SLOPES AND BREAK

The PuttingZone method for any golfer uses only two practice-green putts to establish and learn how much a putt breaks for a given slope and green speed, using that golfer's personal delivery pace, expressing the break as either a percentage of the length of the putt or as so many inches of break to play per foot of the putt distance, locating the aiming target this break distance up along the fall line measured from the center of the cup, as applicable to all putts inside 15 feet so long as the surface presents the same flatness from ball to hole. In addition to this two-putt method, the paper delves into the basic art and science of perceiving fall lines, slopes, and breaks for the skilled golfer's "know how," training skills that travel from putt to putt with minimal streakiness and slumping. The end result is the golfer who makes a much higher quality effort than otherwise and specifically makes a higher quality effort relentlessly and ceaselessly compared to competitors. A skilled golfer may not sink the immediate specific putt, but the higher quality effort consistently applied pays huge benefits for score and for contending.

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NOT MUCH SLOPE, KIND OF SLOW.

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Slope Readings

This paper presents the PuttingZone method for using the practice green to learn the amount of break that occurs for certain common or frequent combinations of green speed and slope steepness or grade. The specific combination is a 2% slope grade tested at the usual green speed (commonly Stimp 9' to Stimp 10' in the United States, perhaps slower in the Spring), from the "make" range of 10 feet. This method is not a calculated break, but is THE break that applies to the specific golfer performing the testing. That is true because the golfer uses HIS OR HER PERSONAL DELIVERY PACE, in contrast to calculations of booklets that use an assumed or supposedly IDEAL delivery pace. Once the 2% slope is tested to find the break, this break can be adjusted for 1%, 3%, 4%, 5%, and 6% slopes at the same green speed and delivery pace by simple proportionality. Or the golfer can separately identify these slopes on the practice green and independently test for break. Once done, the golfer has a full understanding of "paradigm" patterns of slope and break for that green speed, over the full range of slopes likely to have a pin location. If the testing is done when the green speed is the "usual", the testing result will apply nearly all the time. Separate testing may be required for special green speeds, such as faster tournament-quality course preparation.

[For those in a hurry, skip ahead to pages 9-12 for the basic 2-putt break testing.]

The principal aspects of the green that require accurate perception are 1) flatness; 2) slope grade or steepness, and 3) direction over the flat area that is straight uphill-downhill traditionally called fall lines, with the one thru the hole being primary. Green speed perception is not that critical, and the testing in this method takes into account "whatever" the speed might be for the practice green and the course for that day, and also sorts out green speed when the tested speed is the "usual" speed. Green speed may vary slightly from hole to hole and day to day, but usual is a "fat" term that comprehends about one-half a foot of Stimp speed, and greens typically don't vary over the course outside this "fat" range. And in any event, if the green speed does exceed the "usual" "fat" range, the skilled golfer knows what adjustment this requires for break.

The calculated reading booklets that are currently available, incidentally, use delivery paces of the ball at the hole for all calculations that are not typically used by the vast majority of golfers and so are bad reads for almost all golfers. (They were borrowed from a 1986 physics paper by a non-golfing physics teacher calculating "optimal" ball velocity across the hole just to do it, not to find real or actual velocities used by golfers.) Teaching golfers "about" what the break is, even when wrong, can help, but it's better to do the testing as it applies to specific golfers and get it right to start with, and eliminate the golfer's having to try to make compensating differences in his or her usual pace or even misaiming of the start line in unmindful attempts to fit the golfer's putting pace and stroke to a computer's read. The PuttingZone approach is superior to these booklets and applies only and accurately to the specific golfer, without necessitating any effort to change the normal stroke and pace to fit to someone else's notion of the "correct" or "best" delivery pace. And the breaks in this method are not "calculated" based upon necessary, simplifying assumptions, but are the exact analogue breaks that take into account all the specific peculiarities that affect the break.

Learning break this way basically requires nothing more than a little attention to the slope steepness and flatness of the surface in choosing the area of the practice green to perform the testing. Fundamentally, the golfer is trying to test and recognize slope differences on the course, concentrating on the frequently encountered cases, so that on the course the golfer sees and understands the specific putt he or she faces in terms of the tested paradigm patterns. The specific on-course putts will not exactly fit the tested paradigm patterns, but will be slightly different in any number of ways, so the golfer will naturally expect to make a minor adjustment away from the paradigm break to decide exactly how much break to play for the specific on-course putt. But he will START making the adjustment with a great deal of confidence about the normal break that is "about" right, and the adjustment will normally be very minor.

Preliminary Considerations.

Normal and frequent slopes and limits on pinnable slope. What determines the size of the break over a flat but tilted surface is the combination of slope steepness and the green speed that day. Obviously, the length of the putt and the delivery pace used by the golfer also factor in, but assuming that the golfer always uses the same delivery pace, the distance can be simplified to a percentage of the putt length or distance or to a conversion of inches of break per feet of putt length or distance. And because the green speed is most often "the usual" or "normal", in the end what really matters most to reading break is the steepness of the slope at the hole.

The golfer needs to be familiar with the most frequent combinations of slope and green speed, so he should test the most frequent slopes when the green speed is running at the speed he will be facing when he plays the course. Greens typically are sloped between 0% and 6% grade, as above 6% grade a ball on a Stimp 10' green speed will not remain still but will roll off. According to USGA guidelines for fair pin locations, a pin should not be located on slope when the green speed won't allow the ball to rest there. Golf course architects know that greens are usually Stimp 10' or lower speed unless extra

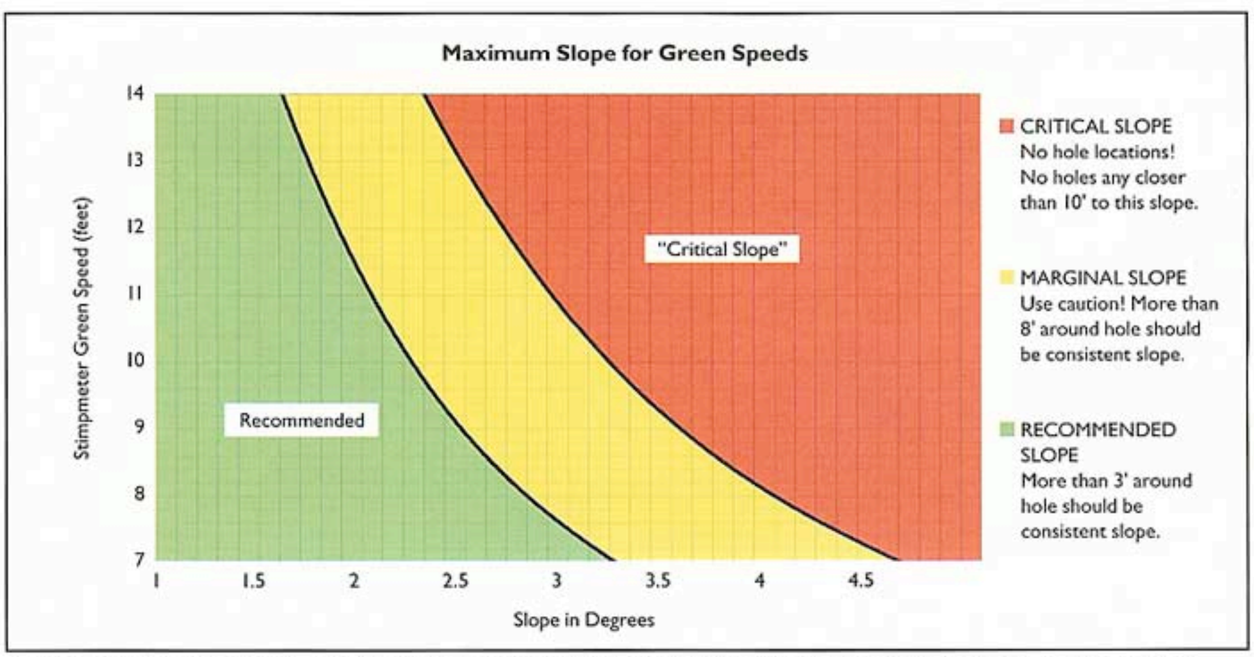


Figure 1. It is important to understand the direct relationship between green speed and putting green slope. As green speeds increase, the potential for uncontrollable slopes also increases.

trouble is taken to speed the grass up for special occasions, which are rare because this also endangers the health of the grass and cannot be a usual speed. Therefore, few greens present more than 6% slope (3.4 degrees in the above chart, where the line from 10 at the left vertical scale intersects the red area, above 3.4 on the bottom scale) except on steep tiers and limited areas of the green that are never pinnable locations and in any event the greenkeepers don't (usually) locate the hole on such a steep area. Indeed, the "recommended" limit for pins when the green is Stimp 10′ is 2.4 degrees or 4.5% grade (where the line from 10 meets the line at the yellow region above 2.4 on the bottom scale).

Green architecture factors affecting fall lines and slope steepness. Architectural cues to surface slope steepness and fall line orientations are:

1) noting that the overall slope of the green complex has underground French drainage pattern that collects and directs the subsurface water downhill into the basic drainage pattern of the hole and the course away from hills towards streams and lakes, and the basic physics of water running downhill usually requires about 2% grade as the minimum to ensure the water has sufficient velocity and momentum to avoid getting trapped and potentially upsetting the ecology of a healthy green;

2) noting the very lowest point on the fringe where the water drains off most heavily combined with spotting the highest point on the opposite fringe (usually at the far back of the fringe) to gain a sense of the "average" or "overall" orientation of uphill across the green and of the average steepness of the green, viewed as an average flatness and ignoring actual contour shaping of the surface;

3) noting that greenside bunkers in the way of off-green drainage normally require protective mounding to divert the drainage and prevent washing the expensive sand out of the bunker into the fairway every time it rains, as an indicator of off-green drainage flow that the architect believes in;

4) noting that greenside humps on the back half of the green are designed to catch the errant shots of amateurs so that play does not slow down too much trying to make a double bogey from the woods and weeds behind the green complex, and whenever these humps infiltrate the green with a projecting cone-shaped ridge, the hump influences the green surface perhaps halfway to the central area of the green before petering out, but if the hole is located within the influence of these humps, the hump acts like a magnet to attract the fall line at the hole and also makes the surface steeper;

5) noting that many greens today have elevated left and right sides with a river-like pattern flowing down thru the midsection of the green, usually from back to front but at times from high back to low left or right with mildly meandering path, and these river patterns have steeper sides and flat tilted bottoms that aim straight up the river bed for fall lines, and pose the issue of whether the hole is located on the flat bottom or off to the side slightly on one of the steepening banks;

6) noting that no greens have “bowls”, as any self-contained depression on the green would pose difficulties mowing and would get shaggy grass and would also collect dirt and sand and pooling water as part of the flow of erosion and weathering, and instead anything that looks “bowl-like” will invariably have one section of the bowl missing off the fringe where the drainage is allowed to escape, with the end result being more of a rounded amphitheater shaping, frequently on the very front of the green but also on sides directing the drainage into unusual collection depressed areas off to the side with a drain grate at the bottom, and the “contour” lines of these bowl-sides have fall lines everywhere perpendicular to the equal-elevation contour lines, and the bottoms of these bowl areas have substantial areas of flatness, and the sides of the bowls are usually a bit too steep and dramatic for hole locations;

7) noting that greens sometimes have isolated humps (in Georgia formerly called "buried elephants" but today much milder humps on faster greens and called "turtles") that act as distorting lenses that wreak havoc with reads and putts. Anything that goes uphill over a hump is most likely to "diverge" off the intended line, and will only adhere to the intended line if the golfer accurately see the exact effect of the hump or if the golfer aims strictly for the highest point on the hump and the hump has basic symmetry between bottom edge and peak, so golfers should never accept having to cross these humps to get to the hole when planning the approach shot except in rare situations; and

8) noting that the function of steep tiers on greens in to "dump" the local terrain's steepness in a short span of space so that the green can have less steep overall areas for putting, and that the presence of tiers in the absence of this local-terrain steepness indicates mere decoration and effect without necessary functionality, and that a sharp drop in elevation over a short span results in un-pinnable surface, with fall lines everywhere perpendicular to the equal-elevation contour lines of the tier, and with the steepness of the tier both causing underestimation of the energy to climb the elevation and to inaccurate estimation of how far a ball would "roll out" past the bottom edge of the tier across the lower normal slope under its own energy from simply being nudged over the top edge of the tier and taking on the energy of the fall / roll down the elevation drop.

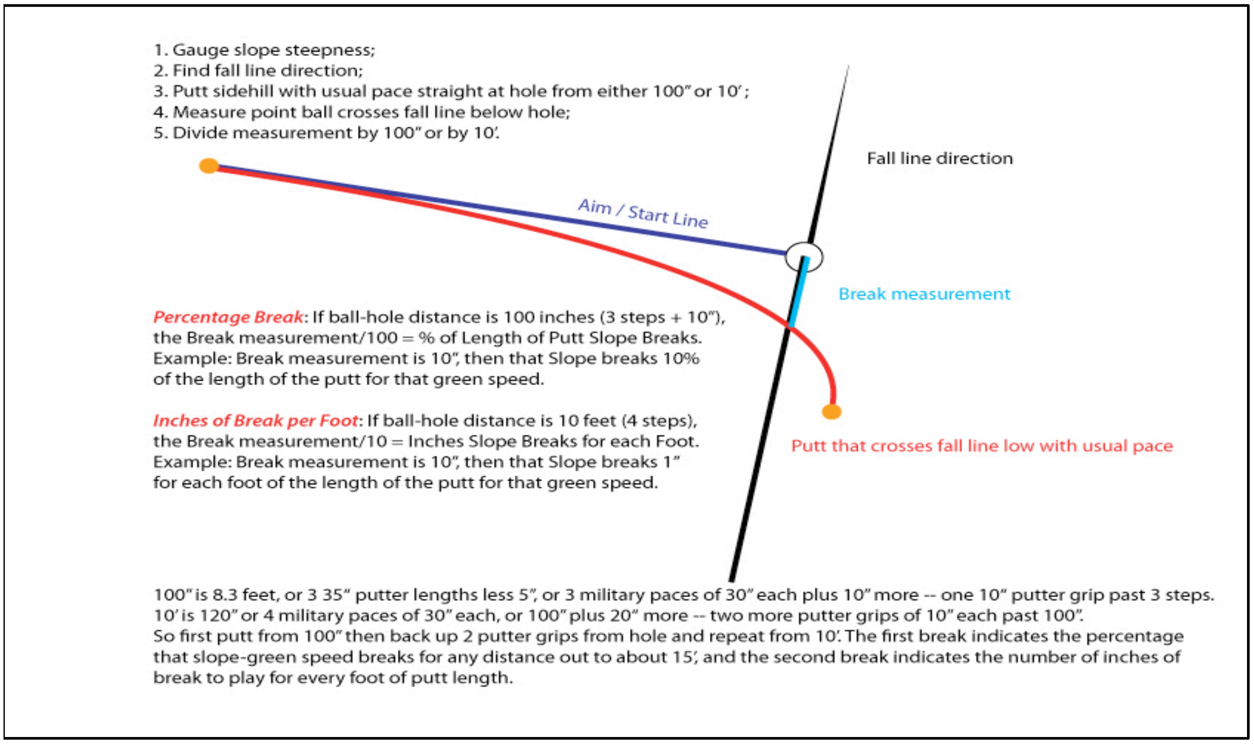
Golfers, then, are pretty safe to assume the hole will be on slope that is tilted between 0% and 6% grade, and the FREQUENCY of actual putts the golfer will face on 18 holes is distributed along a Bell curve, with 0% and 6% grade very rare, 1% and 5% grade not rare but not common (1% more than 5%), 2% and 4% grade common and frequent (2% more than 4%), and 3% grade very common and frequent (2% and 3% may be about the same). Areas where the green is dead level at 0% slope are limited to the peaks of small bumps, the transitions between slopes, and very rarely areas with substantial size for pin locations. Surface with zero slope does not independently drain well, and this undermines the health of the grass, but if the area is "in the way" of better drainage, the velocity of the transiting water can cure the problem of zero slope with its momentum.

