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Conceptual Visual Human Algorithms:
A Requirement-driven Skiing Algorithm Design

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Abstract

As the key visual display- and processing- element of information super highway nodes, computer graphics is advancing into dynamic and higher dimensional visual worlds. So is visual algorithms to program visual worlds as the contents of information super highways. This research presents a drastic approach in designing visual algorithms to construct visual worlds. The address is on the most critical phase of conceptual design that has been conducted ad hoc in designers' mind. Conceptual visual algorithms make mental design processes and design results explicitly represented in a computer executable form after interactive machine translation. Hence, they are explicitly validatable against the design requirements. Taking a popular case of human performance design including dramas, music performance and sporting, recreational skiing algorithm design in particular as an example of visual world design, we show a requirement-driven approach to conceptual visual human algorithm design produces a truly effective skiing method to meet wide varieties of recreational requirements.

1. Introduction

Designing is a process of turning concepts into recognizable forms. In case of visual design, designing can be turned into visual algorithms, first conceptually and finally for visual computation. By doing it, we can computationally visualize designing on computer graphics and can verify the design process and the design results. This is a remarkable advantage of computational approach to designing over purely mental approaches. Yet, without conceptual visual algorithm formation, nothing can be started in computation.

Conceptual visual algorithms are the highest of high level visual algorithms. As usual, high level here means the representations closer to human understanding. Provisions are made to translate the high level representations to the low level representation of computer graphics.

To improve the reusability of algorithms, algorithms are generally defined on sharable data structures. Any researches are effectively conducted having a typical case. Human performance as a series of conceptual visual human algorithms provides distinguished features of conceptual visual algorithms. Human performance goes across almost everything including daily life, manufacturing and art such as sporting, crafting, painting, and musical instrument play. Further, human performance plays a major role in multimedia contents. Let us focus on the case of sporting performance, recreational skiing in particular.

Algorithm design belongs to a later stage of software design in a software life cycle. The initial stage is requirement specification. The requirement specification made wrong usually destroys the entire life cycle. Up to this is a common knowledge of software engineering [10]. However, in human performance including sporting, little has been worked out. Conceptual visual human algorithms in the major areas are, as the consequence, often quite wrong and even at the level of nonsense.

2. Requirement Specification

The requirements of recreational skiing are specified as follows:

1. Anyone can enjoy skiing a whole day.
   "Anyone" implies "without much special training", and hence, "employing only most used muscles in daily life", namely "using only the muscles for standing and walking."
2. Varieties of snow fields can be enjoyed for skiing.
   "Varieties" mean three things:
   - 2.1 The first is "varieties of snow such as powder snow, icy snow, snow frozen on the surface and soft inside, partially melted and heavy snow".
   - 2.2 The second is "varieties of slope shapes such as flat slopes, steep slopes and bumpy slopes".
   - 2.3 The third is "varieties of environments such as wide open fields, forests, rocky mountains and cozy backyard slopes".

3. Invalidation of Traditional Ski Instruction

In skiing, usual instruction forces people to learn conceptual visual human algorithms designed based on a set of assumptions, not based on requirement specifications. The usual assumptions are:

1. Ski control by snow plowing either in a scissors position or a parallel position of a pair of skies.
2. A lean forward body posture.

These two assumptions are made already at the conceptual algorithm level. This means the possibility that the conceptual visual human algorithms in the traditional ski instruction do not satisfy the requirements of recreational skiing. Then, what for the traditional ski instruction is ? Neither for competition nor for recreation. Actually the possibility turns out to be the reality. The assumption 1 violates the requirement 1 of recreational skiing because snow plowing forces recreational skiers to get their legs worn out through the extreme use of muscles other than those for daily walking and standing. The muscles to push snow sideways have no chance to get trained in daily human life. The assumption 2 violates the requirement 2 of recreational skiing. Look at Figures 1 through 3. The lean forward body posture limit the knee lifting range to the 60 % of the upright body posture for walk. The lean forward body posture results in tragedy when skiing on a bumpy slope. The limit in knee lifting can cause throwing up of the whole body into the air at bumps. These figures also show the walking and standing body posture, namely the upright body posture, that satisfies the requirement 1 of recreational skiing, also satisfies the requirement 2.

