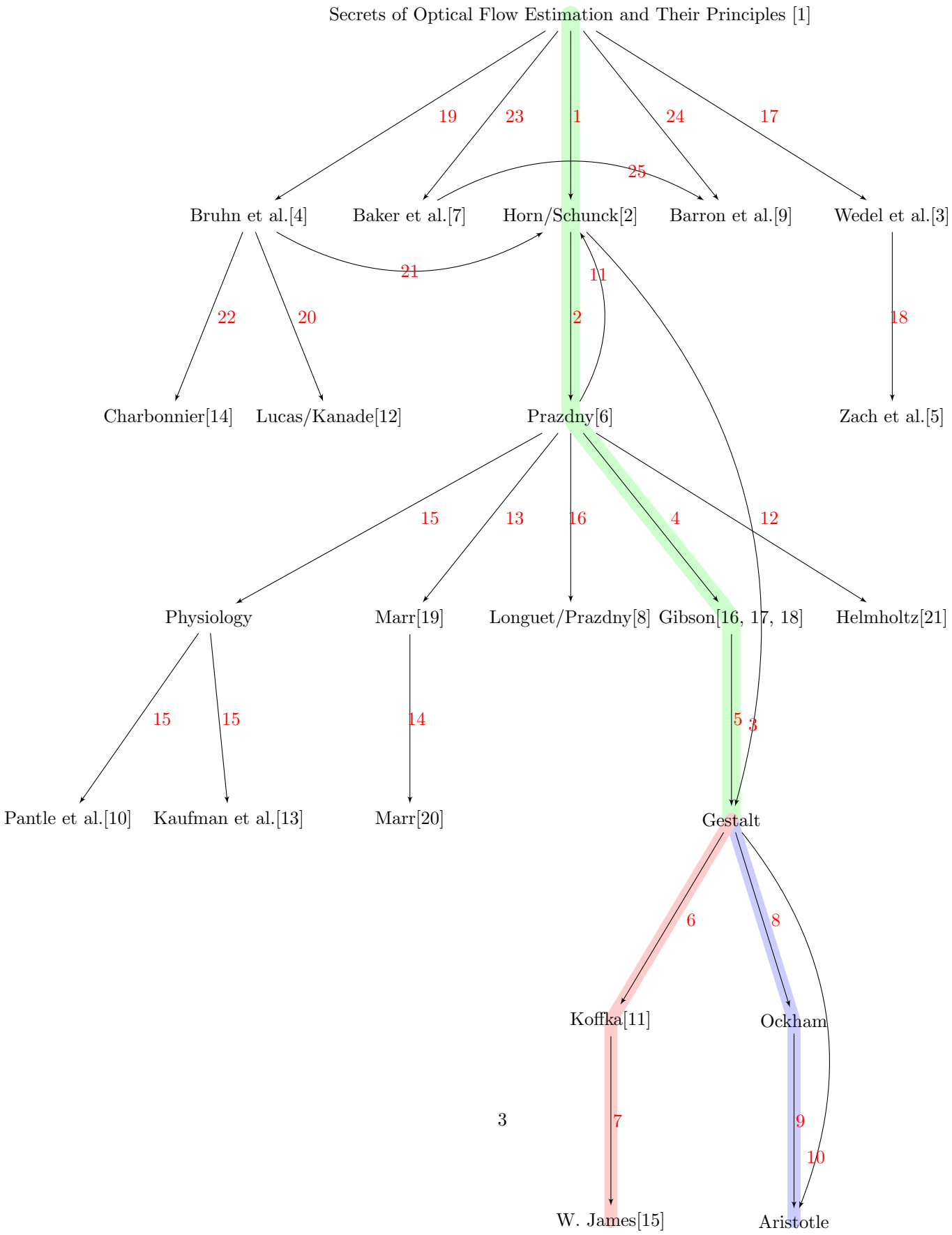
Discussion

The paper "Secrets of Optical Flow and Their Principles"[1] deals with the main idea behind the optical flow [2] and with some recent improvements to the originary algorithm [3, 4, 5]. We found especially interesting the analysis of the former. Horn/Schunck[2] is usually considered as the originary algorithm of optical flow estimation in the modern sense. Prazdny[6] analyzes the information the optical flow carries with . This analysis have roots in physiology, psychology and neuroscience. Two very important pillars of Pradzny's work are Marr's "Vision" and Gibson's "The Ecological Approach to Visual Perception". Gibson explicitly cites the Gestalt movement as a fundamental source of inspiration. A main figure of Gestalt was F.Koffka, who articulated the Gestalt's Prgnanz in six laws on which modern studies on visual perception deeply rely. It's difficult to imagine a way to estimate the optical flow in non-trivial cases without exploiting at least the Proximity, Similarity and Common Fate laws. Specifically for the optical flow estimation, a predecessor of Koffka was W. James; more in general, Gestalt laws heavily trace out the fundamental "simplicity" principle usually ascribed to W. Ockham. The English friar in turn elaborates the aristotelian principle *Numquam ponenda est pluralitas sine necessitate*, widely used in Computer Vision in the form of the assumption that the simplest explanation for a perceived pixel configuration is locally the best choice. Without using this principle we wouldn't be able to estimate the optical flow of flat, homogeneous areas; the assumption that similar neighboring pixels belong to the same entity enable us to make segmentation and parallax estimation is "probably approximately" correct.

Tree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Motivations

1. Deqing et al.[1] - Horn/Schunck[2] :
   - According to Deqing et al.[1], the majority of today's methods strongly resemble the original formulation of Horn/Schunck[2]. In practise, the basic structure of the combination of a data term with a spatial term is unchanged since Horn/Schunck[2].
   - Initially, Deqing et al.[1] use an algorithm that is a direct descendant of the Horn/Schunck[2] formulation.
   - The Horn/Schunck[2] approach suffers from the fact that the quadratic formulation is not robust to outliers. However it, appropriately implemented, remains very competitive.
2. Horn/Schunck[2] - Prazdny[6] :
   - Horn/Schunck[2] states that Prazdny[6] provide a clear exposition of the problem of recovering the motions of objects relative to the viewer from the optical flow.
3. Horn/Schunck[2] - Gestalt :
   - In section 5 of Horn/Schunck[2], it is introduced the "smoothness constraint" for optical flow. It states that neighboring points on the objects have similar velocities and the velocity field of the brightness patterns in the image varies smoothly almost everywhere. From an algorithmic point of view, it means that neighboring points with similar velocities are assumed to belong to the same object. This principle summarizes the two Gestalt law of proximity and similarity and, specifically for the optical flow, the common fate law.