For example, if the course normally at this season has a green speed of Stimp 10′, the golfer might test 2%, 3% and 4% slopes for break (as these are the most frequently encountered slopes), on a Stimp 10′ day. Even more simply, the golfer should test a 2% slope, and then he can adjust the test result to 3% slopes (1.5 times larger break) and to 4% slopes (two times as much break) and to 1% slopes (half as much break), and so forth. If the golfer is facing a tournament green speed, he needs to test the slope on the practice green at that same green speed. And in fact, even if the green speed changes, the testing numbers for break can be adjusted to different green speeds with bigger break on faster greens and smaller break on slower greens by proportionality as well.

Once the golfer gets a sense of the break to expect from this testing, this gives no more than an approximate sense of the ballpark break for any actual putt faced on the course. Each putt is unique for the slope steepness, and putts are not usually exactly 2% or 3% but somewhere in between, and surface may also not be exactly flat all the way from ball to hole but have some other contouring that has to be taken into account, and there may even be slight variations in green speed. And of course if the golfer chooses to use a slower or quicker delivery pace to the hole, this requires adjusting the ballpark break to fit the specific putt faced. So the golfer always starts with the ballpark understanding of "about" how much break (as a % of the ball-hole distance or inches per foot of the putt length), but always expects he will have to make a minor adjustment for the specific situation.

Procedures for Break Calculations.

Procedure: The basic two practice putts from 100" and from 10'. The following graphic outlines and illustrates the process of testing break for a given combination of slope and green speed:



Six steps for the break measurement process. The six steps in the two-putt testing is:

1. The first step is to find a flat area that is also tilted 2% grade out of level gravity (see details below for assessing slope grade of flat-and-tilted surface at the hole).

2. The second step is to find the correct orientation of uphill along this flat area, and this direction uphill corresponds to an infinite number of parallel lines, one of which goes straight uphill thru the center of the hole (see details below for assessing direction of fall lie thru the hole).

3. The third step is to locate the sidehill putt that is 100 inches from the center of the cup.

4. The fourth step is to putt a ball on the start line aimed at the center of the cup, with the nice delivery pace that arrives none short and then stops past the hole within 2-4 more rolls of the ball or "inside the leather" less than 2 feet behind or past the hole.

5. The fifth step is to observe the point where this ball curls low and then crosses the fall line below the hole, measuring the distance in inches from the crossing point to the center of the hole [this number of inches divided by 100 indicates the percentage of the putt length to use for the break].

6. The sixth step is to repeat this putt along the same direction from 120 inches away (two putter grips further than the first putt) [this measured break divided by 10 indicates how many inches of break to play for every foot of putt length].

Finding break as "percentage of putt distance". The sidehill putt from 100 inches with the golfer's personal, appropriate and usual touch or delivery pace results in the ball curling to the low side and crossing the fall line X inches below the center of the hole. X divided by 100 is the Break (Y) expressed as Percentage of Putt Length. So Y% = X/100. The target is above the center of the hole this same X when the putt is 100 inches long and is Y% of ANY putt length for any distance putt. For example, if the putt is 5 feet in length (60 inches), the break is Y% of 60 inches. A typical example might be a 2% slope at Stimp 9.5' green speed: the 100 inch putt might break 10". Then X is 10" and the break, Y, is 10/100 = 10%. A 5-foot putt on this same slope-speed combination breaks 10%. Ten percent of 60 inches is 6 inches. The break is 6 inches in the sense that the target to aim the putter face at thru the ball is a spot up the fall line 6 inches from the center of the hole. Another example is an 8-footer (96 inches): the break is 10% of 96 inches, or 9.6" up the fall line from the center of the cup.

For convenience, the following integer putt distances have the corresponding 10% breaks measured either from the center of the cup or expressed in terms of inches above the high edge of the cup along the fall line:

1′ (12″) breaks 1.2″ (i.e., inside left or right / high side)

2′ (24″) breaks 2.4″ (i.e., left or right / high side edge)

3′ (36″) breaks 3.6″ (i.e., 1.5″ above left or right / high side edge)

4′ (48″) breaks 4.8″ (i.e., 2.7″ above left or right / high side edge)

5′ (60″) breaks 6.0″ (i.e., 3.9″ above left or right / high side edge)

6′ (72″) breaks 7.2″ (i.e., 5.1″ above left or right / high side edge)

7′ (84″) breaks 8.4″ (i.e., 6.3″ above left or right / high side edge)

8′ (96″) breaks 9.6″ (i.e., 7.5″ above left or right / high side edge)

9′ (108″) breaks 10.8″ (i.e., 8.7″ above left or right / high side edge)

10′ (120″) breaks 12.0″ (i.e., 10″ above left or right / high side edge)

Finding break as "inches per foot of putt distance". The putt from 20 inches further away is a ten-foot putt (120 inches). This second putt's break crossing the fall line below the hole, divided by 10, indicates the number of inches to play as break for each foot of the putt's distance. For example, if the 10-foot test putt breaks 12″ below the hole on the same slope-speed combination tested for the percentage method from 100 inches, Y = 12/10 indicates that the break to play for ANY putt (out to about 15 feet) is 1.2 inches of break for every foot of the putt length. Applying this to an 8-footer, playing 1.2″ per foot means playing 8*1.2 = 9.6″ of break. Not surprisingly, the "percentage break" and the "inches per foot break" for the 8-footer both work out to 9.6″ of break. Both methods are testing the same slope-speed surface, but simply express the break in alternatively equivalent forms. The above table of breaks assuming 10% of the putt length matches the breaks expressed as "1.2 inches of break for each foot of putt length." The two methods are not different, just different options.

One aim target for all putts the same distance out. Once the slope percentage combined with the green speed indicates an aim target for one distance of the *sidehill* putt (as a percentage of the distance of the putt or as inches of break per feet of putt), this ONE TARGET serves for ANY putt located the same distance from the center of the cup, provided these putts are concerned only with the one same flat slope. So long as the slope is "flat" and is tilted the same direction and steepness, any putt the same distance out from the hole uses only one target on the fall line above the hole. This general pattern “technically” has a “fuzzy” target that is a bit spread out depending upon whether a putt travels faster uphill than another putt the same distance out travels downhill. But in truth this “technical” difference in targets is hyper-technical so long as the distance is not much over 3 m (10 feet) and the slope and green speed combination is not extreme. And in any event, golfers should not consider “aiming targets” as exact points, but more as “maximum” breaks with generous other workable lower aims available for modest increases in delivery pace. So one target works for almost all makeable putts (inside 15′) that are the same distance out across the same slope. If a 10-foot or 3 m radius circle is drawn around the center of a hole on a slope breaking 6% of the distance, the one aim target 18 cm (6% of 300 cm) serves for any putt from any point around the circle, considered as a maximum break with some fuzziness available for slight increases in delivery speed. The only assumption is that this circular area of surface has only the one same flatness for putts from anywhere around the circle.

Gauging the normal break for different length putts. Using the above process on a 2% slope when the green speed is Stimp 9.5′ probably results in a break of 8″ to 10″ from 10 feet away, so that is 0.8″ to 1″ of break for every foot of putt length. A five-foot putt would then be expected normally to break 4″ to 5″ (0.8″ * 5′ = 4″; 1″ * 5′ = 5″). A 7-foot putt would be expected to break between 5.6″ and 7″. The corresponding measurement when the putt is from 100″ away would likely result in breaks of between 6.7″ to 8.3″, so that is 6.7% to 8.3% break to play for the putt length. That’s fairly normal.

Adjusting the Stimp 10′ break for faster or slower green speeds. A faster green speed will break more, by roughly the proportion of the faster green to a Stimp 10′ green. For example, a Stimp 11′ green probably breaks about 10% more than a Stimp 10′ green, so the Stimp 10′ measurements of 8″ to 10″ break from 10′ away on a Stimp 11′ green probably measure 8.8″ to 11″ (10% more break). A Stimp 12′ green probably breaks 20% more than a Stimp 10′ green, so the Stimp 12′ measurements from 10′ away are likely to be 8″ + 1.6″ (20% of 8″) = 9.6″ to 10″ + 2″ (20% of 10″) = 12″, so 9.6″ to 12″. Basically, add or subtract 1″ more break for every increase or decrease of one foot in Stimp speed to the normal Stimp 10′ test measurements or 0.1″ to the “break-per-foot” determination. The same basic adjustment works pretty well when the green speed is slower than

Stimp 10′. So a Stimp 9′ green speed is likely to break about 1″ less than a Stimp 10′ green (since 9 is about 10% less than 10, bringing the 8″ to 10″ break down to 7.2″ to 9″ on the Stimp 9′ green speed.

Perceiving Flatness, Steepness and Fall Line Direction: General Principles.

Perspectives -- wider scene. The golfer in examining the specific area around the hole should not lose contact with the wider horizon and the general scene and terrain. The basic skill compares the surface at the hole within this wider context. If the surface is dramatically steeper than the local scene or dramatically different than normal level, the golfer will have an easy time perceiving both fall line direction and slope steepness. However, most slopes are in the 1-4% range of slope grades, and mild slope is the most difficult to read. On the other hand, mild slope equates with insignificant break, while unnoticed intervening non-flat mini-areas wreak havoc with reads and putts regardless of the slope. This means that if the slope is mild and the golfer is having difficulty deciding about the fall line, he should 1) widen the perspective to take in more area, first out to the fringe of the green, and then perhaps out to the tree line or far horizon around the hole, and perhaps even further to a "birds-eye" aerial imagination of the local area as if looking down from the sky to see where rivers and ponds and oceans and mountains may be located, and also 2) hunt a bit more carefully to look at the flatness over the putt's surface to detect any un-flat irregular regions (dips, humps, bumps, including ball pitch marks and ant hills and *poa annua* spots and the like) or changes in the plane of the surface getting either steeper nearer the hole or less steep near the hole.

The wider scene should always be inspected while the golfer walks in from the fairway. Typically, golf course architects tilt the greens back-fringe high and front-fringe low so that amateur golfers' shots will be received and held, without running off the back of the green, as this causes log jams in the flow of the tee sheet and costs course owners money and frustrates golfers in the groups behind. It's an economic thing that influences almost every green design in the world. So the golfer should probably step off to the side of the green to see the slope from a better perspective, in addition to standing below the cup on the fall line assessing the percent grade.

Perspectives -- on the green. The perception of whether the green surface is "flat" or "not flat" is more than just "taking a look." The perspective matters, and the way you think while looking also matters. Looking straight down or mostly straight down at the surface is a poor perspective to judge the surface tilt in the local scene in comparison to what is level in gravity or horizontal to level or what is vertical in gravity. That's similar to looking straight down on the roof tops of a big city: this won't show which buildings are taller than others or which sections of the city sits on hill tops or down in valleys.

The other perspective that is not helpful is one that has the golfer looking "downhill" across slope. In perception science, slope detection is similar to looking at a checkerboard to decide whether the plane of the board is level in gravity or tilted. The size of the checks in a left-right row on the board get smaller with increasing distance in the advancing rows in a very well-known and regular pattern that indicates "level" to the brain. If the board is tilted far-side up from level, then the diminishing of the checks with distance is less than expected. If the far edge is lifted to the point that the checkerboard is now vertical like a wall instead of a floor, none of the checks look smaller and all look the same size. The perspective in all this is looking "uphill" towards the higher far edge of the board. But if the perspective is on the other side -- the observer on the same side of the high edge of the tilted board -- then the observer is looking "downhill" and the visual information is now sparse and thin, not rich and ample as it is when looking "uphill". Accordingly, never look downhill to assess slope steepness.

And assessing surface slope really requires "taking in" a certain minimum area or size of the section of the green under examination. Typically, from the nature of greens design and maintenance limits, flat areas on greens are usually about 10 to 20 feet in diameter and sometimes reach out to 30 to 40 feet in diameter before the plane of the surface bends upwards or downwards from the main plane. The golfer's task is to start at the hole and examine further and further away from the hole in the different directions radiating out to detect the point where the surface changes from its plane at the hole. More specifically, the golfer is really interested ONLY in the surface between ball and hole that might be involved in the read and the putt: that flatness only is the one that needs to be assessed. So, the skillful golfer steps downhill away from the area under consideration until the height of the eyes "takes in" the full area plus the margins past the area. This usually means stepping back downhill from the hole at least 5-8 paces.

The side-on perspective is also valuable, since this is similar to positioning oneself to the side of a checkerboard that is tilted with high edge to the observer's left and low edge on the table at the low edge to the right, and then assessing the elevation difference between the high and low edges.

Perspectives -- ground level. This perspective does not inspect for slope steepness, but for unusual mini-areas out of the flatness. This is not to be confused with stepping off to the side of the uphill-downhill direction, beyond the fringe of the green, taking advantage of depressed collections areas or bunkers beside the green in order to see the uphill-downhill difference from the side *and* from ground level.