Fig.1 The limit of knee lifting in a standing straight posture.

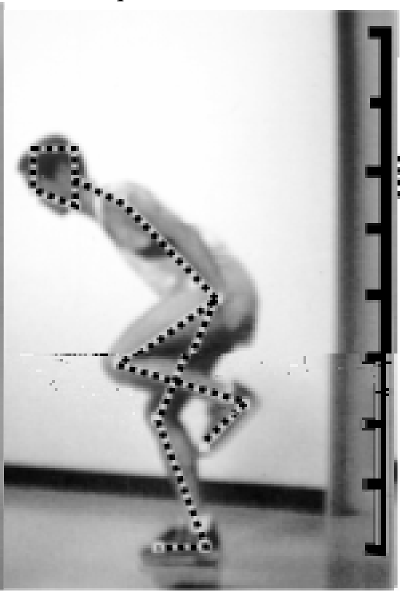

Fig.2 The limit of knee lifting in a lean forward posture.

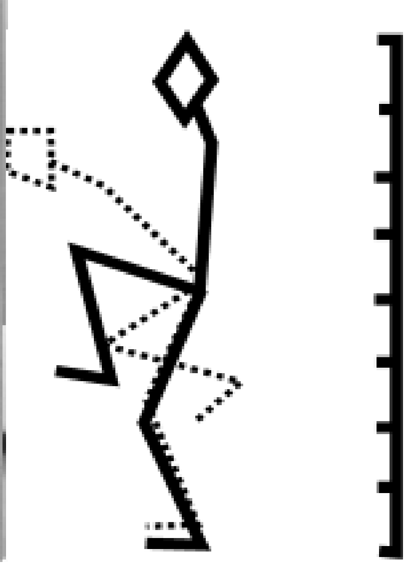

Fig.3 The knee lifting limits.

4. Requirement-driven Conceptual Visual Human Algorithms

Let us see how requirement specification affects conceptual visual human algorithms. Conceptual visual human algorithms in our case are a type of algorithms that specify in skier's mind the mental images of sequences of skiing techniques as the processes of moving both skier's body and ski equipment on varieties of snow fields for recreational purposes. The purposes are specified already as the requirement 1 and 2 above. The requirement 1 specifies the skier's posture such that it is vertical to the ski surface. Such vertical posture uses only the muscles for standing.

As in the requirement 2, the snow conditions and desired speeds are varied. Relative to the snow field surface, ski position is defined by three parameters: the first is the angle α between the sliding surface of a ski along the longitudinal direction and the snow field surface, and the second is the angle β between the sliding surface of a ski vertical to the longitudinal direction and the snow field surface. The third is the sideways angle γ from the straight down direction. When snow is varied or when a skier wants to decelerate, the requirement 1 derives a lean back posture of the whole body slightly to increase the angle α (Figures 4, 5). . In Figure 5, the horizontal axis is taken to the direction of the snow field surface. This posture still let the skier keep standing always vertical to the ski surface by making balance with the snow resistance while increasing the angle α. This is a *dynamic equilibrium standing posture*. It means that the deceleration and varied snow skiing can be done both by leaning back the whole body slightly and then standing, as driven by the requirement 1. While leaning back, a walking motion to stretch legs forward and touch the ground by heels keeping the posture vertical to the ski surface causes the effect of increased deceleration, then the succeeding walking motion of retracting legs in the same body posture causes the effect of decreased deceleration. Thus the deceleration control is completely conducted using the muscles for walking only satisfying the requirement 1. A recreational skier also can enjoy the feeling of walking rhythms on snow by alternating the stretch and retract of legs in walking body posture.

