A large format Photographer's *vade mecum**

3Com Palm program documentation

Robert E. Wheeler

Mar 1999

Contents

1 Introduction

When a university education was mostly a study of Greek and Latin, schoolboys carried about small books containing crib notes, grammatical memoranda, and other helpful bits of information. It is not surprising that they referred to them by a Latin tag, *vade mecum*, which translates as "go with me." I, and I think most large format photographers, do something similar. In my bag is a notebook filled with various things, such as filter factors, reciprocity times, shift limits for various lenses, etc.

In addition, I carry one other thing, which I consider my real *vade mecum*. It is a pocket calculator, and in it I have programmed those calculations that are useful for my sort of photography. Yesterday, for example, I took two pictures while on a walk. One required a tilted lens, and the other involved a nice calculation of DOF to include an object in the foreground. Neither took more than five minutes, and a third photograph was abandoned before the camera was unpacked, because preliminary calculations indicated that it could not be taken in the way I envisioned — I'll probably go back and rethink the composition sometime.

When I started in large format photography, I was unable to find adequate instructions for many fiddling problems in the books I consulted. I found exhaustive discussion of light and photographic materials, but little help on the practical problems. Lens tilt, for example, seemed as much a mystery to many authors of photography books as it did to me — at least if they knew its incantation, they chose not to reveal it.

As near as I could make out, tilting the lens was something to be done by cut-and-try — focus on something, tilt the lens a bit, focus on something, adjust the tilt, etc. until all parts of the subject are in focus[1]. I tried this a few times with middling success, but found it hardly a satisfactory procedure: if for no other reason, than that it takes a long time. I am sure the information exists in the technical literature somewhere, but in exasperation I sat down and derived the equations from first principles. By that I mean I went back to a theorem of projective geometry due to Desargues which underlies the rules artists use to produce perspective drawings, and derived the lens equation relating the focus distance, the lens-film distance, and the lens focal length. From this everything else follows.

The programs described here, calculate the lens tilt angle in several ways. The easiest is by focusing on two points in the subject plane, which is the idea that underlies the Sinar, and Linhoff built-in calculations. Almost as easy, is to use the distance and angle of a pair of points in the subject plane. There are two additional methods which may appeal to some who fancy that they can judge angles by eye.

Of course, a photographer has other problems: depth of field, DOF, for one. The standard formulas that appear in books work well enough for intermediate and distant objects, but are considerably in error for macro photography. This

[1]A discussion of this procedure in exquisite detail may be found in Bond (1998).

is strange, since the correct formulas are not difficult. Perhaps the authors have stuck to formulas that they thought would be easy to calculate. In any case, if one is going to use a calculator, which I hope you will, then there is no need to use the wrong formula. In addition, the practicing photographer needs to make judgments about DOF for tilted lenses, and assess the degree of blur for a background or foreground object. Six programs are provided for these problems, differing in the type of input required.

Various questions arise in practice about focal length: (1) given near and far objects, which focal length will cause these to be the near and far DOF limits? (2) Given the magnification and the distance to the subject, what is the proper focal length to choose. Similar questions occur in relation to the proper F-number. And what about the bellows factor? There are other questions still – what shutter speed will stop motion, or what is the angle of view? Programs are provided for all.

Perhaps the most important thing, is the viewframe: a simple frame made from what you will with a measuring cord attached. I am not aware of any serious discussion of this most useful device. It not only concentrates the photographers attention by framing the view, but enables the appropriate lens to be chosen, and with the two programs included, allows the photographer to find the DOF – all without unpacking the camera.

The programs may be downloaded from a PC via a serial cable. Instructions for downloading are given in an associated document. The mathematical details of many of these calculations do not seem to be available in the literature, and so a collection of notes may also be downloaded.

I assume that the reader is a large format photographer, and that the problems discussed will be those that have been thought about. I wouldn't discourage someone who is new to this format from reading this material and using the programs, but I think it unlikely that they will fully appreciate the programs until they have experienced some of them firsthand. There are a number of good[2] books on large format photography, and I would hope that the neophyte would consult them first. Two that I can recommend are: Stroebel et.al. (1986), Stroebel (1993) For the more technically inclined, Ray (1994) and Jacobson et.al. (1988) are also good.

1.1 Notation

I have chosen to use a few standard symbols both in the programs and in this text, rather than repeat descriptive phrases at every point. They are illustrated in Figure 1, and listed in Table 1. The figure shows three planes: the subject plane, the lens plane, and the focal plane. In addition, the Near and Far DOF planes are shown about the subject plane, as are their cognates about the focal plane. Note that the Near and Far planes are measured from the lens plane. The distances of these planes from the subject plane are denoted FrontDOF

[2]Although on topic, I cannot recommend Merklinger (1992) or (1993) because simple ideas are made overly complicated.

and BackDOF. The Near and Far planes are not symmetrical about the subject plane, but their cognates about the focal plane are symmetrical, for all practical purposes. Thus one may use $d/2$ to represent the distance from either to the focal plane. The lens tilt angle, θ, will be discussed later.

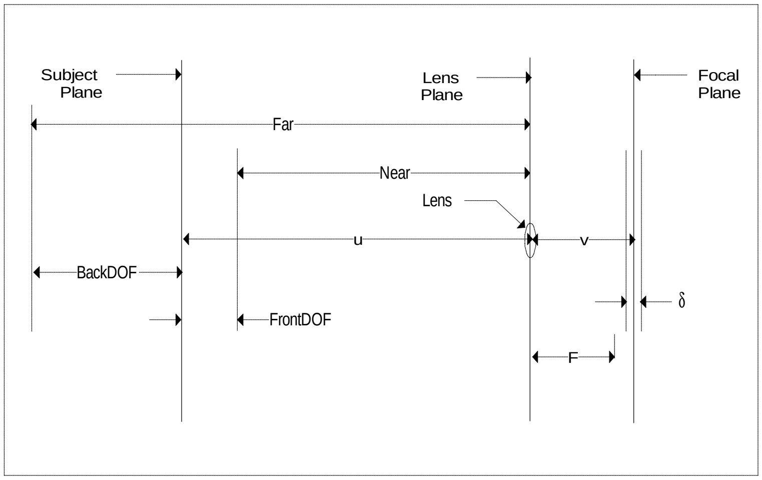


Figure 1: Parallel planes

u	Distance from subject focus point to lens
v	Distance from lens to film
f	Focal length
N	The F-number
d	Defocus ≡ Depth of focus
ϕ	Lens tilt angle
Near	Near DOF limit
Far	Far DOF limit
FrontDOF	$= (u - Near)$: i.e. DOF in front of focus
BackDOF	$= (Far - u)$: i.e. DOF in back of focus

Table 1: Frequently used symbols

In addition, units of measurement are indicated by appending a unit designator to values. Thus 5 (m) means 5 meters, 3 (mm) means 3 millimeters, 10(°) means 10 degrees, etc.

1.2 Fractional stops

The amount of light admitted through the aperture (illuminance) is of great importance, as early photographers quickly learned. It may be controlled by the duration of the exposure and by the lens aperture. About 1880 (Kingslake 1989) it became customary to designate a lens by its F-number. Iris shutters were also introduced about 1880 (*ibid*), and markings on the lenses were likely to have been in terms of F-numbers. Sequences of stops and F-numbers were proposed at the turn of the century, but the present standard sequence of F-numbers (1, 1.4, 2, 2.8, 4, . . .) is fairly recent.

There is not a lot that can be said in justification of this standard sequence for a practical photographer. It requires an act of memory to use, and it increases as the illumination decreases, which is contrary to what one wants. One way to think of it is as a measure of the luminance of the object, in which case a small opening and large F-number represents a bright object, but the odd sequence is still something to remember.