Perceiving slope -- innate sensory organs for level and vertical. Skilled golfers develop an awareness of how things work and what is valuable and ready to hand. The golfer's own sensory equipment is the primary basis for reading putts, and this means: 1) good posture of chest and neck and head so the inner ear is not chronically skewed out of level but instead is accurately and normally registering level without biases; 2) sensitivity to differences in foot pressure when the surface below is tilted out of gravity, which also requires normally erect good posture and symmetry; 3) un-tilted head so that the visual experience of how the far level horizon matches up with the pupils and with the orientation of the skull and the corners of the eye sockets in the bones of the head without a chronic tilt bias in what strikes the golfer as normal; 4) a vivid and accurate sense of what is the highest point of the "dome" of the sky overhead, as this indicates good posture entrained accurately with the real lines of gravity; and 5) an accurate sense of what is straight ahead from the face and from the chest when standing with good posture and balance and symmetry. All great putters in golf history have good posture -- no exceptions.

Perceiving Slope -- external references to horizontal and vertical. Skillful golfers who want to read putts accurately and simply should develop explicit awareness of ready-to-hand references in the local scenery that indicate true horizontal or level in gravity and true vertical in gravity. Some external cues are better than others. The most obvious reference always available is the flagstick. Speaking as a person who cut holes, set pins, and installed flagsticks every day for a few years, golfers should take responsibility to assess independently whether the flagstick is vertical or askew of vertical. Failure to do this leaves the golfer open to influences and assumptions that trouble the reading process. The better the golfer gets at judging whether the flagstick sits vertically in the cup liner, the better that golfer can perceive fall lines and slope steepness. The flagstick should be inserted initially by the greenkeeper truly vertical in gravity, but that depends upon whether the hole is cut vertically and the cup liner installed vertically. Many times this is not the case. And throughout the day the flag is buffeted by wind and handled rudely by golfers, and comes out of vertical.

Other external cues are the edges of substantial buildings (including lines of chimneys, but not usually the vertical sides of old wooden houses settling on their foundations over the decades), communication towers so tall and heavy that any out-of-plumb construction would present a constant torque tending to make the tower fall over (and not street lamp poles, telephone poles, or trees), and nearby surfaces of ponds or lakes. To compare the level of a pond surface to the green requires looking not simply at the water, but at a substantial area of the water surface, and allowing this level area to sort out the local terrain. In a broader sense, terrain is shaped by the forces of weather, most notably by the flow of rain water in gravity off high terrain towards low terrain, where the water collects by streams and rivers into ponds and lakes and oceans. Any divergence of the green surface out of the natural drainage pattern can only proceed so far before the gig is up, as too much variance reveals itself as an oddity in the local scenery.

Finding or Perceiving the Slope Grade.

The slope steepness or grade may be measured with a smart phone application, by a builder's digital slope indicator, by a piece of string a little longer than 100 inches, or by eye.

Percent grade, not degrees. The smart phone app or hardware gadget needs to indicate slope grade as ***percent*** (e.g., a 2% grade drops 2" for every 100" of "run" laterally over the surface) and not as ***degrees***. Unfortunately, most makers of these devices use "degrees" of slope (mistakenly associating "degrees" with "science" rather than considering functionality and human perception processes), which is useless and stupid for the purpose golfers use these devices. A 45 degree slope equates to a 100% grade, and 1 degree is the same as 1.74% grade, and 1% grade is only 0.57 degrees. Grade measurements can be perceived as the difference in ELEVATION of two spots on the surface 100 units apart to get the percentage slope, whereas degree measurement entail comparing the tiny ANGLE where the sloped plane of the green meets an imaginary and perfectly level surface at the hole, with the imaginary level surface being above the real green surface in the air, or where the imaginary level surface meets the real green surface at the point 100 inches away from the hole below the real green surface underneath the ground. Golfers have ZERO skill at focusing on these geometrical relations.

In any event, degrees cannot be perceived accurately and are too small for use anyway. The full range of slopes in 1-6% grade is exhausted by a range of only 0.57-3.43 degrees: the difference the golfer needs to perceive accurately to tell, for example, a 2% slope from a 3% slope is the difference between an angle of 1.15 degrees and an angle of 1.72 degrees, so using degrees as the unit of slope steepness is rather stupid. Make sure the smart phone app or other device allows or provides the measurement in percent grade, and not only in degrees.

A handful of different technologies and techniques (not requiring a gadget) can be employed to assess and perceive slope steepness. Some are better than others. Use of technology might or might not train the golfer's skill, but in any event in the round of golf the golfer needs to assess the slope steepness without the gadgetry but in reliance either upon mere memories built up over time or by "know how" of what to look for and how to perceive the surface accurately, as it really is. There are two comments to make about gadgetry versus "know how".

First, using gadgetry inherently encourages golfers NOT to learn "know how" but instead to build up a memory bank. Memory banks for slope steepness are not accurate and stable memories, so that's a gyp, and the golfer using a gadget really needs to learn HOW to go about perceiving slope with his body and senses.

Second, the nature and accuracy of an inclinometer (engineering and construction tool that assesses slope) is limited to the AREA of its base, as this in fact is all that the inclinometer reports upon. Experience teaches that gadgets with a small "footprint" on the surface, including levels and smart phones, report the slope fall line or slope steepness ONLY with respect to the footprint of the device, and the numbers look very exact and accurate, but moving the device a small distance away to sample another footprint on the green results in wild changes in the supposedly exact numbers. The reason for this is the unevenness of the grass: the device is not being placed down to sample the slope of a flat marble slab, but to measure the puffy grass. So the variability of measurements is quite large. In contrast, what the golfer does with low-tech (long string and tee peg) or no-tech (imaginary long string stretched to foot 100 inches downhill), in addition to teaching and promoting the learning of "know how" for on-course skill, ALSO samples a much larger surface than the gadgets. Okay, you're warned: "*technology ain't all it's cracked up to be.*" The efficacy of the gadget depends upon whether the person designing the technology knew the basic skills and human processes in performing the skill when the product was designed, as poor choices of what to measure and how to report the measurement are quite frankly just wild guesses by uneducated people hoping to make some cash from the game.

The device at below-left is the Exelys digital green reader, and illustrates the usual problem of people designing training aids without comprehension of the skills or human processes that need training. This device has a small footprint, uses only degrees for

slope, and the read for the fall line direction is crudely only one of 16 arrows (the four cardinal directions plus three intervening directions between each of these four). This means the arrows mark directions in 22.5 degree jumps -- not very accurate. The device indicates the following "compass directions": N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW. Since golfers already know up from down, only 8 of these are meaningful: W, WNW, NW, NNW, N, NNE, NE, ENE. Because out of these 8, golfers can always ballpark the direction without the gizmo within about 3-4 of these arrows (NW, NNW, N, NNE, NE), what you are really getting is the benefit of help on picking among these 3-4 possibilities. About half the time, the gizmo fluctuates between two adjacent arrows, shifting back and forth instead of settling on one or the other. So you really aren't getting that much help with direction, and in any event, the help is only accurate at the spot where you locate the gizmo. Using the device might occasionally confirm that the golfer correctly aimed the device in accordance with the real orientation of the fall line, but more usually the golfer aims N one direction and then the arrows indicate that the perception fails to match the reality. Then the golfer learns: 1) his choice was wrong and the line aims left or right of his perception; 2) the line aims "about" 22.5 degrees or 45 degrees more to the left or right; and 3) the slope steepness is reported in degrees, and 4) this data may or may not be the same if the device is repositioned no more than one foot away. *Okaaaayy .....*

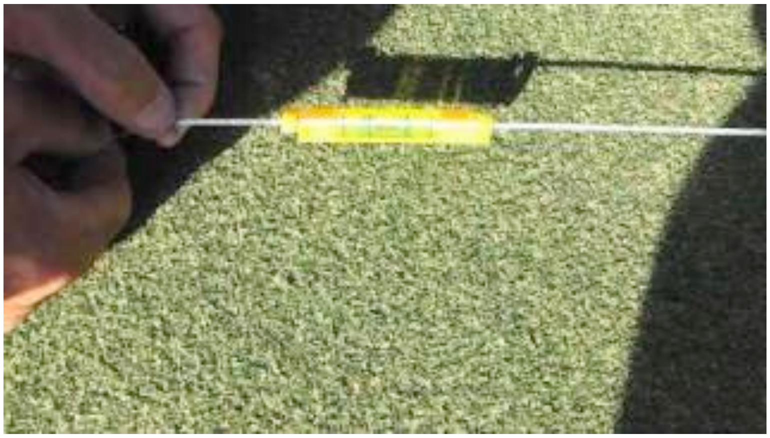
For more, visit this 2003 Flatstick Forum explanation, http://tinyurl.com/dx2pwq7.

Smart phone bubble level apps. The Android smart phone has an application that measures slope direction and tilt as percentage or grade. One application is Bubble 2.0.1, a virtual bubble level, by Ben Zibble, FREE download from http://www.ktk.bz. The level displays either degrees of tilt or grade percentage tilt, and is first calibrated to a level surface. For the iPhone and Android phones, a nice FREE app is the Johnson Bubble Level, "model" name "iPhoneBubbleLevel", at http://www.johnsonlevel.com/levels.asp.

Digital inclinometers. The Johnson Level Company (website above) has a nice digital level "inclinometer" that uses batteries and that one sets on the green surface, locates the uphill direction, and then reads the slope steepness along that fall line direction.

The product is called “10.5” Magnetic Digital Level” (Model 40-6080). There is a smaller 6” Digital Level (Model 40-6060) available on the same products page (photos of each above).

The PuttingZone Gizmo -- string and tee peg with $1 string level.



View the YouTube Explanation: http://yt.cl.nr/OYQKkhEc7Fo

This device finds *both* the fall line direction and the slope steepness in percent grade. A length of string approximately 110 inches long, plus a tee peg, and optionally a small bubble level in a plastic cradle to hook beneath the string ($1), is a great way to find the fall line and to measure the slope in percent grade. Tie the string to the tee peg and push it securely in the green just above the rim of the cup on the fall line straight uphill-downhill thru the hole (see below for finding and perceiving the fall line’s direction thru the hole). Stretch the string level in gravity from the tee peg over the center of the cup and straight down the fall line, noting the piece of the string centered above the center of the cup, and measuring the string 100 inches from the center of the cup to the spot of grass on the fall line 100 inches away. Hold the end of the string above the surface so the length of string is stretched “level”, and then turn the remainder of the string 90 degrees down to the surface and measure the height of the level string above the ground 100 inches from the center of the cup. This measurement of height in inches is the percent-age of grade. If you also have a $1 or $2 plastic bubble level from the hardware store that rides beneath the stretch of string, attach it and use the bubble level to decide whether they way the string is stretched away from the tee peg is “level” in gravity.

These inexpensive string levels are commonly available at DIY hardware superstores such as Home Depot and Lowes, or from the Johnson Level Company.

Bubble levels not helpful. Bubble levels, per se, are useless. The bubble is encased in a dome-shaped glass or plastic enclosure, and if the bubble rises to the top of the dome in the center of the circular enclosure, this indicates the base of the device is resting on a surface that is "level" in gravity. If the base tilts out of level, the bubble slips out of the center in a specific direction, and goes further from the center the steeper the surface tilt. Aiming the bubble level so the two points -- center of level and bubble out of center -- indicates the fall line. This does not indicate slope steepness! *Some* bubble levels mark the dome with concentric circles, and if the bubble moves out of the center only a little, and rests on the first concentric circle outside the center, this indicates a mild slope, usually 1%. This entire enterprise can also be performed with a bottle of water set down on the green, observing how much the level surface of water slides up along the low side of the vertical wall of the bottle. One can mark the wall of the bottle at "zero" or "level" slope, and then at 1%, 2%, etc. Commercial green reading bubble levels, IF they have any markings at all for slope, are not particularly accurate or much of an improvement over this water-bottle device. (Incidentally, the actual use of a water bottle for this purpose during a stipulated round under the Rules of Golf is illegal, and there is a Decision on just this point: *Decision 14-3/12.5*.)

Here is an example (at right) of a bubble level app that is a bit silly -- the main marketing gimmick for the bubble level itself is that the metal for the base is similar to a high-quality watch metal and won't get too scratched up in the pocket jangling with car keys and pocket knives. *Okaaaaayy...* (Note the absence of concentric markings on the bubble level itself.) Then these good folks made a smart phone app for fall line and slope, too, and this promotional picture shows a slope measurement of ***10 degrees uphill***! Good grief, the ignorance pours down like the Lake Huron dumping over the Canadian side of Niagara Falls! A 10 degree slope is the same as ***a slope grade of 17.6%***, about three-times steeper than the steepest possible pinnable position on modern greens with Stimp 10′ green speed. So "*buyer beware*" -- uneducated folks are making and selling things for putting and don't know the first thing about good or bad reality.

Smart phone "green reading" and "break reading" apps promise the moon, but .... These technologies, as usual, are designed by people with questionable familiarity with what is important for putting to *perceive*, the human *processes* of perception involved and how they work and need to be trained and educated, and for the *use* of the information to plan and execute a putt that fits in with the golfer's personal skills for touch and stroke and aim. The golfer needs to *USE* the information for the read and start line provided by the technology in a manner *NOT* requiring the golfer's having to jam his round peg putting skills into the technology's square hole calculations. The technology is NOT giving the golfer HIS read, but an ideal calculated read based upon assumptions that don't really fit the specific putt, and the golfer cannot use the calculation with his personal sense of touch, and cannot use it with his "signature" crooked stroke, and cannot use it with his imprecise aiming.

Sure, something is better than nothing, and golfers believe this sort of thing could not possibly have any problems if they see some successes, but .... So invariably, these technologies purport to be "scientific" with mathematical exactitude and certainty, but in fact present the golfer with at best a suggested read by a caddie who has never seen the golfer read or putt anything and who has a mere academic interest in the subject. *Okaaaayy ....* Just sayin', folks.

And these apps always have the following issues that require the golfer to assess: 1) does the designer know what really matters for a specific golfer facing specific putts so that the device is seen in this context as merely suggestive and helpful, or is the device purporting to have unrealistic scientific incontestability?; 2) does the device have accurate and sound mathematical programming and assumptions in its algorithms?; 3) does the device use appropriate units with the right level of precision for real golfers to benefit?, 4) does the device discourage learning perception skills and the "know how" that carries onto the course or does it purport to entrain mere memories without skill know-how? There are further issues. Golfers should always check the consumer reviews to see how the app actually works. Some apps lock up or crash routinely or have very imprecise functions, and most golfers using these apps want a refund! *Caveat emptor*!