The increased α frees the most top portions of a pair of skies from the snow resistance, and as a skier directs the body to wherever the skier wants to go, a pair of skies moves freely and instantly towards the body direction with any sideways angle γ from the straight down direction, as the skier wishes. Varieties of snow (requirement 2.1), varieties of slope shapes (requirement 2.2), and varieties of environments (requirement 2.3) can be all enjoyed for recreational purposes. Hence, the requirement 2 drives the identical conceptual visual human algorithms to increase the angle α by leaning back the whole body slightly. When going sideways, of course the speed is less than when going straight down. This sideways angle γ from the straight down direction is also utilized to control speed to meet the requirement 1. Even sudden stopping is achieved by going the snow field upwards by making $\gamma > 90°$. Hence, the muscles for daily life to stand and walk are enough to control skies , and there is no need of a tiring posture for snow plowing. The walking posture gives a recreational skier a joy of panoramic view of varieties of snow fields while the lean forward body posture as traditionally instructed gives a very limited and narrow view. From the safety standpoint, securing as wide views as possible is the key factor to avoid any danger of falling into a hazardous situation such as colliding with obstacles or the other skiers. Further, the lean back standing or walking posture remarkably strengthens the other safety features in two ways:

1. defending a skier from obstacles with the least damage to the obstacle, by arranging ski sliding faces as shields and preventing the cutting of the obstacle by ski edges; the obstacle is often the other skier and this is an essential safety requirement;
2. riding over the obstacle, instead of skier’s being thrown down having the ski outside edge caught by the obstacle.

In other words, the requirements 1 and 2 turn skiing into a true recreational safe skiing for fun to enjoy the views of the places skiers are traveling on skies including bird watching, naturalist activities and photographing. Recreational skiers are now free from the captive to poor traditional recreational ski techniques and from the needs for often life time ski lessons by traditional ski instructors leading skiers neither to recreation nor to safety, even not to competition. Thus, the requirement-driven approach to the design of conceptual visual human algorithms creates a fundamentally new design, far versatile and desirable.

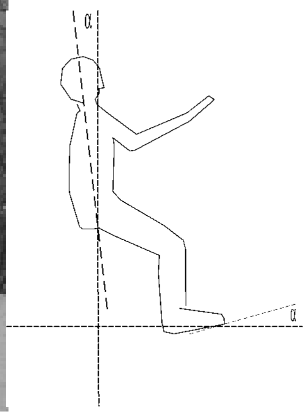

Fig. 4 Increasing α. Fig. 5 The solid model of increasing α.

5. Generating Computational Visual Human Algorithms

Once the conceptual visual human algorithms are specified, they can be tested and validated to satisfy the requirements. The testing and validation are done by turning the conceptual visual human algorithms into physical human body performance algorithms. Human beings are made to learn conceptual visual algorithms and to realize them as physical body performance algorithms. The learning processes are usually by a try-and-err approach, and are known to be extremely inefficient. For example, the learning and mastering of one expert technique in a martial art requires 3 year practices in average. According to our 8 year experiments, generating computational visual human algorithms from conceptual visual human algorithms shortens the learning and mastering time to 30 minutes, with 50,000 times efficiency increase [3,6].

Generating computational visual human algorithms from conceptual visual human algorithms can be done through constructing, as sharable data structures, the models of three types of objects, namely a human body model, a ski equipment model and a snow field model, in computers, and then determining sequences of the movements of a human body and a set of ski equipment on a snow field whose surface deforms according to the ski movements. Among the three types of objects, the most difficult to model is a human body. The simplest model of a human body is a wire frame model (Figures 1-3). The second simplest is a linked plate model or the Pinocchio model (Figure 6) that allows us to indicate the direction of individual body segments. We used this model many years ago to represent a human body of a skier [8, 7, 9]. The best model is a solid model such as a linked elliptic cylinder model (Figure 7) that additionally allows us to get the approximate mass of individual body segments computed, and hence to compute the dynamics of a human body model through solving the Lagrangian equations [6]; it is easy to compute the trace of the approximate center of gravity of a human body (Figure 7). This is a model we are currently most extensively using.