Twice the base 2 logarithm of the F-number sequence is (0, 1, 2, 3, . . .), which would make things easier if only cameras were marked this way[3]. In this sequence, the steps represent a halving of the light intensity, so that 3 represents half the light intensity of 2. For intermediate values, light meters report the decimal fraction from this scale: thus one may read 1.4_5 on a light meter, representing a tic half way between the f/1.4 and f/2 tics on a camera[4]. Shutters on automatic cameras can be capable of controlling aperture to a tenth of a step, but others may not be so accurate. A likely practical limit is a setting to the nearest 1/3 stop.

The notation adopted herein is 1.4_5. The “_” is required. The programs read and write numbers in this form, but internally they are translated into F-numbers, so that 1.4_5 is translated into $N = 1.68$.

1.3 Numerical accuracy

All calculations are made with at least 12 significant digits and are rounded to reasonable precision for output display. This rounding may cause the results of two complimentary programs to differ when the rounded output of one is input to the other. For example in Section(3.2) one inputs $u = 10$ m to the program **Viewu**, and the program outputs $v = 215$ mm. When one inputs $v = 215$ mm to the complementary program **Viewv**, as in Section(3.1), then $u = 9$ m is returned. The corresponding FrontDOF and BackDOF values between the two differ as a consequence. Allowing more decimal values would make the two results agree, but it would complicate things and have little practical effect. The problem only occurs in the output since one may input as many decimals as one likes: suppose one knew $v = 214.5$ mm then one could input it, and the output calculations making use of this greater accuracy, would give $u = 10$ m, and the DOF values would agree more closely.

[3]The EV system was originally developed for this purpose, but never became popular.

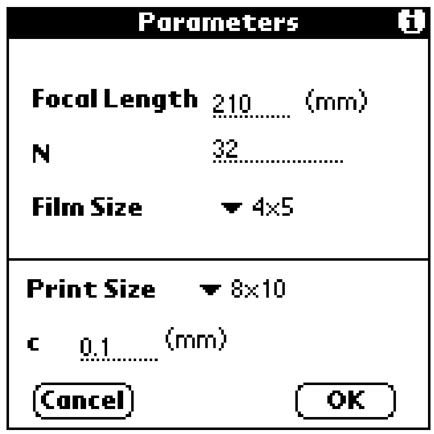
[4]Such an intermediate tic does not represent the halfway intensity of 75%, but rather about 71%.

2 Setting parameters

Params, basic parameters

Three parameters are needed for most calculations. They are focal length, the F-number, N, and the format. It is incumbent on the user to make sure that they are always current. Some programs use them, others do not, but it is a waste of time to try to remember which is which, so always make sure they are current.

They may be set by running the **Params** program. This function throws up a display showing the current values, and allowing them to be edited. The following screen capture shows the display.



The film size and print size are changed via drop down lists. When they are changed, the diameter of the circle of confusion, c, is changed. Usually, c should not be changed by the user, since it is set at values appropriate for the various formats; however, it may be changed as the last thing before clicking the OK button.

The diameter of the circle of confusion derives from considerations about human visual discrimination. If one takes the resolving power of the human eye at the closest distance of near vision as a standard (about 25 cm for a normal eye), then the diameter of the circle of confusion may be calculated. At this distance an 8x10 print occupies approximately the human eye's angle of view. Moving the print farther away increases the diameter of the circle of confusion, which normally happens when one views a larger print at an appropriate distance – say at a distance of 50 cm for a 16x20. Choosing a print size in this dialog adjusts the diameter of the circle of confusion appropriately.

No doubt some will prefer to always set the print size to 8x10, which will produce prints that are always sharp to the eye no matter how closely they are viewed.

Illustrations in the rest of this document assume the parameters are set as in the above screen capture – Focal length at 210 mm, N at 32, *FilmSize* at 4x5 and *PrintSize* at 8x10.

3 The viewframe

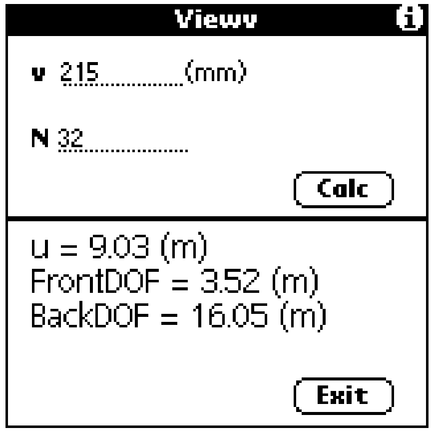
Even before the camera is set up, a decision about the view to be captured should be made. This is aided considerably by the use of a simple viewframe held so as to frame the scene. Almost anything with the right sized hole will do — I use a bent coat hanger. The inside dimensions should be the same as the size of the image on the film. In addition some means should be provided for measuring the distance from the viewframe to the eye. I attach a flexible tape marked in millimeters to my viewframe. Figure (2) shows some items from my gadget bag, among them may be seen my bent coat hanger viewframe.

Figure 2: Gadgets

Use the viewframe to frame the view, and note either of two distances: (1) the distance, v, from the viewframe to one eye — the other should be closed, since a camera has only one eye; or (2) the distance, u, to the point of focus. The following two programs will provide depth of field and other information.

3.1 Viewv, From v

The program asks for two parameters and outputs three results.

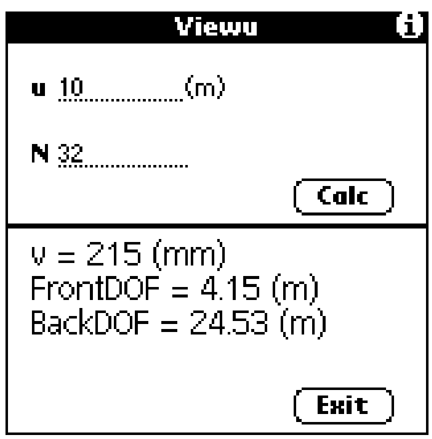


Here v is the distance in millimeters from the lens to the film plane. The F-number, N, may be input since one sometimes needs to compare the effects of different N. If N is changed, the changed value will be used only for this calculation – the changed N will not effect the N input in **Params**.

On the output, the u value is the distance from the lens to the in-focus subject. The *FrontDOF* and *BackDOF* values are the distances from u to the near and far DOF limits. In this illustration, the DOF is 19.57 m (3.52 + 16.05).

3.2 Viewu, From u

The program asks for two parameters and outputs three results.



The only difference from the previous program, is that u, the focus distance, is input. The F-number, N, may be input since one sometimes needs to compare the effects of different N. If N is changed, the changed value will be used only for this calculation – the changed N will not effect the N input in **Params**.

On the output, the v value is the distance from the lens to the film. The *FrontDOF* and *BackDOF* values are the distances from u to the near and far DOF limits. In this illustration, the DOF is 19.57 m $(3.52 + 16.05)$.

3.3 Discussion

A viewframe improves the visualization of a composition. It aids in deciding the composition's orientation (landscape or portrait), and aids in the elimination of extraneous detail which the eye might otherwise not notice. There are other uses.

It may be used to find the appropriate focal length. Suppose a composition frames nicely in the viewframe when the subject is about 4 m away, and that the viewframe to eye distance, v, is about 220 mm. Any lens with less than 220 mm focal length may be chosen and then extended to 220 mm for focusing. A 210 mm might be appropriate. Of course one could also choose a 150 mm, but the extension to 220 m (150 mm + 70 mm) would result in a bellows factor of about 2. In this case, **Viewv** using $v = 220$ m indicates the *FrontDOF* and *BackDOF* values are 1.12 m and 2.17 m, assuming $F = 210$ and $N = 32$.

In making a decision about focal length, there is no need to be overly precise about v. A few millimeters either way will not change the composition much. The important thing is to decide on a focal length with approximately the coverage desired and leave the fine details to that time when the camera is focused.