Low-Tech method with foot and shoe: The easiest way is to step off 100 inches from the cup, and then just eye the difference in elevation "as if" stretching the string level from the hole above the fall line, and then estimate how high the stretched string would meet the shoe or foot of the golfer. The 100 inches is equivalent to three military paces (30 inches or 2.5 feet each stride) plus one additional 10" segment the same as all putter grips on conventional putters. The 100 inch distance is also "about" three putter lengths: a 35" putter tripled is 105", so subtract 5", but a 34" or 33" putter is close enough not to worry about an adjustment. If the imaginary level string meets the shoe at the top of the toe, that is a 2% slope grade. If the level string meets the laces of the shoe, that is a 3% slope grade. If the level string meets the ankle bone, that is a 4% slope grade.

Ultra-No-Tech method -- just roll a ball. Caddies have traditionally simply rolled balls across greens in practice rounds to "test" the surface for contour and fall lines. If you think you have accurately perceived the orientation uphill of a flat area of the green, fine, now test your decision with accurate feedback by aiming straight uphill at the hole and then rolling the ball straight on that line to the hole with good delivery speed. If the ball curls off line instead of rolling straight into the cup with that sort of putt, there are only two possible explanations: 1) the fall line is not oriented in that direction, and/or 2) the green is not really flat from ball to hole. Assuming the green is flat, a ball that curls off line to the right of the hole indicates that the true fall line's starting point at the ball should also move to the right (and vice versa for balls rolling off line to the left of the hole). On the 6-12 line of a clockface, this means the clock the golfer thought was oriented to match the real fall line needs to rotate counter-clockwise looking uphill if the ball misses right of the hole and rotate clockwise if the ball misses to the left of the hole. The "extent" of the miss right or left roughly corresponds to how much rotation brings the initial estimate in line with reality. The golfer can also roll balls downhill, or from one or the other side, to confirm the flatness of the area and the symmetry of the pattern of breaks. Rolling balls, however, does not directly indicate steepness of slope.

Finding or Perceiving the Fall Line.

Any flat planar surface that is tilted out of level presents one direction uphill in space. If the surface around the hole is envisioned as a CD-Rom disc with a hole in the center, tilting the disc helps learn what to perceive on the green to see accurately the direction in space the surface aims uphill. Perceiving this direction as a line straight uphill and downhill thru the cup implies a pattern of breaks from all directions in a circle around the hole. If the CD disc is also seen as a clockface, one orients the 6-12 to the fall line.

Of course, the technological gizmos surveyed above will often also provide information from artificial sensors about the direction in gravity of the surface tilt. But the small-footprint and other limitations, and the diversion of the golfer from developing independent skill using innate perception processes, argues for not relying upon these gadgets. Golfers have a poorly educated notion of what constitutes "feedback" that combines with an equally uneducated ability to use critical intelligence in analyzing and assessing the fitness of any given technological embodiment to provide "accurate" information that differs in kind and precision from information sources commonly available without the gizmos. The net result is golfers don't commonly believe that any "feedback" without an electronic, computer-chip gizmo could be "accurate" or appropriately precise or useful. The truth is that human eyes are biological sensing technology that is vastly more detailed and veridical than any modern camera for the wavelengths received, and simple "probes" like a straight-putted ball transiting across the visual field near the feet of the observer give all the accurate feedback about whether a given line is in fact the fall line, at a level of precision and usefulness that avoid the small-footprint problem and does not in the least discourage learning how the innate senses that accompany the golfer onto the course actually are best used skillfully to sense fall lines and other read-related cues on the course. Duh!

Five methods for perceiving fall line orientation in space. The PuttingZone has pioneered perception processes for putting, including methods for perceiving the fall line. Five of these methods are:

1. the highest point on the rim, plus the center of the cup, indicates the straight putt;

2. the lowest point on the rim, where a filling cup of water would first leak out and make a stream trailing straight downhill, indicates the fall line;

3. imagining placing the hands left and right of the fall line at equal elevations in order to perform a pushup on a slanted surface, without making a lower hand work harder, has the spine aligned with the fall line;

4. imagining a pole in the cup with a 6-foot rope tied to your neck like a donkey's neck, with the donkey walking in a circle around the hole on the tilt, and sensing with all four feet the laborious plodding uphill suddenly changing once the very first step downhill across the fall line occurs, indicates the crossing of the fall line;

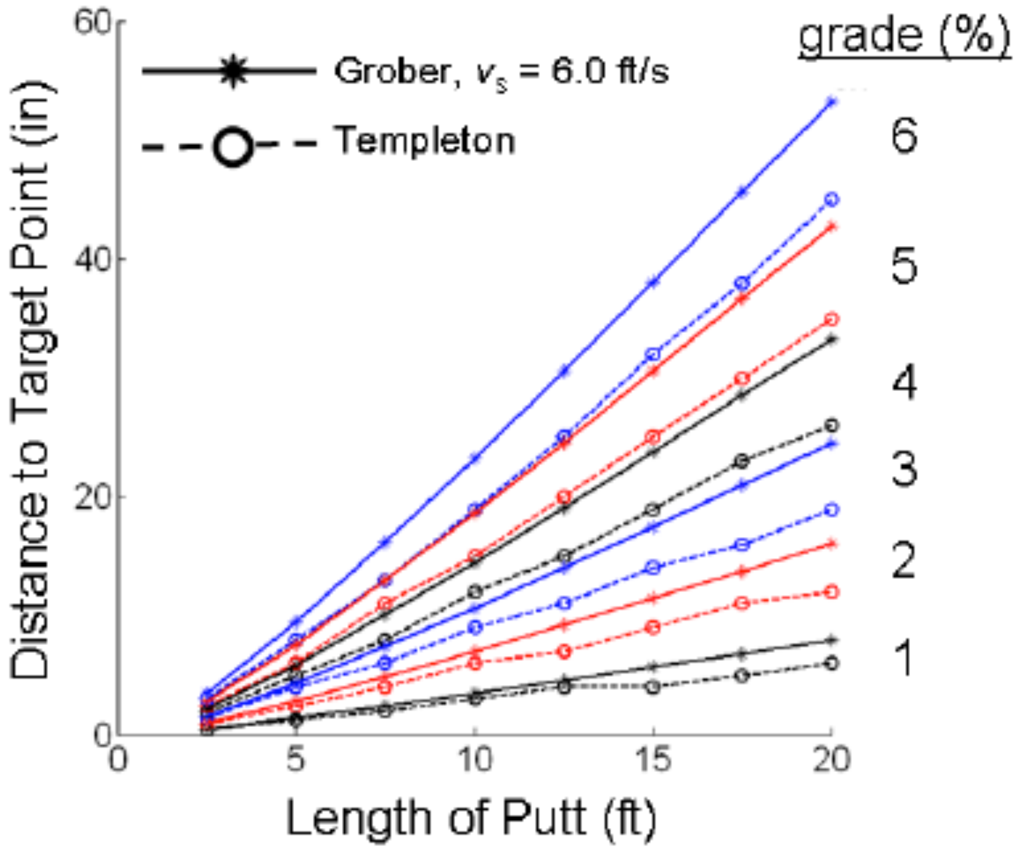
5. using your putter suspended at belt buckle level with thumb and forefinger lightly holding the top of the grip, then positioning the putter head equally between the ankles slightly back from where it hangs between the toes, and then releasing the putter so it swings lowside from between the ankles and "hunts" in a circling action, ends with the hosel itself finally swinging back and forth along a single line -- the fall line.

The perceptions can use a favorite but it is best to use a handful, like judges at Olympic skating, bag the perceptions one at a time, then toss them out on the table, throw out the obviously bogus perceptions, and then the consensus decision emerges.

It is not terribly important to be very precise about the fall line orientation, unless your ball is fairly close to the fall line or when the slope is pretty mild and this in itself makes perceiving the fall line difficult. If seeing the fall line is hard, then widen your perspective away from the hole to the total fringe, then perhaps wider to the tree lines around the whole scene, and perhaps even wider to unseen mountains and lakes and rivers, until a clear decision on which way the highest local reference lies. This deals with subtle slope, usually under 2%.

Break Calculations and Test Data from Other Sources.

Here are some data points from two sources (H.A. Templeton's field tests plus calculations with assumptions from *Vector Putting: The Art and Science of Reading Greens and*



Computing Break (Dallas TX, 1984), and calculations by Yale's Robert Grober using assumptions without field testing in "The Geometry of Putting on a Planar Surface" (unpublished manuscript, n.d.)), on various slope steepnesses on a Stimp 6.5′ green speed, using slightly different delivery paces. The lower / smaller break data of Templeton are a result of testing greens with actual putts over a number of years using a fairly robust delivery pace (24″ past the hole) and also calculating the breaks using an off-ramp velocity of the ball exiting the Stimpmeter of 6.5 ft/s (1.98 m/s) as the basis for green friction values in the calculations of break. The higher / bigger break "data" offered by Grober is a result only of calculations using certain assumptions about delivery pace (18″ past the hole) without any real-green testing or experience, and using a "calculated" off-ramp velocity of 6.0 ft/s (1.83 m/s). Making sense of this debates unfortunately first requires untangling and parting the gauzy curtains concealing the Yale Wizard's control booth. The whole enterprise of calculating break is flawed by both Grober and Templeton, so a step by step elucidation of the errors is necessary to get us out of the dark woods of complex error and onto the well-lighted path of simple common sense.

Since in reality golfers cannot control delivery pace exactly, and different putts arrive and stop past the hole AT LEAST 6" longer than the golfer's usual and 6" shorter than the golfer's usual go-by distance, the REAL delivery pace that should be counted on is a bit "fuzzy" and "spread out" and is a range AT LEAST as wide as 12" 90% of the time, with balls sometimes stopping 7-10" past the back edge of the hole and sometimes stopping 30" past the back edge. The REAL range of variability 95% of the time is wider than 12" and extends out perhaps to 24" of variation for the extreme differences of delivery pace. The faster the green speed and the steeper the slopes, the wider this variation becomes. This means that delivery pace is not an exact figure, and the chart should be considered only suggestive of "about" how much break a given slope and green speed should be played.

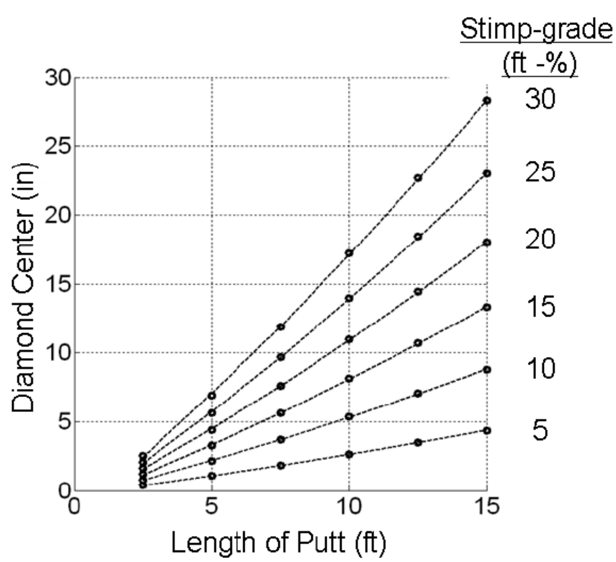
The anemia in Robert Grober's "academic formalism" compared to real putting. Grober, using assumptions and calculations, asserts that Templeton's breaks are 10% too low. However, academics without practical knowledge of real putting skills and without field testing their calculations, very frequently adopt assumptions about putting that are frankly ignorant of the real situation, and Grober is no exception to this academic style of "playing" with golf with physics formulae. The assumption about delivery pace and the assumption about the Stimpmeter used by Grober are typical examples of mistakes by academics unfamiliar with golf skills and realities, and his calculations are too high. Golfer "touch" in reality does not match the calculated and suggested "optimal touch" used by Grober, borrowed from another physics teacher's calculations in 1986 (Brian Holmes, "Diaglogue Concerning the Stimpmeter," *The Physics Teacher* (Oct. 1986): 401).

The calculations of Grober and others (Brian Holmes, Tony Penner, Mark Sweeney) about aim points are dependent upon an assumed off-ramp velocity of the ball exiting the bottom of the Stimpmeter. Grober borrows the calculations from Holmes (as did Penner and Sweeney), and Holmes also did not measure the off-ramp velocity. The assumed value, however, does not comport with practical reality of actual Stimpmeter use by greenskeepers or with actual measurements of off-ramp velocity.

As a person who daily used the Stimpmeter working as a greenkeeper setting pins on greens and mowing greens, and also as a putting coach who studies and has studied and experimented with greens and the physics of balls rolling on greens daily using the official USGA Stimpmeter for nearly a quarter of a century now, my studies and empirical measurements indicate the actual use of a Stimpmeter and the real physics and measurements of the Stimpmeter shows an off-ramp ball velocity that is somewhat variable depending upon the dimples of the ball as it is seated in the release notch affecting when the ball releases, and also upon the exact movement of the greenkeeper lifting the back of the Stimpmeter ramp to the release height. Scientific testing of real use of the Stimpmeter indicates that the usual off-ramp velocity is 6.2 ft/s (1.89 m/s), a figure about midway between Grober's low 6.0 ft/s and Templeton's 6.5 ft/s.

Grober acknowledges he neither calculated the off-ramp velocity nor measured it, but this value is critical in his factoring in the friction in formulae where ball distance and rolling speed is dependent upon green friction and "Stimp speed" values. Both these mistakes indicate that Grober's "office calculations" are off compared to reality, and that simple steps to make the calculations better were not undertaken. The end result is that Grober under-estimates the friction in real greens implicit in Stimpmeter measurements, since the ball comes off the Stimpmeter faster than he assumes, and a delivery pace in excess of a mathematical ideal pace is one closer to the pace of real golfers, both of which promote a lower line and a more robust delivery. This all suggests that Grober's calculations are the outer margin of successful putting too dependent upon ideal performance by variable golfers lacking the requisite skill, but the heart and core of more frequently successful putting by real golfers is closer to Templeton's figures.

The flawed approach of both Grober and Templeton. However, in point of fact, *neither* Grober nor Templeton have a sound approach to the issue, as golf is not played with numbers and general-application formulae and rules or with the illusion of exact mathematical precision, but with specific facts for putts and golfer's touch and stroke skills, with all the variability and range of messiness (even if the range is whittled down severely by expertise and long practice) that entails from one putt to another. The best approach is that of the PuttingZone, to teach a golfer to *perceive* paradigm patterns that result only from the golfer's personal touch or pace, and to teach also the correct *use* of these paradigm patterns in the *recognition* of optimal break patterns when reading on-course, specific putts. In that way, the calculations are placed in their proper light, and used intelligently, as suggestions to help this or that golfer get oriented to the ballpark reality of specific putts and their actual breaks and then help to adjust from the general "ballpark" pattern to the specific putt at hand.