4. Prazdny[6] - Gibson[16, 17, 18] :
   - Prazdny[6] cites Gibson as the originator of the term "optical flow". This term is used to emphasize the fact that, according to Gibson, the retinal motion is not the stimulus proper.
   - Prazdny[6] sets Gibson in the 'psychological approach' to the problem of optical flow. This approach aims to show that the optical flow is an effective stimulus for the human visual system. The psychological approach doesn't address computational nor mathematical issues.
5. Gibson - Gestalt :
   - In his works, Gibson claims that he has extended many of the ideas of the Gestalt psychologists;
6. Gestalt - Koffka[11] :
   - Koffka is one of the most representative figures of the psychological movement of Gestalt. He wrote in 1935 the book [11], where he summarizes and formalizes the famous six laws of Gestalt.
7. Koffka[11] - James :

- Koffka revises W. James' work "The principles of psychology" and intentionally quotes him by adding the word 'Gestalt' to the title.
- W. James seems to be the first to refer to extrapolation of movement through the analysis of differences in time.

8. Gestalt - Ockham:
   - The fundamental principle of gestalt perception is the law of "prgnanz" (pithiness) which says that we tend to order our experience with the simplest possible explanation. According to[22], the six Gestalt laws are only a refinement of this 'simplicity' principle.
9. Ockham - Aristotle:
   - In his writings, Occam stressed the Aristotelian principle that entities must not be multiplied beyond what is necessary. This principle became known as Ockham's Razor or the "law of parsimony".
10. Gestalt - Aristotle:
    - The Gestalt psychology is defined as a holism movement. The general principle of holism was concisely summarized by Aristotle in the Metaphysics: "The whole is more than the sum of its parts".
11. Prazdny[6] - Horn/Schunck[2] :
    - Prazdny[6] considers the work of Horn/Schunck[2] as an "effort in computing retinal velocities".
12. Prazdny[6] - Helmholtz :
    - Prazdny[6] cites Helmholtz as the first to suggest that the pattern of angular velocities of rays of lights carries information about depth relationships.
13. Prazdny[6] - Marr[19] :
    - Prazdny[6] states that the Computer Vision research is dominated by the methodological orientation known as the "computational approach", firstly introduced by Marr. This approach stresses the importance of understanding the goals of a visual system. Its main objective is to derive computational procedures by using mathematical formulation of how the world events affect the image. The analytical models can be compared to biological system.
14. Marr :
    - The so-called *computational approach* is based on the assumption that the human mind can be described as a computer system. In Marr[20], the author develops a complete and sophisticated computational approach.
15. Prazdny[6] - Physiology :