Using a viewframe in this way is quite easy. What happens if one needs more depth of field, such as a foreground object? I raise the point, because some will attempt to adjust the DOF by changing their lens. There is nothing wrong with this if it meets the artistic needs, but often the resulting change distorts the composition. Extraneous detail which was outside the frame is now included, or the composition loosens up and becomes uninteresting. To keep the same composition when changing the lens, the camera must be moved. This will keep the magnification constant. Unfortunately, the DOF does not change very much when magnification is fixed. You might like to use the **DOFMag** program which gives DOF as a function of magnification to establish the truth of this statement[5].

To increase DOF in a substantial way, the F-number, N, must be changed. In this case with $v = 220$ mm, doubling N from 32 to 64, produces $FrontDOF = 1.8$ m and $BackDOF = 8.21$ m. The composition remains unchanged.

4 Determining lens tilt

When the subject, lens, and film planes are parallel, focusing on any one part of the subject focuses on all parts. This is illustrated in Figure (1).

[5] The magnification for the above illustration is about 0.021, which can be found from the **Magv** program.

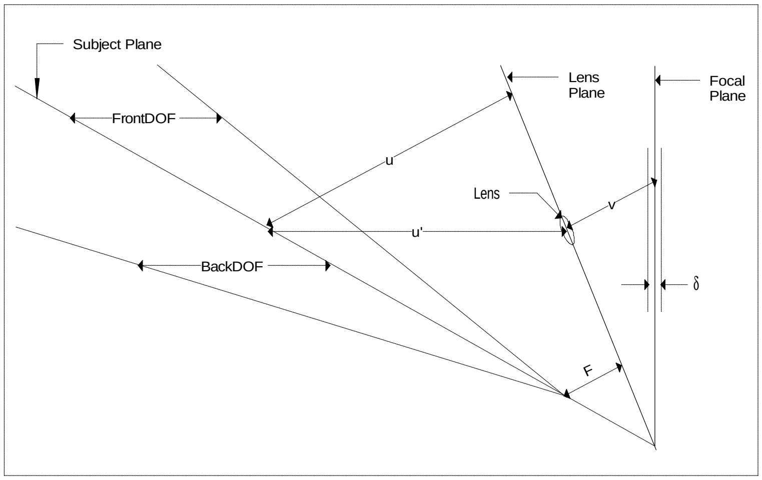


Figure 3: Tilted planes

This is not true when the subject plane lies at an angle to the other planes. Focusing on one part of the tilted subject plane may cause other parts to be out of focus. To bring all parts of the subject into focus, the lens must be tilted so that all three planes meet at a line. This is Scheimpflug's rule. Figure (3) illustrates this rule. The parallel planes in Figure(1) also obey Scheimpflug's rule if one agrees, as is usual, that parallel planes meet at infinity.

If the subject plane is tilted, then it will meet the focal plane somewhere. The problem is to find the tilt angle of the lens such that a plane through it will also meet where the other two planes meet. Many experienced photographers decide on the tilt angle by cut-and-try mixed with considerable experience. If the ground glass were brightly illuminated, I would not find much fault with such a procedure: but it is not, it is almost always dim requiring a dark cloth to block light, and for some lens's with small maximum apertures, the ground glass can be grainy making nice judgments difficult. I prefer to calculate the angle from observations, and the following programs do this. The *BACK TILT* parameter which appears in the input menus of the following programs will be discussed in Section (4.4).

It is important to note, that although "tilt" is used in this section, the information applies equally to "swing."

4.1 Tiltb, By back focusing

The easiest way to determine lens tilt is by focusing on two subjects which image near the top and bottom of the ground glass. Figure (4) shows this for two back positions, one when point A is in focus, and one when point C is in focus. The distance along the rail (in millimeters) between the focus points, together with the distance between the images (in millimeters) on the ground glass can be used to determine lens tilt. In figure (4) the *Rail d* is the distance from a to b, and the *Glass d* is the distance from b to c. The calculation of the lens tilt angle in degrees is given approximately by Wheeler's rule of 60. To wit $\phi \approx 60(b-a)/(c-b)$. The rule is not appropriate for close up work, but the **Tiltb** program always gives the correct value.

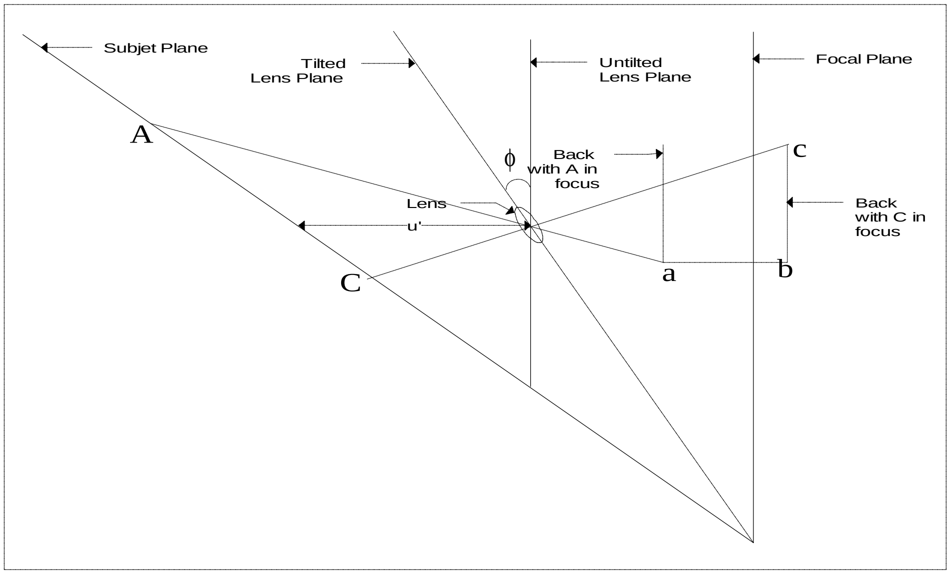
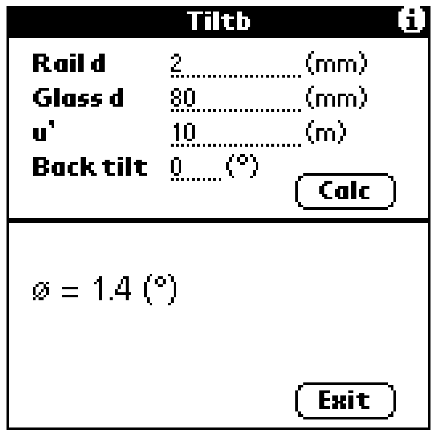


Figure 4: Tilt Diagram

The input asks for the distance u' shown in Figure(4) which is the horizontal distance to the subject plane. The tilt calculation does not make use of u' in calculating the tilt angle ϕ, but u' is used in calculating the slope, *gamma*, which slope is saved for later use by **DOFTilt**. One may indicate that u' is infinite by inputting *inf* for "infinity."



The program outputs the lens tilt angle, ϕ, in degrees. The angle is positive for forward tilts, and negative for backward. Once the lens is tilted, and refocused, all points in the lens plane will be in focus.

In refocusing after the lens tilt, those with center tilt cameras will find the focus point somewhere between the two previous points, while those with base tilt cameras will find it necessary to move the rear standard a considerable distance forward. Base tilt cameras move the lens in addition to rotating it, and the rear standard must be brought forward to adjust for this movement.