The "Combo" Surface. The actual data in the above Templeton-Grober chart were derived on a Stimp 6.5′ green by test putts by Templeton and by calculations by Grober assuming a Stimp 6.5′ green speed, so the chart has to be adjusted to a Stimp 10′ green speed. Looking up the Stimp 10′ and 2% slope data from the above chart is done by considering the slope 3% data on the Stimp 6.5′ chart as representing the slope 2% data on a Stimp 10′ green. That's because a Stimp 10′ green speed is slightly more than 50% faster than a Stimp 6.5′ green speed (6.5′ + (50% * 6.5′) = 9.75′. The slope that is 50% steeper than 2% is the 3% slope (2 + 50%*2)=3.

This chart from Grober illustrates the power of the "combo" identification of slopes and green speeds, rather than keying solely on a single slope and then considering different green speeds on that slope. The concept is present in Templeton, and Grober follows Templeton's lead. In the above chart, the "20" line represents the combination of 2% slope and Stimp 10′ green speed. But it also represents ANY combination that is also a "20" or nearly so, such as the combination of a Stimp 7′ green speed and a 2.9% slope (the equivalent of a "20" in the parlance of the "combo"), or a 4% slope and a Stimp 5′

green (a “20”), or a 1.7% slope and a Stimp 12′ green (a “20”). Any combination that is a 20 breaks exactly the same for the same delivery pace of the ball. Grober’s calculated break in the above chart, 12”, has to be understood in the context that other assumptions about delivery speed and surface friction result in lines that are higher (slower delivery speed, less friction) or lower breaks (more robust delivery speeds, more friction). This means that Grober’s calculated 12” is at the highest margin of all breaks, because he assumes an off-ramp velocity at the low end and also a ball delivery speed at the hole at the low end. His calculations have slow balls and more friction than he assumes.

What the Templeton-Grober data comparisons teach us. The Templeton-Grober comparison chart requires interpreting to elicit its data in terms of a 2% slope and a Stimp 10′ green speed. Focusing upon the data at the 10-foot length and the 3% slope lines above for the slope 2% data from a Stimp 10′ green, both tests come up with between 10″ and 12″ of break for the 2%-10′ combination. That corresponds to the above measurements, with a 2%-10′ combination breaking between 10″ from 10 feet away (10″/120″ = 8.3%) to 12″ from 10 feet away (12″/120″ = 10%), or between 1″ per foot and 1.2″ per foot. So a “20” is 10% of the putt length or 1″/ft break.

As the slope increases, comparing the gap in the two data points as the slope increases, the “spread” of the break becomes more sensitive to the delivery pace and the range of break widens as the slope steepens. That is, when the green is steeper, the pace matters quite a bit more. Success or failure of the putt is quite a bit more dependent on the precision of the delivery pace being very stable when the steepness of the slope is 3% than it is when the slope is 2% steep. And if the golfer varies the usual delivery pace on steep slope, he is in effect making a significant difference in how much break gets played.

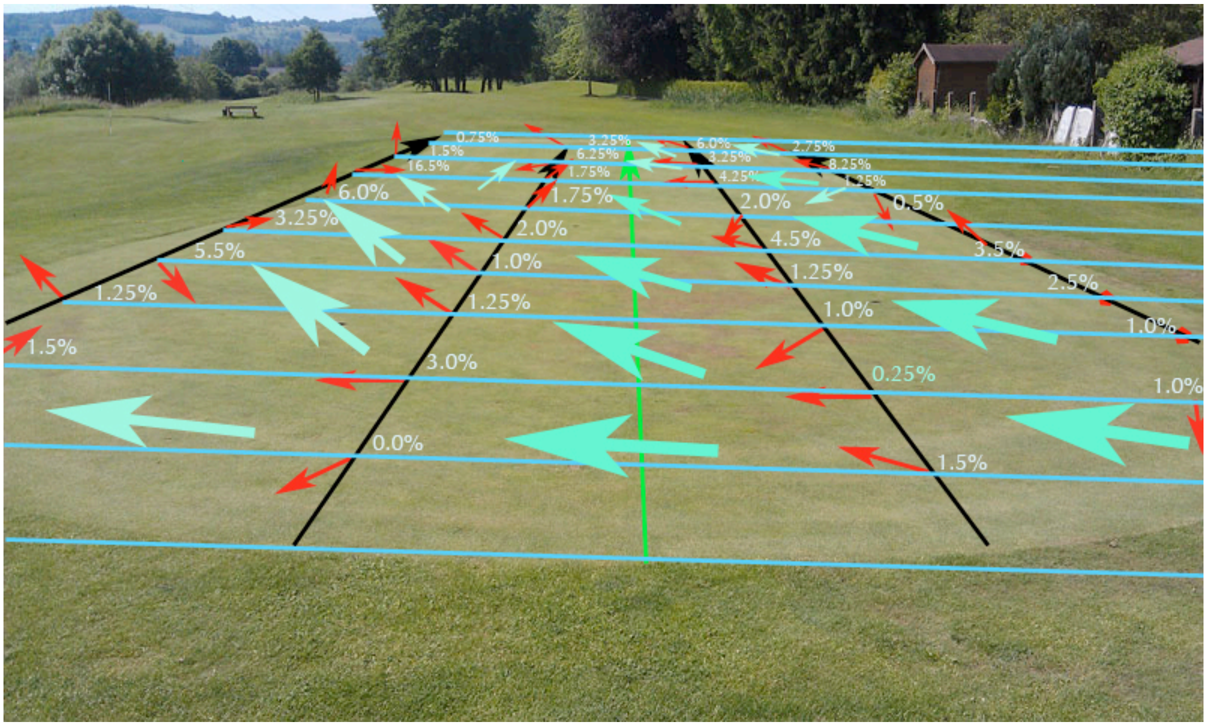
For example, in the above chart 4.5% slope data corresponds to a 3% slope on a Stimp 10′ green. If one golfer putts the ball to stop 24″ past the hole, he will see the ball break 16″, according to the chart. A golfer who sends the ball 18″ past the hole will see 20″ of break. That’s one cup difference on a 10-foot putt. So a golfer who “reads” or plans the break with the usual 24″ past the hole in mind, but who executes the putt with a slower pace of only 18″ past the hole, will see his ball drop about 4″ lower than expected. The gap is not nearly this significant at the 2% slope, and slowing the delivery pace from the "reading" pace causes the ball to fall lowside about one-half a cup (2" or so). That much difference may not prove fatal to the putt, whereas a full-cup or 4" drop of the putt to the lowside will almost always prove fatal and the putt will miss.

The message is "stick to your rhythm", all the way nicely to the hole, and don't get into the game of being especially careful and overly precise with the delivery pace. Yes, determine not to go too far past the hole (that is always true), and in dicey situations where the surface is steep and the green speed slick, by all means pay close attention to the danger and be very careful about making sure the outcome takes all relevant factors into account. But once that is done, do NOT baby the rhythm, but keep the rhythm smooth and even. Learn how to execute putts with a rhythm that handles fast greens and steep slopes and then "stick to your rhythm"! Any "quit" in the rhythm in these dicey situations is especially harmful, as that takes some pace out of the putt and changes the "read" pace to a slower "execution" pace. On a 10-foot putt in such a situation, that "quit" rhythm feels like precise control but in fact makes the ball drop 4" lower than planned and misses the cup. Stay smooth and even, especially in these cases.

Mapping a Green Using a SmartPhone App for Bubble Level Slope Readings.

If the golfer wants to, he can map each green on the course, or more specifically the handful of separate flat areas of each green, for fall line and slope grade. With a series of green maps like that, the golfer then can use the paradigm two putts on the practice green to ascertain the breaks for slopes with that day's green speed, and then use the slopes on the maps to understand how large the break is across any slope on that day.

This process was followed on the practice green at Henrik Jentsch's PuttingZone Academy at Wiesenthal Golf Course in Schopfheim, Southern Germany. Establishing a 10-foot by 10-foot (3m x 3m) grid with string, measurements of fall line direction and slope grade were taken at each intersection on the grid. The green measures in the long dimension North-South 100 feet along the midline (30 m) and is generally 30-35 feet wide (9-10 m) East-West. Exclusive of the Northern and Southern margins, there are 9x4 grid points that were measured (36 points). Then basic elevations were measured with zero



being the Southern boundary, taking readings in inches below zero at each 10-foot (3m) point along each of the five N-S meridian lines (11x5 measurements). Finally, a free-hand effort was made to approximate equal-elevation contour lines to represent isolated surface features such as humps and hills and dips. Once this data was compiled (see the hand drawing below), further calculations of break and contour are performed.

Using the Green Map. Putts across constant slope flatness are the simplest to calculate for break and target location. These putts have a simple break that uses a target directly calculated as described above. So the use proceeds as follows:

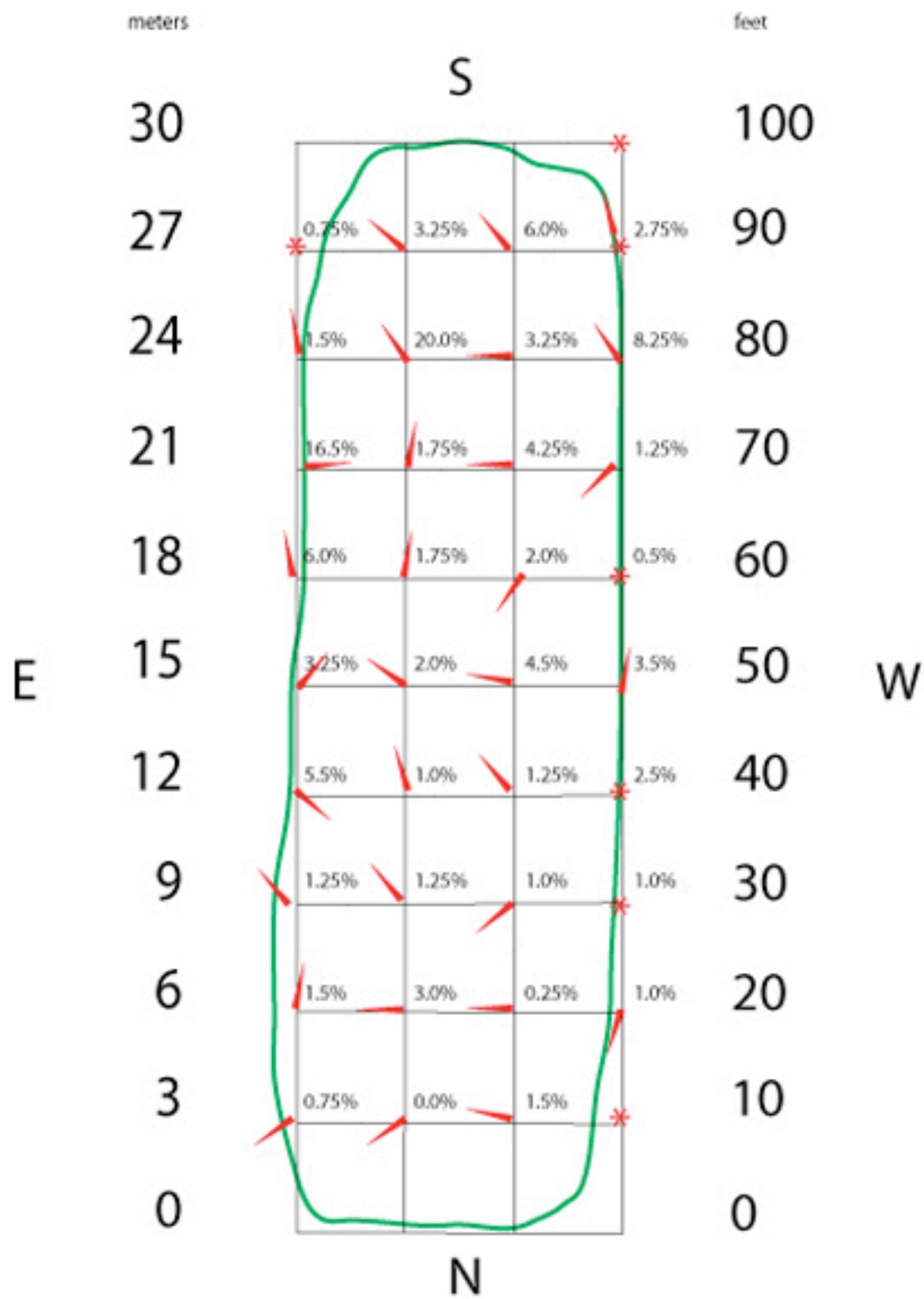
1.Once the ball position is known, the flatness of the surface from ball to hole is judged, and if found to be relatively the same flatness, the calculation proceeds without adjustment;

2.The green speed is judged, and if found to be “the usual”, the calculation proceeds without adjustment;

3.The fall line direction uphill is judged;

4.The distance from ball to hole along a straight line is judged;

5.The map is consulted to see the nearest grid point to the hole, and the slope direction and grade is then used so long as the instant putt does not seem to involve significantly different contour;



6. Using the map's slope grade (slope percent), the percentage of break to use is interpolated from the general understanding (e.g., 2% breaks 5% of distance; 3% breaks 7.5% of distance, etc.) for the specific slope from the map: example: 2.5% slope breaks half between 5% and 7.5% or 6.125% of the putt length;

7. The target is then this percentage break times the length of the putt, locating the target this distance up the 6-12 fall line from the center of the hole;

8. The golfer then aims the putter face thru the center of the ball at this target and then strokes the ball with the energy that matches the initial measurement, or 1-2 rolls past the fall line, also starting the ball straight online wherever the putter face aims;

9. The golfer may also adjust the read LOWER than the target by planning to deliver the ball at the hole with more than 1-2 rolls past the hole velocity (which is 1-2 rolls/second velocity at the front of the hole), reducing the distance of the hole-target segment by about 20% for each additional roll/second velocity at the hole (e.g., a 5" break for a 5-foot putt might reduce to 4" of break by adding 1 revolution per second ball speed delivered to the front of the cup to the usual pace).

The target thus calculated is not an exact point, but is more of a maximum break with lesser breaks closer in to the hole in a gradient of advisability, since speeding up the ball dramatically over the reading speed is not in general a sound plan and only modest increases in delivery velocity result in high percentages of success.