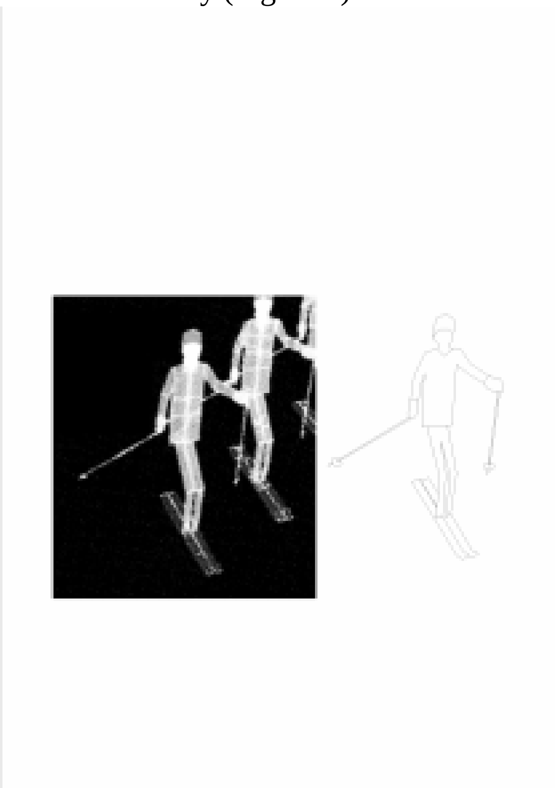

Fig. 6 A linked plate model.

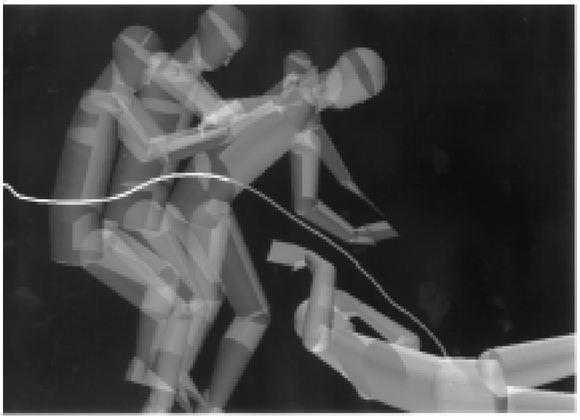

Fig. 7 A solid model, and the trace of the center of gravity.

The generation of computational visual human algorithms is most efficiently done by the SYDEM method [5, 2, 4]. The SYDEM stands for SYstematic DEcomposition of Manufacturing. It is a kind of top-down design methods. Consider a target conceptual ski algorithm, say a sudden and effortless stopping conceptual algorithm without snow plow, the top design. Consider an assembly of the steps of skiing movements leading to the posture from a certain starting posture. The computational algorithm of the stopping as the steps of the movements of the segments of the solid model of a skier is the bottom design. The segment movement computations to obtain the posture of the next step skiing is conducted following the steps of the conceptual visual human algorithm of the stopping. It is far more efficient to specify the computational steps of the segment movements directly from the steps of the conceptual visual human algorithm as the top level design, rather than randomly computing the movements of the segments until the computed movements coincide with the conceptual visual human algorithm. The computational steps thus obtained are the computational visual human algorithm of the stopping. Suppose the number of segments is n. In the bottom up computing approach starting from the computational algorithm, the computational complexity is in the order of the exponential of n; in the top down computation approach starting from the conceptual algorithm, the computational complexity is in the order of the square of n. The efficiency increase is drastic. The solid models of a human body we use rages from a 38 segments model that approximates each hand as a segment to a 70 segment model that represents all the 16 segments of each hand faithfully. For an average case with n=50, assuming one movement computation takes one microsecond, the bottom up approach requires 30 years whereas the top down approach requires only 3 milliseconds.