4.2 Tiltd, Tilt from distance and angle

Another way to determine lens tilt is by specifying the angles and distances to two objects in the desired subject plane. Figure (5) shows two points A and C on the subject plane. The distances and angles of these points are input to **Tiltd**. The program assumes that angles above the horizon are positive, and negative below the horizon. One can buy palm size devices to measure angles above and below the horizon from shops that sell surveyors's equipment. Distance can be guessed. The calculations are not very sensitive to the far distance, but the near distance should be as accurate as possible. If a compass is available, then the program **Triangulate** may be used to triangulate from two bearings — the

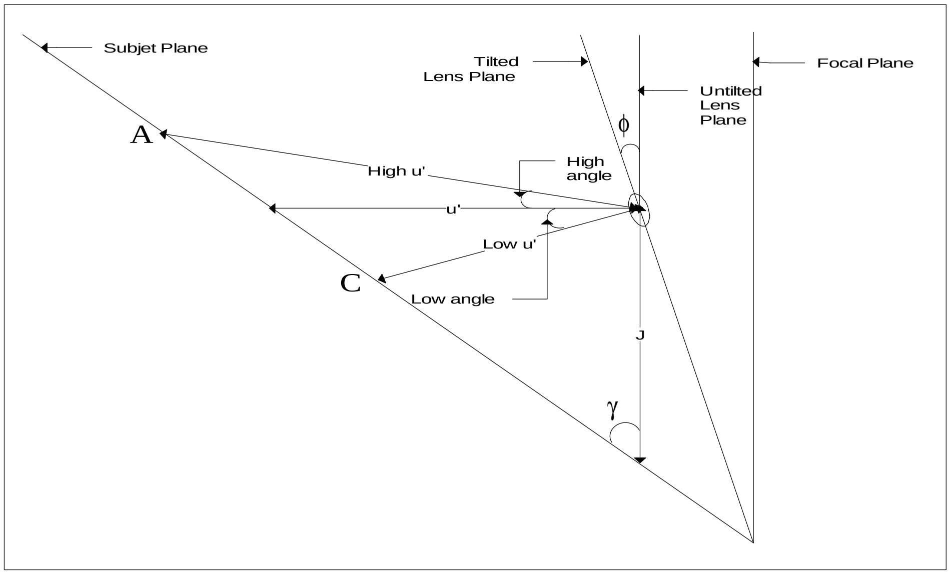
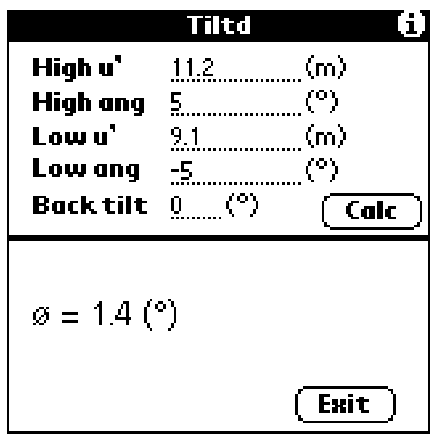


Figure 5: Distance and angle

compass must read in degrees or finer.

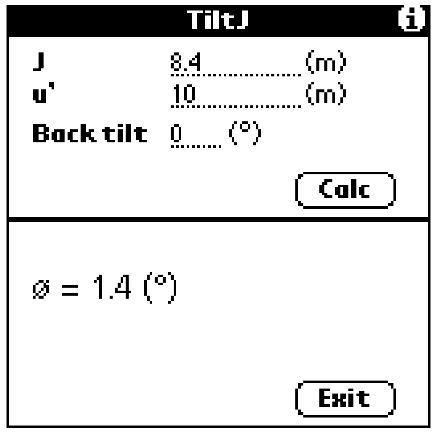


4.3 Tilt from geometric parameters

The next two programs ask for inputs derived from the geometry of the problem. These inputs can often be guessed with reasonable accuracy, and may prove easier to use in certain circumstances. Figure (5) shows the planes and rays involved for lens tilt calculations. The distance J is the vertical distance from the lens center to the subject plane, and *gamma* is the angle that the subject plane makes with the lens plane.

4.3.1 TiltJ , Tilt from J

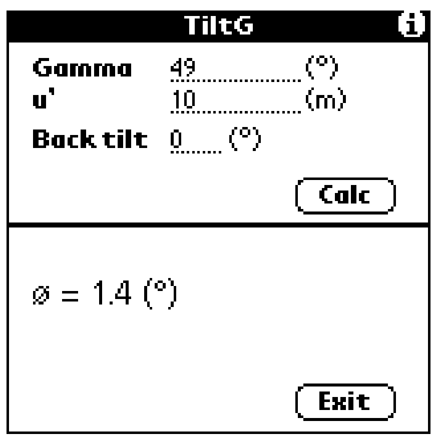
The values of J and u' are guessed.



Merklinger (1992) and (1993) recommends this method using J alone, which is all that is required to calculate the tilt angle ϕ. **Tiltd** asks for u' in order to calculate *gamma* which is needed for **DOFTilt**.

4.3.2 Tiltg, Tilt from the slope of the subject plane, *gamma*

The tilt angle is calculated from the subject plane angle *gamma* and u'.



4.4 Tilting the back

Tilting the back changes perspective by altering the way lines converge to vanishing points. Sometimes this change is desired. Scheimpflug's rule still applies when the back is tilted, as Figure (6) shows. The appropriate lens tilt angle will be calculated by each of the above programs when the *Back Tilt* parameter is input. The input parameters should be obtained with an untilted back precisely

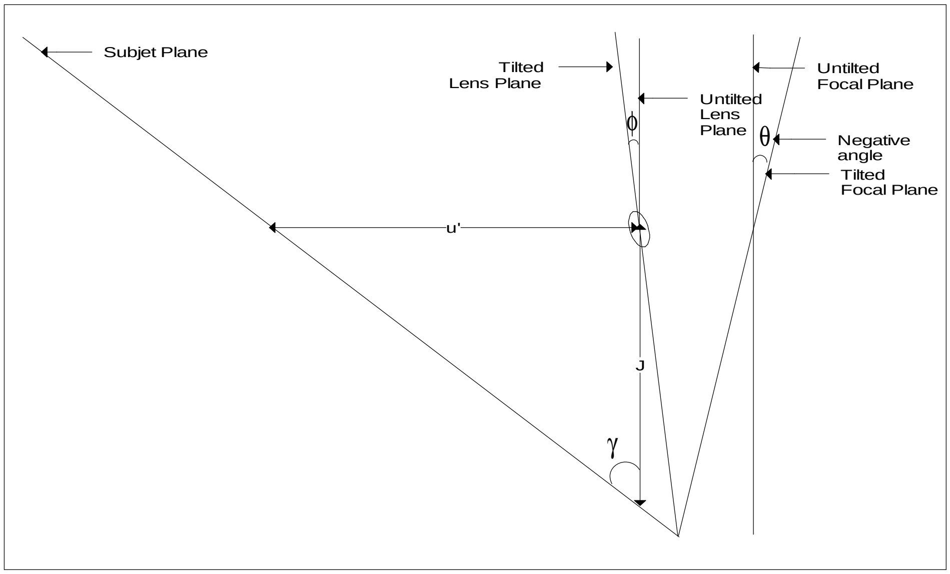
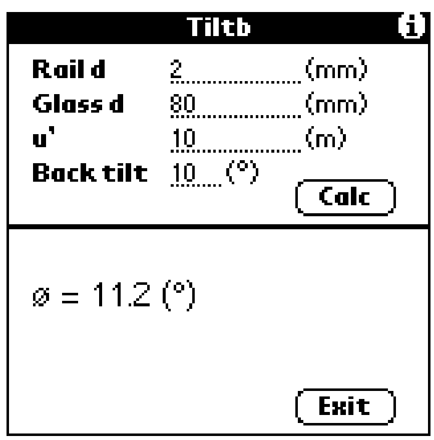


Figure 6: Tilted back

as has been done above. The only change in the program input, is the setting of *Back Tilt* to a non-zero value. Consider the **Tiltb** example above:



With the back tilted forward 10°, and the lens tilted 11.2° the subject plane will be in focus, although lines that were previously vertical will now diverge. It is assumed that positive back tilt angles imply a forward back tilt, and negative angles a backward tilt, just as they do for the lens tilt.

Back tilts can be used even when the subject plane is vertical, but the lens tilt is the same as the back tilt in this case – in other words the back and the lens axis remain parallel.