Reiteration of the process as applied to the slow greens in Schopfheim Germany. Break is calculated based upon slope percentage and green speed. The calculation first ascertains by measurement the slope grade as percent, and then the green speed is measured using the official USGA Stimpmeter according to its usual instructions. On the day of measurement, 29 May 2012, the green speed measured Stimp 7', somewhat slow by American standards but fairly normal for mid-Spring in Germany. Once a slope was found that measured at 2% grade, and the surface of the slope was estimated within reason to be essentially "flat" or "planar" out to 10 feet (3 m) or more from the hole, the following procedure was implemented: a) the fall line straight uphill was found by measurement with the smart phone application and also by putting balls straight up the indicated line to confirm the absence of left or right curving off the line; b) treating the fall line from low to high as the 6-12 vertical axis of a clockface, the 9-3 sidehill axis was found at right angle to the 6-12 line (90 degrees) and a ball located on this axis 3 meters from the center of the hole (the same as 10 English feet) at the 3 o'clock position; c) the ball was then putted straight at the center of the hole (started in this direction along the 9-3 axis) with a pace and speed of the ball that carried it across the 6-12 line below the hole breaking "downhill" right-to-left from the direction of travel from 3 o'clock to the hole 1-2 rolls beyond the 6-12 line before the ball stopped (5.28 inches of circumference of the ball per roll); d) the distance of this crossing point on the 6-12 line was then measured from the center of the hole; and e) the break is then calculated as a percentage of the putt length by dividing the measurement of the crossing point below the hole by the length of the putt.

For example, when the slope measures 2% grade and the Stimp measurement is 7 feet, a ball putted along the 9-3 axis from 3 meters (300 cm) with the delivery / terminal velocity that carries the ball 1-2 rolls across the 6-12 line, the measurement of the "break" the ball experiences downhill was 15 cm. This calculates as 15 cm / 300 cm = 0.05, or break that is equivalent to 5% of the distance of the putt. The assumption is always that the surface from ball to hole has uniform plane, or the same "flatness". Hence, a 5-foot putt (60 inches, or 1.5 m, or 150 cm) breaks 3 inches (5% of 60 inches = 3 inches) or 7.5 cm (5% of 150 cm is 7.5 cm). The target is then located this distance above the center of the hole. As the hole is 4.25 inches (10.8 cm) wide and 2.125 inches (5.4 cm) from center to top edge of hole along the 6-12 line, the 3 inch target is located just above the top edge of the hole on the 6-12 line (3" - 2.125" = 0.825" above the top edge of the hole, or 7.5 cm - 5.4 cm = 2.1 cm above the top edge of the hole). This target is where the putter face aims thru the center of the ball and is the line the ball is putted along at the beginning of the putt, and is also the distance for the putt with the ball arriving with the same 6-12 crossing speed used to find / calculate the break to begin with as if the putt from ball to target was a straight, level putt without any break.

The specific green speed on the day of measurement was Stimp 7', which means sending a ball off the end of the USGA Stimpmeter ramp dropping from a height above the ground at the beginning of about 11 inches (28 cm) and exiting the ramp at roughly 74 inches/second or 1.83 m/second (about 14 revolutions/second of a ball 5.28 inches in circumference), the ball rolls across level green about 7 feet and stops. With this green speed, the slopes break the following percentage of the distance of the putt:

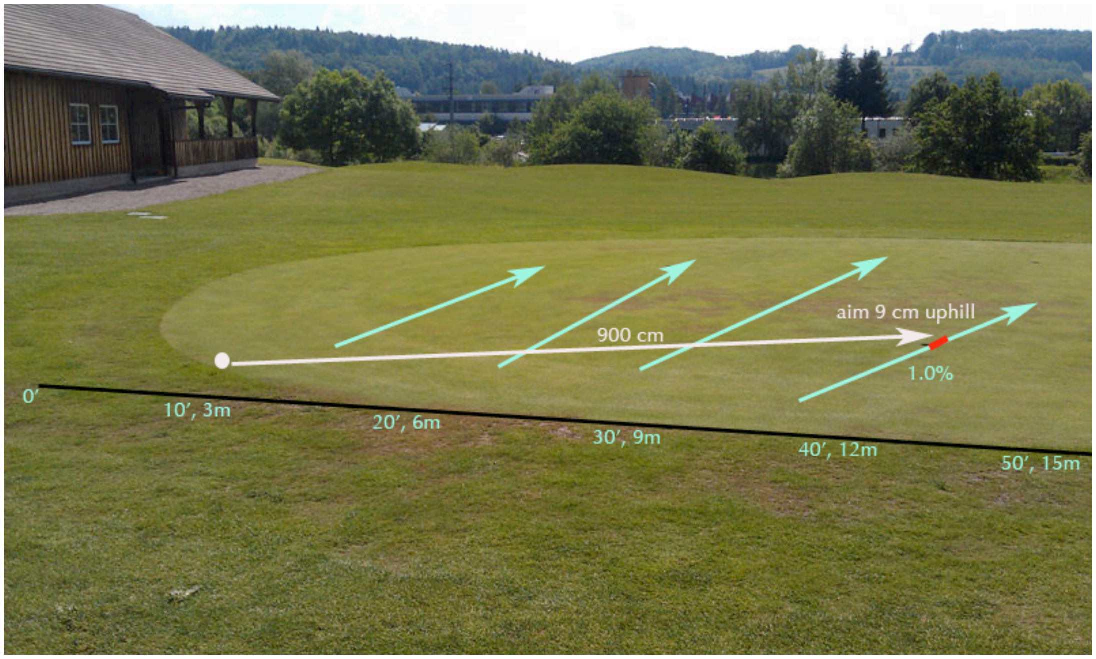
1% slope = 2.5% break
2% slope = 5.0% break
3% slope = 7.5% break
4% slope = 10.0% break
5% slope = 12.5% break.

Example Putt Reads from the Schopfheim Green.

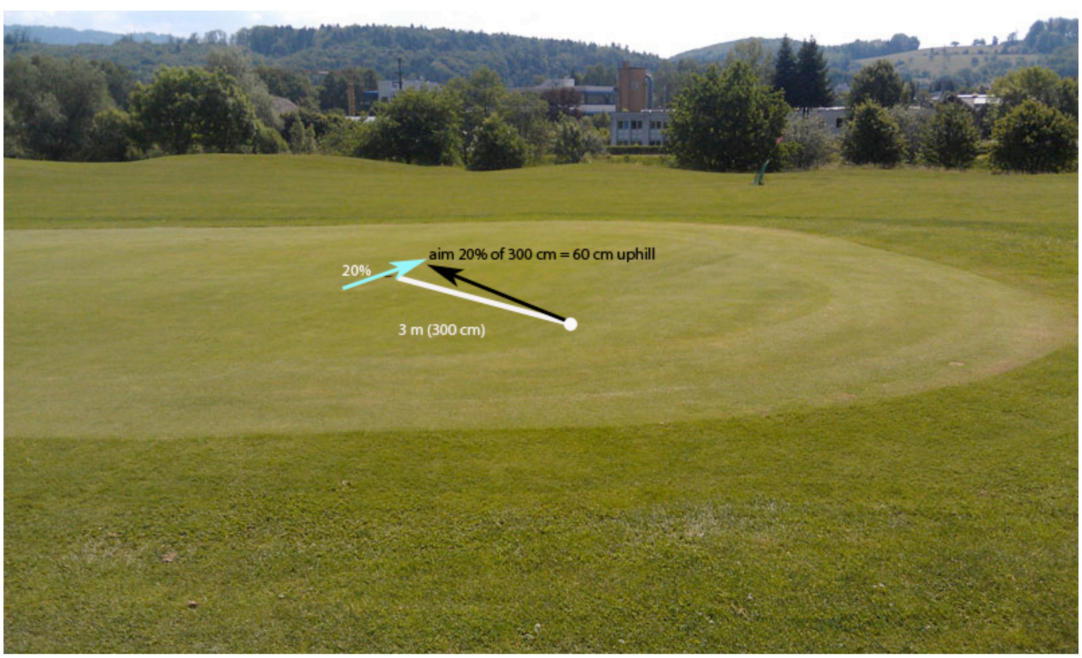
The chart above indicates the direction uphill at the point on the green (the fall line) and the break percentages for the slope and the usual (Stimp 7') green speed. Points are identified by N-S, W-E distances with the N line 0, the S line 100, and the W edge 0 and the E edge 30 feet. Each 10 feet grid is a 3m x 3m grid also. The target is located the percentage of the total putt across the same slope measured along the direction uphill from the center of the hole.

For example, a putt from 3 meters away on a straight line to the hole (300 cm) to the location at point 60, 20 (60 feet line, third column from the left) aims 1.75 x 300/100 = 5.25 cm out of the center of the hole along the uphill direction of the red arrow. The hole itself has a diameter of 10.8 cm and a radius from center to edge of 5.4 cm, so this target is not quite outside the edge of the hole. This target is the same as "right edge" or "left edge", depending upon the location of the ball.

Here is an example of a 1.0% slope at the hole for a putt across basically the same slope from9.0 m (900 cm) distance, aiming at a point 1.0% of 900 cm or 9 cm straight uphill thru the cup measured from the center of the cup.



Here is another example, this time a 3 m (300 cm) putt on a slope breaking 20%, aiming 60 cm (24") uphill from the center of the cup.



Multiple Slopes.

If the ball crosses over different slope before entering onto the final slope at the hole, ONLY the distance of the final slope calculates the break, and then that fixes the final segment of the putt. The correct aim for the earlier segments of the putt cannot argue against this final segment but instead must coordinate with it. This means that all putts of complex slopes start the reading at the hole and then work backwards over each succeeding slope until each different slope is solved back to the beginning at the ball.

One can also "average" the several slopes, but each slope is "weighted" proportionately not according to its proportion of the total length of the distance from ball to hole, but according to the proportion of TIME the ball will travel along each separate slope. The amount of time the ball experiences the gravity of one specific slope is what matters, not the length of the slope. Hence, if a ball crosses two slopes each half the total distance, the first slope is traversed more quickly in less time than is the second slope. In general, for typical modern green speeds, the first half of a putt requires about 35% of the total time, or roughly one-third, compared to the time the ball spends traversing the second half of the distance. The typical TOTAL drop in speed over distance for most putts and green speeds is about 6 feet per second for every 10 feet of travel across the green. The first half of these putts will drop about 65% of the velocity loss, and so spends about 35% of the total time on this half -- roughly one -third. Hence, the proportionality of equal slopes is to weight the first slope 1/3rd and the second slope and second half of the distance 2/3rds.

This "average" slope is useful especially when facing long lag putts, as these typically cross several different slopes. An example might be a 30 foot (9 m) putt across three slopes, the first 1% grade, the second 3% grade, and the third 2% grade, each slope about the same length or one-third of the total 30 feet, so each slope is 10 feet (3 m) long. The first segment may require about 25% of the total time, the middle slope may require about 35% of the total time, and the final slope require about 40% of the total time. The "average" slope is then 1% x 25% plus 3% x 35% plus 2% x 40% = 0.25 + 1.05 + 0.8 = 2.1%. Then the average "fall line" straight uphill is also used to locate the target. For the

9 m putt (900 cm), the target is then 2.1% of 900 or 18.9 cm uphill (in inches, the putt is 360 inches long and the target is 2.1% of 360" or 7.6" uphill).

This multiple-slope problem most frequently affects lag putts over 30 feet. For more on this subject, read the free-download PDF *Avoiding Three-Putts* I wrote in early 2012, from this link: http://puttingzone.com/Downloads/ThreePutt.pdf.

Make Your Own Ballpark Break Chart or Table Any Day.

Even if the green speed is not known, anyone can develop a chart for the day's green speed (whatever it is) simply and quickly on the practice green before the round. First, identify a flat area that extends away from the hole at least 10 feet in radius, and also a flat area that tilts 2% (as this is an ideal surface to test). Correctly orient the fall line straight uphill-downhill thru either a hole on this surface flat area or thru a specific spot that can serve as a virtual golf hole if none is conveniently present. To judge the slope grade (as percentage), simply move straight downhill from the hole 100 units (either metric or English inches), and compare the elevation at the hole with the lower elevation 100 units straight downhill. If the distance downhill is 100 cm or 1 meter, and the elevation drop is 2 cm, this is a 2% slope. If the distance downhill is 100 inches (three military paces 30" each plus 10" or one putter grip further), and the drop is 2 inches, this is the same slope or 2% grade.

Once the flat 2% slope is found, locate the ball at the 3 o'clock sidehill position 100 inches (8.3 feet, or 3 steps plus a putter grip more, or three putter lengths) and putt the ball on a start line straight at the center of the cup with speed that carries past the 6-12 fall line 1-3 rolls. Measure the point the ball crosses the fall line below the hole center. That is the percent break for the 2% slope with "whatever the green speed now is for today."

Repeat the same sidehill putt but this time from 20" further away, at the distance of 10 feet (10 feet or 3 meters (300 cm) away is 4 military steps, or simply two additional putter grips past the 100 inches mark). The measurement of the crossing point in inches this time, divided by 10', indicates how many inches of break to play for each foot of the putt distance. The whole process requires only two putts with good delivery pace.

Once the 2% slope has a break percentage, 1% slope breaks half this much, 3% slope breaks 1.5 times as much, 4% slope breaks twice as much, 5% slope breaks 2.5 times as much, and 6% slope breaks 3 times as much. That's the chart for "whatever" green speed one faces that day.

Adjusting the Mathematical "Ballpark" Read.

Once a mathematical amount of break is calculated using the percentage or per-foot approach outlined above, the golfer has to adjust this "ballpark" or paradigm read for the exact oddities of the specific putt. There are three redundant methods developed in the PuttingZone to use normal perception processes and the intuition so as to predict with great accuracy and precision the exact break in these situations.

These methods apply to adjust for the exact slope percentage, the exact green speed, the exact direction of the ball to the hole in relation to the fall line of the slope thru the hole, the exact distance of the putt, and the exact pace or delivery speed the golfer in fact will use in executing the putt. Each of these methods use the SAME golfer delivery pace, so each method results in perceiving the SAME breaking curve and start line and target near the hole along the fall line. To the extent, these methods result in differences in target and start line etc., that is simply the variance in how effectively the golfer employed one or the other of these methods, and over time the golfer will likely come to rely on one or two of the methods in preferences to another in case of conflict.