It is possible in this course of generating computational visual human algorithms to go through the physical human body performance algorithms, first, of satisfactory plays meeting all the requirements for use as the reference algorithms of computational visual human algorithms, and second, of lesson plays for diagnosis to identify and correct the erroneous portions of the plays that do not meet the requirements. The correction requires delearning explained below. Capturing the physical human body performance algorithms have been done in our martial art research by using 5 video cameras shooting from the right-, left-, front-, back- and above- directions, and then solid human body models are generated interactively from them (Figures 8,9) [6].

Fig. 8 Video images from 5 directions.

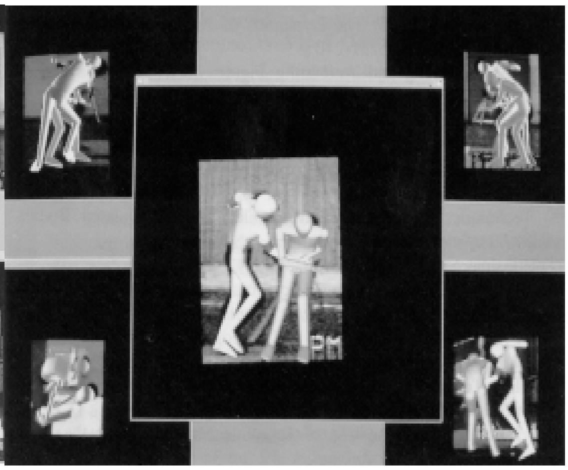

Fig. 9 Generated human body models as seen from the 5 directions.

6. Delearning in human algorithms as deprogramming

Now we explore the science of delearning in human physical performance for improved understanding. You know how difficult to delete a program from a computer. Delearning is not just deleting a file containing the program. After installation, the program becomes a part of the interrelated complex programs. The same is true with a human being. Years of our lessons indicate the difficulty of delearning as a mission far beyond the task of making a beginner an expert. After learning traditional skiing techniques, it requires around 10 years of delearning time to get rid of the habit of leaning forward and snow plowing. Learning is installing a program. Delearning is deprogramming. In case of a human being, learning installs a physical human body performance algorithm.

Human delearning starts from analyzing the physical human body performance algorithm, and the analysis is helped significantly through capturing the physical human body performance algorithm by video cameras from various directions as explained above. The analysis becomes, then, the following procedures: digitizing video picture frames of plural numbers of video cameras, fitting the segments of the solid human body model to the human body digital images, and analyzing the thus obtained solid human body movements as the computational visual human algorithm representing the physical human performance algorithm.

After the analysis, the obtained computational visual human algorithm representing the physical human performance algorithm of a person under delearning is compared with the computational visual human algorithm representing the physical human performance algorithm that satisfies the requirements. The comparison clarifies the differences, and hence provided is the basic material for delearning algorithm creation.

7. Semiotics as visual human algorithm abstraction

The study of signs is called semiotics or semiology. Semiotics is a convenient conceptual representation for communication. A visual human algorithm is abstracted to a structure of signs. For example, a skiing algorithm is generally a sequence of signs such as: start, downhill, left turn, downhill, right turn uphill, stop. The requirement-driven conceptual visual human algorithm to implement the above sequence is represented in semiotics as another sequence: start, increase α, left γ, $\gamma=0$, right $\gamma> 90°$, stop. Neither complicated control of β nor knee operations exists. This means the conceptual simplicity of requirement-driven conceptual visual human algorithms, resulting in 2 to 3 days for a complete new skier to master deep snow parallel skiing. The semiotics of human performance in general is an interesting subject for further study [1].

8. Conclusions

The requirement-driven approach presented actually conforms with a quite universal academic discipline of discovery and invention. The requirement corresponds to a hypothesis or an assumption in science, and an axiom in mathematics. The conceptual design satisfying the requirement is a theory to meet the hypothesis in science, and a theorem to satisfy the axiom in mathematics. The research presented here concludes that human performance is a wide open area where even a bit of serious scientific study clarifies so much. Considering our life to be a series of human performance on a stage called a society, this research indicates the possibility such that each role each person carries can be better performed by the help of a reasonable amount of scientific study on improved human performance.

9. Acknowledgments

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