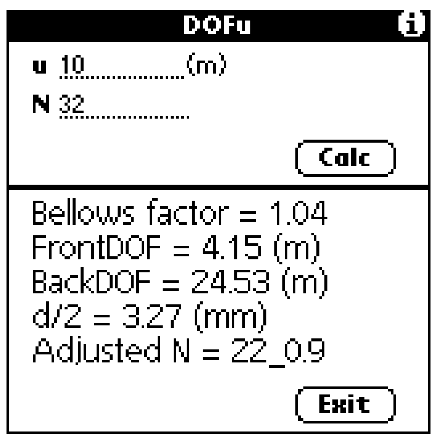
5 Determining DOF

DOF is an important topic, and the photographer needs to assess it in several ways. The usual way is to calculate DOF as a function of u. But one can also use v, subject height, magnification, or the defocus d. Programs are provided for each of these input values, as well as one that calculates the DOF along an arbitrary ray when the lens is tilted. Please refer to Figures (1) and (3). In addition, there is a program to calculate the hyperfocal distance, one that assesses the *blur* of objects at various distances, and two that translate DOF to and from d.

All DOF programs report the same information, so this output will be described more fulsomely in the next subsection, (5.1) than in the other subsections.

5.1 DOFu, As a function of u

The input is u.



All DOF programs output u. For **DOFu**, it is input. For other DOF programs it is calculated. The **FrontDOF** and **BackDOF** are distances about u. Thus the near point of the depth of field is $u - FrontDOF$, and the far point is $u + BackDOF$, as is illustrated in Figure (1).

The defocus distance d is the distance on the rail corresponding to DOF[6], see Figure (1). For practical purposes, this distance is symmetrical about v, the distance on the rail cognate to the subject distance u. Thus, the points $v - d/2$ and $v + d/2$ are defocus limits, corresponding to near and far DOF limits. One can use the defocus limits to locate the near and far DOF planes. Simply move the standard backward or forward by $d/2$ and observe those objects in sharpest focus — these correspond to objects on one of the DOF planes.

The adjusted F-number, *Adjusted N*, is the bellows corrected F-number. In

[6] Translating from d to DOF or vice versa involves both focal length and magnification so that DOF will translate into various values of d as these parameters change.

this case, the original F-number, N, was 32. Allowing for the bellows extension produces a value of 22_9, which is not practically different from 32. The bellows factor by which the shutter speed may be adjusted is shown at the top of the screen.

> *Before releasing the shutter, it is always a good idea to perform a DOF calculation in order to check the bellows effect on the F-number – surprises do occur.*

The DOF limits shown by the DOF programs are calculated assuming the input N. If the *Adjusted N* differs practically from this N, and if the *Adjusted N* is actually used to set the shutter, it will be necessary to recalculate the DOF limits by inputting the *Adjusted N* to **DOFu**. Of course a doubly *Adjusted N* will be output, but this should be ignored.

5.2 DOFtilt, From ray angle, for tilted lenses

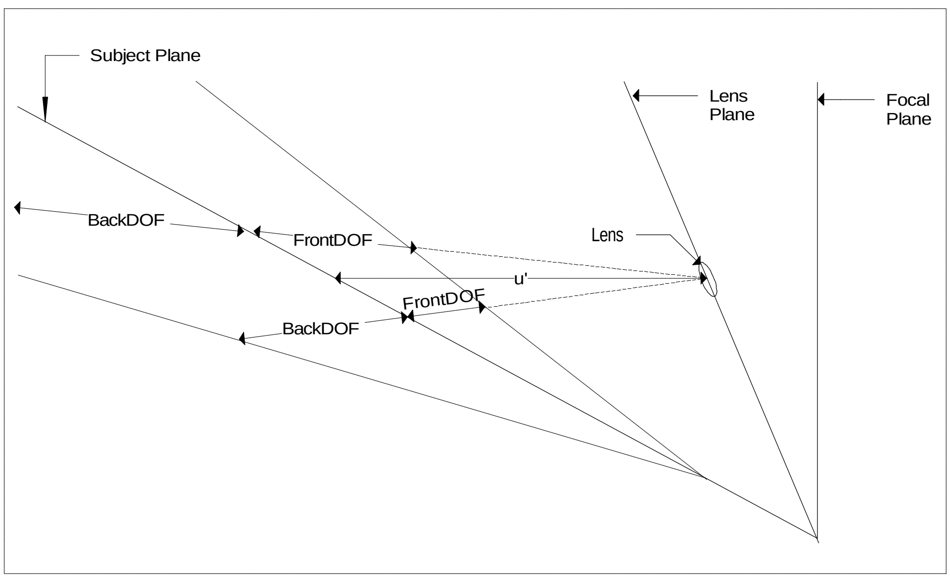
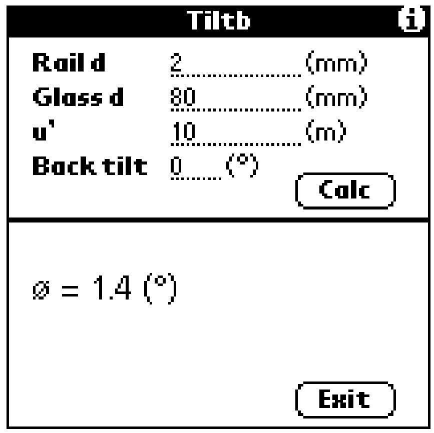


Figure 7: DOF for tilted lens

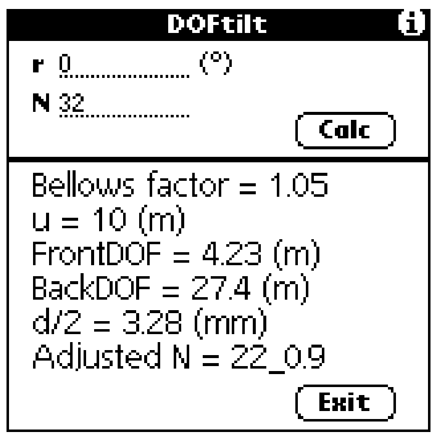
In order to set parameters that will be used by **DOFtilt**, it is necessary to run one of the tilt programs. Other programs may intervene. **DOFtilt** uses the parameters from the last run tilt program, and no other programs tinker with the saved tilt parameters.

The **DOFtilt** program accepts a single input, an angle, and outputs the *FrontDOF* and *BackDOF* values along a ray at this angle to the horizontal.

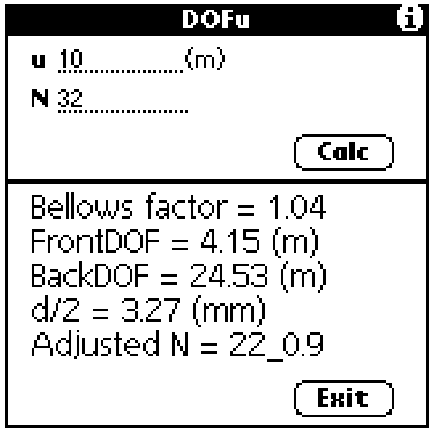
Figure (7) illustrates the situation. Assuming that **Tiltb** has been run with the following parameters



then inputting the angle zero into **DOFtilt** produces the following.

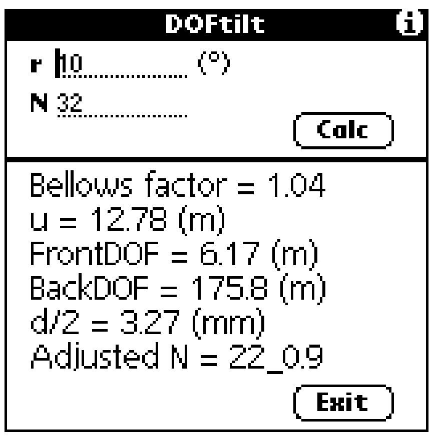


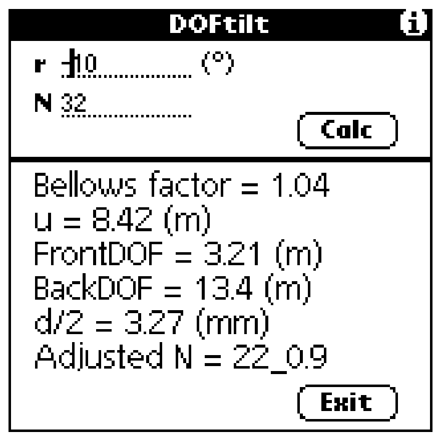
This calculation represents DOF for horizontal distances through a tilted lens. It can be compared with the output of **DOFu** for an untilted lens:



There seems to be little difference, but this is not the case when one looks along rays at an angle.