The only assumption required for these methods is that the green surface from ball to hole maintains the same "flatness". In the case that some green contouring other than flatness intervenes between ball and hole, this constitutes the break being not simple but complex. Whenever the ball traverses more than one slope en route to the hole, the break will be complex (and the term "complex" is a much better term than the golf-speak term "multiple", as "multiple" implies discrete slopes, whereas slopes actually blend into one another along a continuum of change, so that "complex" better captures this reality.) In the case of “complex” break, there are additional “rules of thumb,” but the MAIN rule is to read the putt backwards, starting with the outcome-determinative slope at the hole, and then generating the read’s curve backwards from what “must happen” at the hole to take into account the various slope back to the ball.

The three overlapping methods to perceive the exact break in the simple case are:

1. The Drop-off: predict what happens if the putt is aimed straight at the center of the hole with good pace to see exactly how many inches below the center of the hole the ball crosses the straight-uphill fall line thru the cup (aim that same distance above the center of the cup along the fall line);

2. The Headlights at the Ball: predict the exact curve over the final 1-2 feet into the cup from the high side, and then retrace that curve backwards to the ball -- filling in whatever the surface shape requires -- and then as if driving a car in reverse back to the ball, once there, turn on the head lights to illuminate the target spot on the fall line above the hole -- this spot will be the same (very nearly) as identified in the first method, since both methods are predicting with the same delivery pace over the same surface); and

3. The First High-Enough Start Line: using the straight line from ball to hole to divide the surface into one high side and the other low side, aim less than enough when putting where aimed with the usual ball speed tempo and rhythm, so that the "gut reaction" is that this too-low aim requires speeding up the pace in order to keep the ball on the high side as far as the hole, and from this you know the aim is not high enough, and so aim a little higher and recheck the gut, until the first time the aim is high enough that you do NOT feel a need to add speed to the putt, and the ball for the first time will STAY on the high side as far as the hole, and then do not aim any higher, and then a putt where aimed with the USUAL tempo and rhythm and pace will stay high side all the way to and into the cup -- then if the putter face had head lights, they would also shine on the fall line at the same spots identified earlier, so that's the start line and the read for your pace.

<u>Reading Complex Contour.</u>

In the case of a "complex" surface with variable slope between ball and hole, the main rule is to read the curve of the putt backwards starting at the hole and conforming the predicted curve to changes in contour on the way back to the ball -- always having in mind the realtime pace of the ball at that specific section of the putt -- and then use the tangent at the ball of this curve for the start line. Other "rules of thumb" are:

1. <u>Distinct Contour Features</u>: Treat each distinct contour feature encountered en route back to the ball in a cartoon-like simplification when possible. That is, if the contour feature stands out as separate from the general contour of the green, like a hump or ridge or swale, imagine the boundary contour of this feature where it separates from the general contour as drawn with a fat cartoon outline. Then, predict how the backward-running predicted curve first "exits" from this separate feature, and then proceed to predict how that exit requires a corresponding "entry" point of the read curve into that feature. Than keep moving backward towards the ball.

2. <u>Steepening or Milder Slope at Hole</u>: Observe whether the general contour (usually without separable features intervening) steepens up nearer the hole or whether the area nearer the ball is steeper and the area near the hole is less steep. If the hole has steeper slope, the break will increase compared to a sense of the "average" slope from ball to hole or compared to the starting slope near the hole. And because the ball is slowing at the hole and therefore "taking the break" more at this slower pace, a steepening of slope at the hole will have a greater increase in break than often suspected. In the case when the slope near the hole is less steep than the beginning near the ball, the break will peter out and be less than compared to the "average" slope and the slope near the ball.

3. <u>Uphill at the Hole</u>. If the contour near the hole changes so that the slope at the hole is essentially MORE and/or nearly ONLY "uphill", the break will be much less than before. If a hole is located, for example, on the side of a hump or hillock that

stands out as a separate feature of contour from the general slope around this feature, the curve at the hole is governed by the hill, and assuming the hill is more or less symmetrically shaped like an upside-down bowl over the surface the putted ball might travel, the fall line will be from the top of this hill straight thru the center of the hole and on down to the bottom edge of the hill where the feature rejoins the general contour. If the approaching curve over the general contour meets and matches this hill's fall line to the cup, no more break will take place from the bottom of the hill into the cup. If the approaching curve meets the hill on an oblique angle to the fall line thru the cup on the hill, and the obliqueness is minor, the ball will a) slow down dramatically climbing the hill, and b) not be subjected to much sideways curling since it is close to the fall line on the hill. If the approaching curve meets the hill on an oblique angle to the fall line thru the cup on the hill, and the obliqueness is major, the ball will a) slow down dramatically climbing the hill, and b) be subjected to substantial sideways curling since it is not close to the fall line on the hill and is traveling suddenly more slowly than before due to climbing the hill. This later situation results in sudden breaks at the hole that look like a "duck hook" or "duffer's banana slice".

4. <u>Downhill at the Hole</u>. If the final slope near the hole is substantially MORE and/or ONLY downhill to the hole than the general contour before then, the fall line thru the hole will govern the break. If the preceding curve matches this fall line thru the cup, the break will cease once the ball enters this final contour downhill. The entry point, then, back to the ball is the only section of the green where "reading" any curved path is required, since thereafter the putt is straight. If the approaching curve enters this final area obliquely to the fall line thru the hole, and the obliqueness is minor, the ball a) may increase speed a little down the hill but this will be very modest unless the down hill is lengthy and the increasing speed has time to gather, and b) not be subjected to much sideways curling since it is close to the fall line on the hill. If the approaching curve enters this final area obliquely to the fall line thru the hole, and the obliqueness is major, the ball a) may increase speed a little down the hill but this will be very modest unless the down hill is lengthy and

the increasing speed has time to gather, and b) be subjected to substantial sideways curling since it is not close to the fall line on the hill. In this later case, the golfer has to take some care to manage the ball's speed once it enters this final downhill contour, to avoid the gathering speed causing the ball to "blow thru the break". This care taking is a two-step process: first, make sure that the speed of the ball over and into the downhill area is slow enough to accept any increase from the slope without blowing thru the required curving into the slope's collection of fall lines and specifically so the speed is right that the ball conforms to the fall line thru the hole (or nearly so), and second, make sure that the ball speed upon entering the downhill area is not too slow that the ball fails to make it all the way to the hole. One trick to handle the second aspect is to predict whether placing the ball at the top margin of this downhill area and then just nudging the ball to start it rolling will in itself suffice for the ball to make it all the way downhill to the hole. If so, the pace required for the putt is that which delivers the ball to the top edge of this downhill area with only a slight extra speed to make sure the ball enters the downhill section. If more pace is required from the top edge of this area, then the total pace is the addition of whatever pace gets the ball to this top edge plus the extra pace required to go the remainder of the way to the hole. In either case, the golfer has to imagine what is needed from the top edge of this downhill section.

5. Up a Steep Tier and then Onward to the Hole. Tiers are sudden changes in elevation over a short lateral span of green. The outline of the tier in a cartoon-fashion with bold boundaries at the top edge and bottom edge is useful, as the "fall lines" across the tier from one side to the other run perpendicular to the contour lines of the tier. Contour lines are "lines connecting all points of equal elevation". A tier may be convex or concave or some more complicated shape when viewed from below, so the fall lines are everywhere perpendicular to these contour patterns. It would be unusual for the surface of a tier to have any pronounced irregularity of contour other than a smooth shape that overall flows in a convex or concave way between the top and bottom areas of the green. If the tier were totally flat but steeply tilted, the bottom edge would exactly parallel the top edge and all contour

lines in between would also be parallel, and hence all fall lines would be perpendicular to these contour lines and also all parallel, so the flat area would have a perfectly rectilinear grid pattern of contour lines and fall lines. The definition of "flat", in fact, is just this: an area where all fall lines and all contour lines are mutually parallel in a regular grid pattern. Viewed locally, then, the fall lines on tiers that have convex/concave flow are very local "flat but steeply tilted" areas of surface. When a putt crosses an area of tier, the tier's fall lines in that area will all direct the ball "downhill". Hence, if the ball is to the right of these fall lines when entering an uphill tier area, the ball will break downhill to the left, and vice versa. The AMOUNT of breaking will vary, however, depending upon the total elevation change of the tier and the remaining distance from the top of the tier to the hole: in other words, how FAST the ball travels up and over the tier. Typically, a tier might be two feet in elevation change from bottom edge to top edge, and this usually computes to the tier's "costing" 24 feet of level putt energy simply to climb the tier. But the actual tape measure of distance the ball travels while on this tier might be only 6-10 feet, typically, so the ball looks like it starts as fast as a 24-foot putt but is dragged to a complete stop when it reaches the top edge only 6-10 feet later. That's the independent effect of the tier on the ball speed, without taking into account any additional pace required for the ball to continue past the top of the tier the remaining distance to the hole. Once the ball clears the top edge of the tier, the dramatic slowing discontinues, as the more general friction of the mild slope without the huge "cost" of the ball climbing elevation takes over, and the ball resumes a more normal pattern of decaying velocity. The combination of velocity required simply to climb to the top of the tier plus the remaining velocity to proceed on to the hole somewhat obscures the effect of the tier, but correctly imaging how the tier affects this total ball speed across the tier is implicitly required for accurate reading of the path across the tier. As usual, reading backwards from the hole to the top of the tier identifies the "exit" point of the read off the tier as a separate feature of contour. Given this "required" exit pathway off the top of the tier onto the final slope of the hole, the golfer is tasked to correctly predict the "entry" pathway and point onto the bottom of the tier, which involves running the “movie” of the putt backwards with realtime ball speed down the tier from “exit” point at top to “entry” point at bottom, at least implicitly. To do this, the golfer appreciates the obliqueness of the angle from the ball at his or her feet to the fall line of the tier or collection of fall lines on the tier to the “exit” point, combined with the ball pace across or athwart the tier and the length of the path on the tier. This process identifies the “entry” point onto the tier, and backwards from there to the ball, the start line across the approach slope so that the ball enters the bottom of the tier correctly with its necessary pace. The longer the path on the tier, the steeper the tier, and the closer to the top of the tier the hole is located, and the more oblique the approach to the fall lines on the tier, the MORE the tier will cause the ball to break while on the tier. But once the ball exits the tier, the drama is over, and the ball will break only according to the more normal top area of slope. Considering sloes and green speeds paradigmatically as more usual slopes are treated in this paper, a “paradigm” slope is a simple plane that rises about two feet over a lateral span of 10 feet, approached from the 4:30 o’clock direction (with the top exit point being the center of the clockface) compared to the fall lines of the slope. Hence, the slope percentage is 20% (2 feet rise over 10 feet run). With a typical green speed of Stimp 10′, the tier combination is a “200”. A “200” surface breaks ten times more than a “20”. Assuming the total distance across the tier straight from bottom entry point to top exit point on the 4:30 to 10:30 line is about 14 feet, one would predict “about” ***140 inches of break*** such that aiming to a point past the top exit spot along the fall line thru that point 140 inches (10 feet plus 20 more inches) would successfully handle the tier. That would be true except for the additional pace of the ball to continue past the tier. This extra pace reduces the break of the tier. One way to conceptualize this is to translate the distance on the top slope area past the tier to “tier climbing distance” for energy (e.g., perhaps 10 feet of roll on the mild top slope compares to a climb on the tier of only 1 foot), and then subtract that from the total tier distance. In this case, if the hole were 10 feet past the top of the tier, the tier distance would be about 14 feet less 1 foot, or 13 feet, requiring about 130 inches of break, so the correct "putt" up the tier takes a direction 130" up the fall line thru the top exit point. Not much of a difference really -- only 10" less when playing a break over 10 feet! Just be sure to remember the target 130 inches is "further along the fall line thru the top exit spot", and not some target located sideways from the exit spot on the top edge of the tier.

6. Down a Steep Tier and then Onward to the Hole. The MAIN trick to putting down a tier is the skill to predict how far a ball gently nudged over the top edge will roll out past the bottom of the tier. Once this is known, then the pace required to continue from this roll-out point the remaining distance to the hole establishes the pace of the putt over the top edge of the tier. As usual, the putt is read backwards from the hole to the exit point off the bottom of the tier, but with this required pace over the top edge and down across the tier already set, the predicting of the breaking curve down the tier is much more direct and simplified. From the exit point at the bottom of the tier, the golfer assesses the tier fall line(s) in that vicinity. The putt must "feed" the ball down these fall lines so that the ball exits the bottom of the tier correctly as proceeds on to the hole. Then, assessing the obliqueness of the approach to the top of the tier and these fall lines from the ball's location at address, with the required over-the-top pace, the golfer identifies the top "entry" point onto the tier. In a paradigm case (2-foot elevation change over 10-foot span, Stimp 10' green speed, approached from 10:30 o'clock in relation to the fall line thru the exit point), with 10 feet remaining to the hole after the roll out, the 14 feet of tier is expected to break about 140 inches without taking into account any extra pace for the remainder of the putt past the roll-out. Converting the roll-out to hole distance to "tier dropping" distance / energy, and then subtracting that from the 14 feet, the effective tier distance is about 13 feet, and so the expected break on this "200" surface is 130 inches. The target this time, however, is located 130 inches straight up the fall line thru the bottom "exit" point. Wherever the line from ball to this target crosses the top edge of the tier is, then, the top "entry" point for the pace that crosses down the tier and on to the hole.

7. Mid-Green Humps or Turtles. An hump or hill that is a separate feature out of the general contour wreaks havocs with reads. A putt that is required to traverse a hill or hump en route to a hole is subjected to the “divergence” caused by the shape of the hill up against gravity. The paradigm case is a shape in the green surface like an up-side-down shallow and symmetrical bowl about 5 feet in diameter with a rise above the local surface of half a foot. If the fall line of the general slope includes the ball, the center of the hill, and the cup, the putt is dead straight and the hill has no effect. But if the putt in any manner traverses the surface of the hill other than straight over the top of the hill, the hill will deflect the putt in difficult-to-manage paths. Because a hill is rounded, it differs from the more-or-less tilted planar surface of the tier, and putts across a rounded side of a bowl do not break the same as they do across a tier of comparable slope steepness. The succession of fall lines, all aiming at the center top of the hill, amount to a series of downhill pulls on the ball that effectively turns “downhill” ahead of the preceding “downhill” direction, advancing around the side of the bowl-hill. A paradigm case might be a hill that is 5 feet in diameter with the top one foot higher than the surrounding surface, with a top area that is approximately flat out 6 inches from the center. Imagining the line from this 1-foot diameter flat top area out to the bottom edges as straight-not-rounded sides of the bowl, then the slope of the side is everywhere 25% (rise of 1 foot over run from bottom edge to outer top edge of 4 feet). At Stimp 10’, this hill’s side surface is a “250” and breaks about 25 inches per foot. The length of a side crossing might be about one fourth the circumference of the bottom edge (pi*D, or 3.14*5’ = 15.7’), which is 15.7’/4 = 3.9’. If the side of the bowl were a planar tier, the break to expect would be nearly 100” (25”/ft times 3.9’) for a putt to end up in a hole at the exit point off the tier. But because the hill’s fall lines progressively turn away from and ahead of the preceding fall lines, the ball experiences less overall break traversing the side of the hill. This is similar to crossing athwart a concave shape of a tier.