- Prazdny[6] recognizes that a lot of work has been done in the neurophysiological area, but it is unknown a reasonable and computationally feasible way of computing istantaneous retinal velocities. Velocity sensitive neurons have been discovered (Pantle et al.[10], Tolhurst[23]), and it seems a proof that the optical flow is actually used by the human vision system.
- Moreover, some works (Kaufman et al.[13]) pointed out that the human vision could have two independent and complementary systems, which reflect the distinction between short-range schemes, computing an instantaneous characterization of retinal motion and long-range schemes that integrate information from discrete "event slices".

16. Prazdny[6] - Longuet/Prazdny[8] :

    - Longuet/Prazdny[8] assume that the visual system has access to the velocity vector at each retinal point, as well as to the first and second spatial derivatives at that point. It seems questionable that these derivaties can be obtained with sufficient precision.

17. Deqing et al.[1] - Wedel et al.[3] :

    - Using the results of Wedel et al.[3], Deqing et al.[1] use a 5x5 median filtering heuristic after each incremental estimation step to remove outliers. It improves the accuracy of *all* methods they tested. This median filtering is considered "the single most important secret".
    - Deqing et al.[1] pre-process the images using the approach and the parameters of Wedel et al.[3]. However, the simpler *gradient* approach performs good results.
    - Wedel et al.[3] report that the bicubic interpolation is more accurate than the bilinear.

18. Wedel et al.[3] - Zach et al.[5] :

    - Wedel et al.[3] reproduce the approach of Zach et al.[5], but improve the robustness and flow accuracy.

19. Deqing et al.[1] - Bruhn et al.[4] :

    - Among the penalty functions considered by Deqing et al.[1], there is the Charbonnier penalty that was used in Bruhn et al.[4]. A slightly non-convex version of this penalty function performs better.

20. Bruhn et al.[4] - Lucas/Kanade[12] :

    - Bruhn et al.[4] classify Lucas/Kanade[12] in the *local* method for computation of optical flow. The local methods minimize a local energy-like expression and offer relatively high robustness under noise, but do not give dense flow fields.

21. Bruhn et al.[4] - Horn/Schunck[2] :

- Bruhn et al.[4] classify Horn/Schunck[2] in the *global* method for computation of optical flow. The gloabl methods minimize a global energy functional and offer a flow field with 100% density, but are experimentally known to be more sensitive to noise.

22. Bruhn et al.[4] - Charbonnier[14] :

    - Bruhn et al.[4] decided to replace the quadratic optimisation of Lucas/Kanade[12] and Horn/Schunck[2] by *nonquadratic* methods. In general, nonlinear methods give better results at locations with flow discontinuities. In particular, Bruhn et al.[4] use a function that has been proposed by Charbonnier[14].

23. Deqing et al.[1] - Baker et al.[7] :

    - The "Middlebury optical flow" benchmark is used to validate the accuracy of optical flow estimation techniques.
    - Deqing et al.[1] claim that their approach is ranked 1^{st} in the benchmark, at the time of publication.

24. Deqing et al.[1] - Barron et al.[9] :

    - Deqing et al.[1] states that the Horn/Schunck[2] formulation has long been thought to be highly inaccurate. In particular, Barron et al.[9] reported an AAE of 30 degrees on a test set. However, this conclusion is not correct, because if we optimize the Horn/Schunck[2] procedure with today's method, it achieves competitive results.

25. Baker et al.[7] - Barron et al.[9] :

    - Barron et al.[9] introduced a datasets for quantitatively evaluating optical flow estimation algorithms, but Baker et al.[7] provide new e more comprehensive datasets; they also extend the set of performance measures and the evaluation methodology.

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