The output resulting from an angle of 10° is shown below on the left, and -10° on the right.



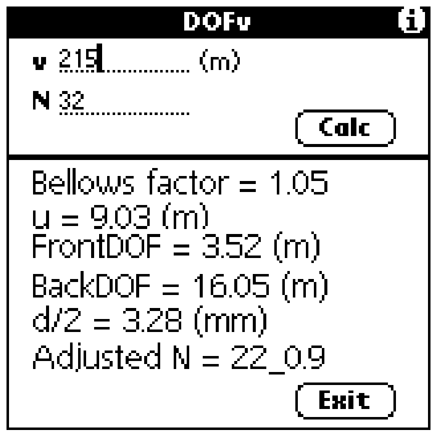


The effect of lens tilt on DOF is substantial.

It is important to note that the defocus, d may be used to find the near and far DOF planes for tilted lenses, just as it can be for untilted lenses. The defocus limits are $v - d/2$ and $v + d/2$, and the distance v is the distance of the rear standard from the lens when the subject plane is in focus. By moving the rear standard forward or back $d/2$ millimeters the DOF planes are those which are in sharpest focus.

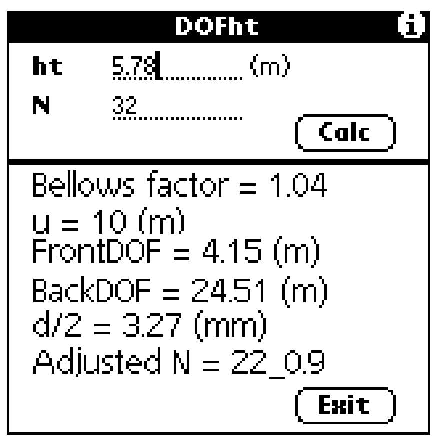
5.3 DOFv, From v

The distance between the lens and the film plane is v. It may be used to find DOF. Input and output for the **DOFv** program are shown below. As a sidelight, note that the *Adjusted N* value is little different from the nominal N of 32. This is because the extension $215 - 210 = 5$ mm is very small relative to $F = 210$ mm. For close up work, however, the *Adjusted N* will be considerably different. Suppose one were interested in a 1 to 1 image, then the 210 mm lens would have to be focused at 440 mm, and the *Adjusted N* would become 11_9, and the DOF would shrink to about 11 mm.



5.4 DOFht, From subject height

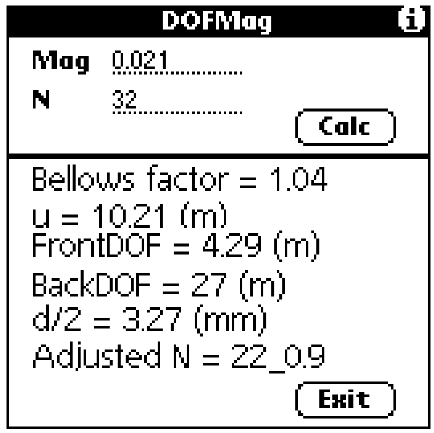
By subject height is meant the vertical extent of the subject which will fill the long side[7] of the image on the film. In the present case with $u = 10$ m, the height is 5.78 m. The input and output are shown for this value.



[7]The program chooses a film height of 124 mm for 4x5.

5.5 DOFMag, From magnification

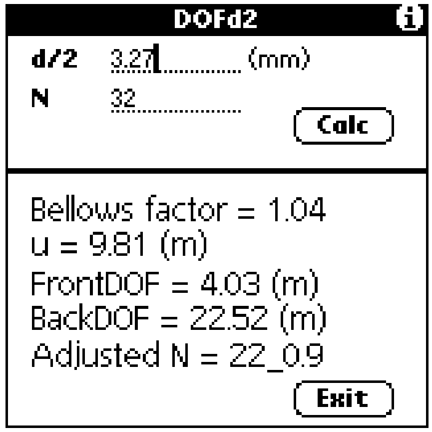
Magnification is the ratio v/u. In the present case it is $210/10000 = 0.021$ with both v and u in millimeters. Magnification is small for distant objects, but becomes large for close up photography. A magnification of 1 occurs when the image and subject heights are equal.



The output would have been slightly different had 0.02 been used for magnification. Whenever the output of two programs is unexpectedly different, look to the input values for an explanation. The calculations are done to many more places than are shown, and using too few places in the input can cause discrepancies.

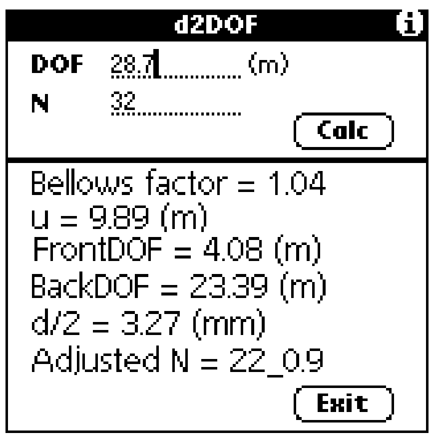
5.6 DOFd2, From defocus

The defocus, d, is the distance along the rail between the cognates of the near and far DOF: i.e. the difference between the locations of the two standards when the lens is focused on each of the two DOF limits. This is illustrated in Figure (1). For practical purposes, it is symmetrical about v, the position of the rear standard when the subject is in focus. Using $d/2 = 3.27$ mm to be consistent with the previous examples, the input and output appears as:



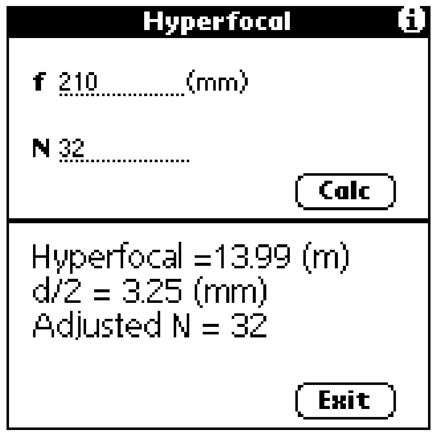
5.7 d2DOF, From depth of field

This program accepts a *DOF* value. To be consistent with the previous examples, the DOF is set to 28.7 m. The *NearDOF* and *FarDOF* in the output are calculated from $d/2$ which is calculated from *DOF*, and as may be seen these do dot add up to the input *DOF* value. The calculation of $d/2$ from *DOF* is not too stable numerically, so these results should be used cautiously.



5.8 Hyperfocal, Hyperfocal distance

This returns the hyperfocal distance for the input prameters.



The $d/2$ and *Adjusted N* are different from the previous programs because u has changed from 10 m to the hyperfocal distance of 13.99 m.