8. Ridges and Projections into the Green off a Greenside Hump. Ridges most frequently accompany green side humps whose shape projects inward into the green.

A typical case is a hump on the back edge of the green designed to catch errant shots and protect the golfer from too much penalty. These humps have a half-cone feature that projects inward into the green. A typical hump of about 3 feet height might have a projection into the green interior that continues 10-15 feet or so before petering out into the more general contour of the green. Because these catching humps are nearly always at the back of the green, and because for similar reasons greens are almost always tilted back to front downhill back to the fairway, these humps are locally the highest surface. As such, the fall lines on the general slope near one of these humps usually aims at the peak of the hump, and the ridge-line of the projection into the green also has a fall line aimed at the peak. Putts frequently are required to cross these features or to terminate in a hole location on this feature. If the putt crosses this ridge / conical projection, the basic rule of reading the putt backwards from the hole to the separate feature applies, to identify the exit and then the entry points across the ridge. The devilish situations are when the hole location is near the conical end of the ridge or when the putt must travel along the ridge on a precarious path without falling off to one or the other side. If the putt has to travel along the ridge, the fall line of the ridge-line is key. If the putt comes from the general slope onto the conical ridge to a hole, the putt will have a final uphill climb onto the projection. As discussed above, the final fall line of the uphill area governs, and the ball will slow more than usual when climbing uphill, and so break more dramatically. The sides of these projections are usually more like slanted tiers than like rounded humps, except at the end of the projection, where frequently the contour more closely resembles a rounded hill.If this is the case, any putt that climbs a rounded hill that aims straight to the top of the hill does not break at all. But a putt that aims athwart a hill will break, and dramatically so. If the fall line off the projection area at the hole matches the approach path, there will be no break on the projection. And if the hole is “on top” of the projection, the approach path MUST be directed straight at the top of the projection area and the hole. But if the hole is not on top and the approach line cannot be aimed at the top, but is somewhat athwart the fall line thru the hole, the projection area can be treated like a “tier” except to the extent it is more rounded. The rounding reduces the break.

9. River Beds. A green frequently has a contour that is sometimes called a swale or ditch or river bed, with an up-slope to either side of a bottom area. And this bottom area might meander like a river bed, but is also itself sloped. The bottom area is, however, usually “flat”, although there is a downhill tilt of the flatness. In this case, if a hole is located in the bottom flatness and the ball is also on this bottom flatness, the ball may be either exactly on the same fall line thru the hole or not far off to the side, since these river beds are usually not all that wide. Assuming the direct line from ball to the hole does not involve any of the “bank” slope, the putt is either dead straight, either uphill or downhill, or nearly so. A “paradigm” river bed might be one that has a flat bottom about 5 feet wide, with banks up-sloping about 3-5%, and the overall downhill tilt of the river bed perhaps 2-3% conforming to the overall slope of the green so that the banks stay about the same height as the river runs down the green. If the hole is located slightly out of the flat river bed on one of the banks, the distance from the boundary of the river bed and the bottom of the bank to the hole is not likely to be long. If the fall line down the bank thru the hole crosses the river bed and the ball in the river bed lies on that line, the putt is dead straight. Otherwise, when the ball is coming from the river bed *below* the hole, the approach to the fall line of the bank is oblique to some degree and is an uphill putt; and when the ball is coming from the river bed *above* the hole, the approach is a combination of downhill putt in the river bed plus an uphill putt onto the bank. If a putt comes from outside the river bed, from slope beyond the margins of the banks, then the bank is simply the equivalent of a “tier”.

10. Half-Bowls on the Edge of the Green. No greens have “bowls” with completely enclosed depressions, since these areas cannot usually be mowed and will collected dirt and sand and trash and excess water, all of which is intolerable for a green surface. Hence, any “bowl-like” contour is restricted to “half-bowls” where one side of the (incomplete) bowl opens out either off the green or onto green that drains away from the half-bowl. Putting down to a hole at the bottom of one of

these bowls is the same as putting down a "tier", as is putting up and out of these features. Putting athwart a half-bowl contour en route to a more general surface past the half-bowl is similar to putting across a convex shaped tier. The convexity presents a succession of fall lines that keep presenting the ball with a downhill direction that is behind the preceding direction, and this dynamic increases the overall break. A putt across a planar tier experiences X break; a comparable putt across the concavity of a hill / hump experiences X-Y break; a comparable putt across the convexity of a half-bowl depression experiences X+Y break.

The above discussion is more abstract than the reality of greens calls for in effective predicting of curved paths across complex contour. But, it's still useful to many if nor all golfers.

CONCLUSION

The great majority of makeable putts are simple breaks across flat and tilted slope, over usual green speed and common slopes. These putts have fairly predictable break, and it behoves serious golfers to know as much as possible about these breaks and how to play them effectively. The basic skills are perceiving fall lines, flatness, and slope steepness for usual green speed and distances inside 15 feet; accurate aiming; straight strokes that roll the ball exactly where aimed; and touch skill that rolls the ball with the same speed and pace used to read the putt to begin with. In this context, using the Slope-X-Speed combination concept greatly simplifies calculated break as a starting point for making a final and minor adjustment on any putt. Beyond these simple and common putts, the skill for reading complex contour is less susceptible to mathematical regularity, but nonetheless offers certain paradigm patterns that help out quite a bit in making sense of things. Ultimately, reading putts effectively integrates pace control with pattern recognition for surface contour. Anything that makes the pattern recognition more effective and accurate and consistent cannot be a bad thing for the score.

APPENDIX: Break Tables

Here are some breaks for different combinations of frequent Slopes and Green Speeds, given as ranges that depend upon the golfer's personal delivery speed, with the higher break being the maximum, and some lower break probably being advisable, and in any event these breaks are simply applicable to the paradigm situations and require adjusting to real on-course putt, which almost always involve slopes other than the exact paradigm slopes, distances not exactly measured, green speeds at some "in between" number compared to the charts, across surfaces that are "not quite" or "obviously not" the same flatness from ball to hole, that may be delivered with a pace not quite the same used to generate the paradigm breaks, etc.

Table 1. The Stimp range extends from 7' to 12'. The Slope range extends from more than 0% to 7%. The "combinations" of Stimp and Slope, however, stop at 50, at which point the recommended limit is reached where the ball would not rest on the slope-speed surface. For each Stimp speed 7', 8', 9', 10', 11', and 12', all "combo" slopes up to combo 50 are given. All distances are 10', and all putts are sidehill 90 degrees off the fall line.

For each Combo in the Stimp table, both a "Maximum" break is given from Grober's calculated ideals, and then a "Mid-range" break is given using Templeton's empirical and calculated breaks. The next column indicates the maximum number of inches the break of the downhill slower putt might be increased, or the break of the uphill faster putt might be decreased. The actual adjustment for up or down break depends upon how close the ball position sits to the fall line or the sidehill line. The FULL or maximum adjustment applies only when the ball lies directly on the fall line. When the ball lies between 45 and 60 degrees from the fall line (either between 1:30 and 2:30 or between 3:30 to 4:30 or between 7:30 and 8:30 or between 9:30 and 10:30 on the clock, with the fall line running 6 to 12), about 50% of the suggested adjustment applies. When the ball lies within 15 degrees of the sidehill line (i.e., between 2:30 and 3:30 or between 8:30 and 9:30 on the clock), then only 25% of the suggested adjustment applies. The maximum adjustment applies only nearest the fall line (6-12 on the clock).

For each Stimp table, the 2% slope row is highlighted in blue, since this slope is frequent and allows easy adjustment to the other slopes by proportionality.

Once the mid-range and maximum break is listed, the break is calculated as the corresponding range of "inches of break to play for each foot of the putt". The "percentage of putt distance to play for the break" is calculated solely from the maximum break.

Table 2. The next Table sets out only the 2% slopes for the range of Stimp speeds 7' to 12', to allow the golfer easy reference to this key slope. This table also promotes interpolation for "in-between" Stimp speeds.

Table 3. Table 3 lists the maximum and mid-range breaks for the full series of Combos between 1 and 50 in increments of 5, with "inches of break per foot of putt" and "break as percentage of putt distance" and the maximum up-down adjustment values as well.

Table 4. The final Table lists the basic 2% slope breaks for each green speed and then elaborates the other main slopes 1%, 3%, 4%, 5% and 6% based on the 2% slope. Each separate Stimp speed from 7' to 12' is given in this manner. For each slope and speed, both the mid-range break from 10 feet and "inches of break per foot" are given.

TABLE 1: Series of Stimp Speeds 7' to 12'

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 7':1%	7	3.5"	3"	0.35"	1/3"	3%
Stimp 7':2%	14	7.5"	6.5"	0.9"	2/3"	6.25%
Stimp 7':3%	21	12.5"	10"	2.1"	1"	10%
Stimp 7':4%	28	16"	13"	3"	1.5"	13.3%
Stimp 7':5%	35	19.5"	16"	6.5"	1.75"	16.25%
Stimp 7':6%	42	24"	22"	10"	2.25"	20%
Stimp 7':7%	49	32"	29"	14"	3"	26.7%

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX +/-	INCHES PER FOOT	% OF LENGTH
Stimp 8':1%	8	4"	3.5"	0.4"	4/10"	3.3%
Stimp 8':2%	16	8.5"	7"	1.2"	3/4"	7.1%
Stimp 8':3%	24	13.5"	10.5"	2.3"	1.25"	11.25%
Stimp 8':4%	32	18"	15"	3.75"	1.75"	15%
Stimp 8':5%	40	23"	20"	9"	2.25"	19.2%
Stimp 8':6%	48	30"	27"	13"	2.75"	25%

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 9':1%	9	5"	4"	0.5"	1/2"	4%
Stimp 9':2%	18	10"	8"	1.3"	9/10"	8.3%
Stimp 9':3%	27	15.5"	12"	3"	1.5"	13"
Stimp 9':4%	36	18"	17"	5"	1.75"	15%
Stimp 9':5%	45	26.5"	24"	12"	2.5"	22%

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 10':1%	10	5.5"	4.5"	0.5"	1/2"	4.5%
Stimp 10':2%	20	12"	9.25"	1.2"	1"	10%
Stimp 10':3%	30	17"	14"	3.5"	1.3"	14.2%
Stimp 10':4%	40	23"	21"	7"	2.25"	19.2%
Stimp 10':5%	50	31"	29"	14"	3"	25.8%

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 11':1%	11	6"	5"	0.5"	1/2"	5%
Stimp 11':2%	22	13"	10.5"	2.2"	1.2"	10.8%
Stimp 11':3%	33	18.5"	14"	3.5"	1.5"	15.4%
Stimp 11':4%	44	26"	22"	9"	2.5"	21.7%

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 12':1%	12	6.5"	5"	0.5"	1/2"	5.4%
Stimp 12':2%	24	13.5"	11.75"	2.4"	1.3"	11.25%
Stimp 12':3%	36	20"	18"	5.5"	2"	16.7%
Stimp 12':4%	48	30"	28"	9"	3"	25%

TABLE 2: 2% Slopes for Series of Stimp Speeds 7' to 12'

SPEED-SLOPE	COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH
Stimp 7':2%	14	7.5"	6.5"	0.9"	2/3"	6.25%
Stimp 8':2%	16	8.5"	7"	1.2"	3/4"	7.1%
Stimp 9':2%	18	10"	8"	1.3"	9/10"	8.3%
Stimp 10':2%	20	12"	9.25"	1.2"	1"	10%
Stimp 11':2%	22	13"	10.5"	2.2"	1.2"	10.8%
Stimp 12':2%	24	13.5"	11.75"	2.4"	1.3"	11.25%

TABLE 3: Breaks for Each Slope-Stimp Combo 1 to 50 in Steps of 5

COMBO	MAX BREAK	MID BREAK	UP/DOWN MAX+/-	INCHES PER FOOT	% OF LENGTH	PLAY
5	2.5″	2″	0.25″	0.2-0.25″	2%	1/4″ / ft
10	5.5″	4.5″	0.5″	0.45-0.55″	3.75%	1/2″ / ft
15	8″	7″	1″	0.7-0.8″	6.7%	3/4″ / ft
20	12″	10″	2″	1-1.2″	10%	1″ / ft
25	14.5″	11″	3″	1.1-1.45″	12.1%	1.25″ / ft
30	17″	14″	4″	1.4-1.7″	14.2%	1.5″ / ft
35	19.5	16.5	6″	1.65-1.95″	16.25%	1.75″ / ft
40	23″	21″	8″	2.1-2.3″	19.2%	2.25″ / ft
45	26.5″	24″	10″	2.4-2.65″	22.1%	2.5″ / ft
50	33″	30″	12″	3-3.3″	27.5%	3.25″ / ft

TABLE 4: 2% Slope Data Expanded to All Slopes for Each Stimp Speed.

STIMP	1%	2%	3%	4%	5%	6%
7′	3.25″ / 1/3″	6.5″ / 2/3″	9.75″ / 1″	13″ / 4/3″	16.25″ / 1.675″	19.5″ / 2″
8′	3.5″ / 3/8″	7″ / 3/4″	10.5″ / 1.125″	14″ / 1.5″	17.5″ / 1.875″	21″ / 2.25″
9′	4″ / 1/2″	8″ / 9/10″	12″ / 1.35″	16″ / 1.8″	20″ / 2.25″	24″ / 2.7″
10′	4.6″ / 1/2″	9.25″ / 1″	13.375″ / 1.5″	18.5″ / 2″	23.125″ / 2.5″	27.75″ / 3″
11′	5.2″ / 0.6″	10.5″ / 1.2″	15.75″ / 1.8″	21″ / 2.4″	26.25″ / 3″	31.5″ / 3.6″
12′	17″ / 0.65″	11.75″ / 1.3″	18.6″ / 2″	23.5″ / 2.6″	29.375″ / 3.25″	35.25″ / 3.9″