5.9 Fuzz, Blurred images

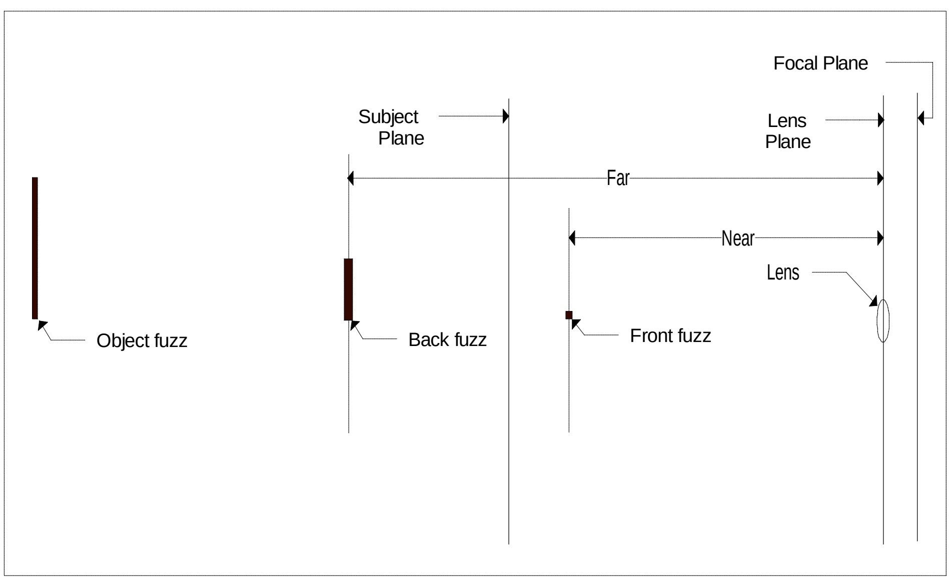
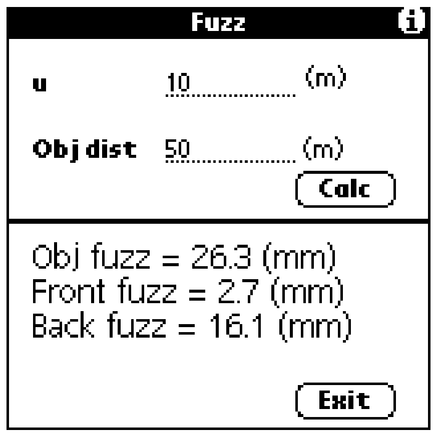


Figure 8: Fuzz at three distances

Bokah is the Japanese term for out of focus or blurred objects. There is *good bokah* and *bad bokah*, but this is not the place to discuss its nature, and is only brought up here to introduce the fact that blurred images can form useful parts of a picture. Sometimes one has intrusive objects in the frame that need to be blurred, and sometimes it is just better to have a fuzzy area in a picture to support in a sense the main subject.

In any case, the **Fuzz** output shows the degree of blurring for objects at specific distances. **Fuzz** always calculates blurring values for the DOF limits, and in addition it will calculate them for a user input distance. Consistent with the above examples, suppose $u = 10$ m and let us suppose we need to know about an object at 50 m. Figure (8) shows the size of objects at three distances which image on the film at exactly twice the diameter of the circle of confusion. The input and output are:

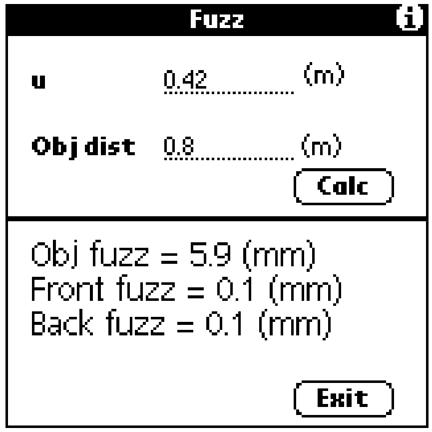


The "fuzz" values reported in the output, are the sizes of objects at the given distances which will image as twice the diameter of the circle of confusion[8]Thus objects of size 2.7 mm at the near DOF limit will barely be distinguishable. Similarly, objects of size 16.1 mm at the far DOF limit will not be distinguishable. At 50m, a 26.3 mm object will not be distinguishable. This means that inch high lettering on an intrusive billboard some 50 m distant, will not be readable in a print. The lettering would have to be at four or more times this size to be readable, and even then would be very fuzzy.

This is especially useful for macro photography. Suppose you are photographing a flower at one-to-one magnification and there is an unavoidable object in the background. How visible will this object be? For a 210mm lens, one-to-one magnification puts the subject plane 420mm in front of the lens. Suppose the objectionable object is twice this far, say 800mm away from the

[8] To find the size of an object which images k times the diameter of the circle of confusion, one should multiply the size, s, output by the program, by $k - 1$. For $k = 2$ the multiplier $k - 1$ is 1, and this is s as output by the program. The size of the object imaging at four times the diameter of the circle of confusion would be $(k - 1)s = 3s$. Using $4s$ instead, however, does little harm.

lens. The **Fuzz** input and output are:



If the object is smaller than 5.9 mm, then it will not be visible. If it is larger, say 25mm, then it will be very fuzzy because its top edge will not be distinguishable from a line 1/4 of this distance down. The size of the object will thus correspond to about four times the circle of confusion on the film, clearly a negligible amount.

6 Finding the subject's height

By subject height is meant the height of the subject that just fills the long side of the film image. The ratio of the long side of the film to the height is the magnification[9]. The height may be calculated from any of several parameters. Five programs are provided. They and their parameters are shown in Table (2).

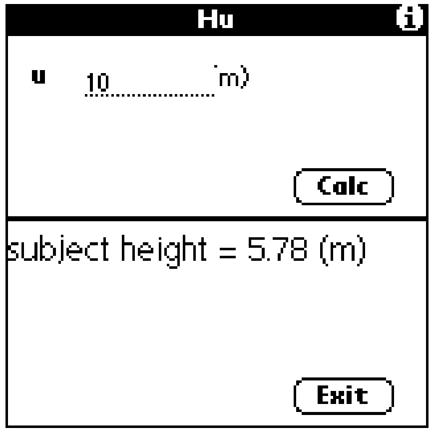
Program	Parameter
Hu	u
Hv	v
Hm	magnification
HDOF	FrontDOF
Hd2	$d/2$

Table 2: Height program parameters

All input screens are similar, requiring a single parameter. Only the **Hu** program will be illustrated. The output screen shows the subject height in

[9]Subject and film diagonals are often used instead of the height.

meters.

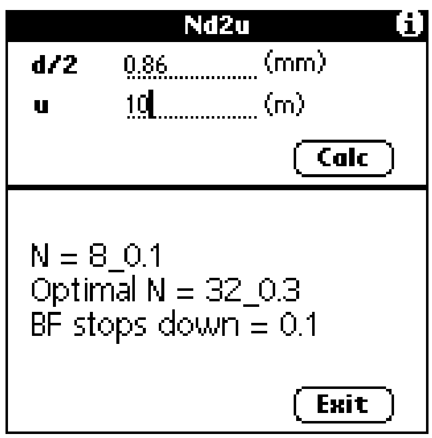


7 Finding the F-number, N

There are three programs, **NNearFar**, **NDOFu** and **Nd2u**, which calculate the F-number, N.

7.1 Nd2u, N from $d/2$ and u

The inputs are $d/2$ and u, as shown on the input screen.



The bellows correction shown at the bottom of the output depends only on the bellows extension and is thus the same for any N. It is given in stops, and may be subtracted from whatever N one selects. Thus 8_1 becomes 8_0 and 32_3 becomes 32_2.

Figure (9) illustrates the situation for the case when the lens is focused at infinity. In this figure, the optimum N line may be visualized as the crest of a mountain with the land sloping downward away from it. The “10 l/mm N”

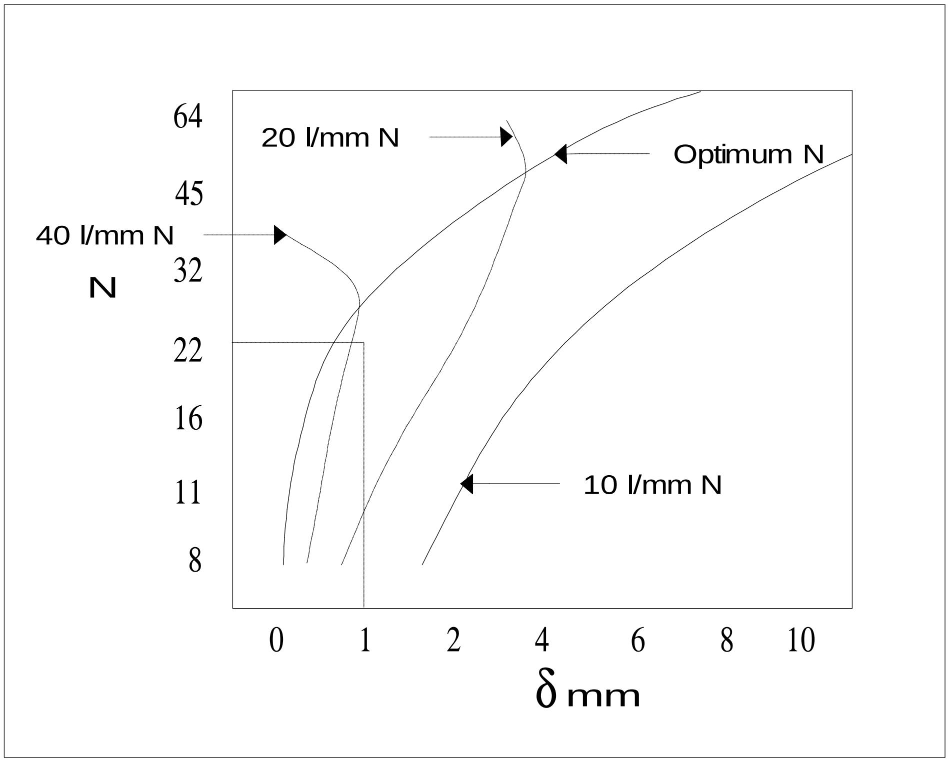


Figure 9: Optimum and resolution curves

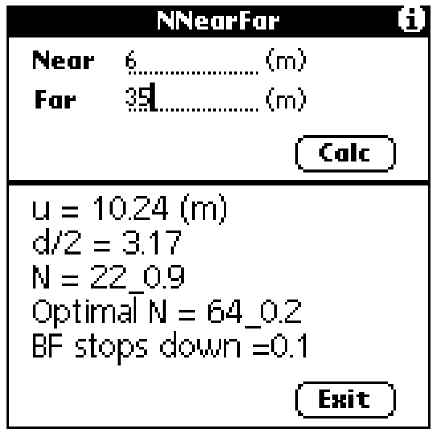
curve relates N to d such that the on-film resolution is 10 l/mm. The “40 l/mm N” and “20 l/mm N” curves do the same for 40 l/mm and 20 l/mm respectively. The extent of the d scale is appropriate for the 4x5 format. As a contrast, the dotted box at the lower left represents the d scale appropriate for the 35 mm format. The reason that manufacturers choose $N = 16$ or $N = 22$ as the maximum F-number for 35 mm should be clear from this figure.

Should one use N or optimum N? It all depends on what is wanted. The N output by the programs, corresponds to 10 l/mm, which is appropriate for an 8x10 print. The optimum N will of course support larger prints, but there seems little reason for choosing the optimum unless such large prints are the goal, and even then as may be seen in Figure (9) the optimum N will be less than 20 l/mm for d's greater than about four. The program Resoltn may be used to calculate the resolutions for particular combinations.

7.2 NNearFar, N from near and far values

NNearFar accepts *Near* and *Far* values for which it finds the N that will make them near and far DOF limits.

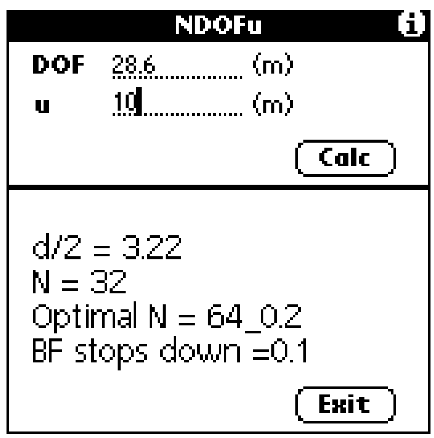
The screen for **NNearFar** are as follows. Do not confuse the *Near* and *Far* values with *FrontDOF* and *BackDOF* values.



The calculated N is about 32. In addition the N which produces maximum resolution is shown as the optimal N.

7.3 NDOFu, N from DOF and u

NDOFu accepts *DOF* and u, and finds N.



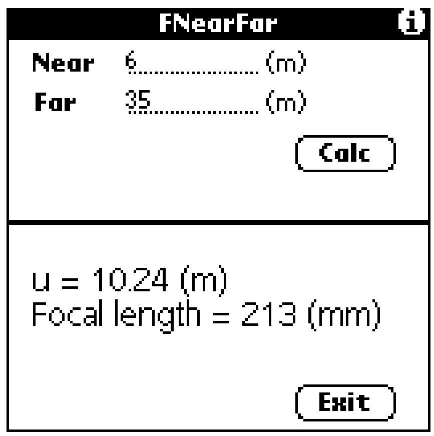
8 Finding the focal length

Focal length can be chosen in a variety of ways. The best way is to use a viewfinder to obtain a proper framing of the scene; however, other ways are possible. One may choose two distances, and map them into the DOF limits by a proper choice of focal length. Similarly, one may fix some other parameter, such as *DOF* or u, and calculate the focal length. Five programs are provided. They and their input parameters are show in Table (3).

Program	Parameters	
FNearFar	Near	Far
Fd2u	$d/2$	u
FDOF	DOF	magnification
Fmu	u	magnification
Fmv	v	magnification

Table 3: Focal length programs

The program **FNearFar** will be illustrated. The screen is shown below. The F returned is the focal length required to make 6 m and 35 m the DOF limits.



9 Finding the magnification

Magnification is the ratio of the film size to the subject size[10], thus for a 2 m tall subject imaged on a 4x5 film with long side 124 mm, the magnification is $124/2000 = 0.062$. Magnification controls the appearance of a picture, in that the subject size will fill the same area of the film if the magnification is constant. A picture taken with a 210 mm lens will frame the same composition as one taken with a 600 mm lens if the magnification for the two is the same. For example, in the case of a 2 m tall subject taken with a 210 mm lens on a 4x5 camera, the subject must be 3.6 m away. For a 600 mm lens, the subject must be 10.2 m away. The **uvm** program may be used to confirm this.

Two pictures with the same magnification taken with different lenses may or may not appear identical – there can be a difference in resolution. The difference will be quite small, as may be seen by checking the **DOFm** program which produces the values in Table (4). The F-number in this table is $N = 32$

[10] Any film dimension may be chosen. Each dimension will produce a slightly different value. The long side of the image is chosen here. Magnification is also equal to v/u.

for both lenses.

Lens	Distance	FrontDOF	BackDOF
210 mm	3.6 m	0.71 m	1.17 m
600 mm	10.6 m	0.81 m	0.97 m

Table 4: Constant magnification for 2 m subject on a 4x5

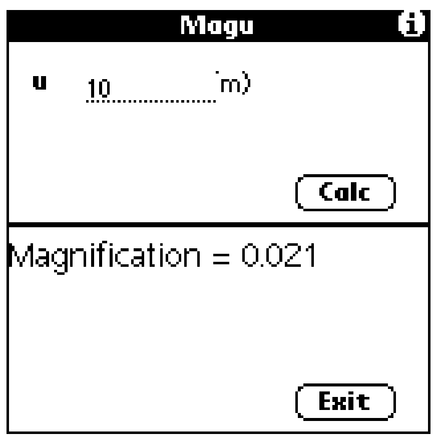
Of course changing N will produce considerable differences in resolution, since DOF changes dramatically as N changes, but the point that has been made is that lens changes have little effect when magnification is constant.

There are four programs for magnification, as shown in Table (5).

Program	Parameter
Magu	u
Magv	v
Magh	height
MAGd2	$d/2$

Table 5: Magnification program parameters

The input and output for **Magu** is shown below:



10 u <=> v

The parameters u and v satisfy an equation called the lens equation, and one may be computed from the other. In addition, either may be obtained from other parameters[11]. Four programs are given here. The **utofromv** program

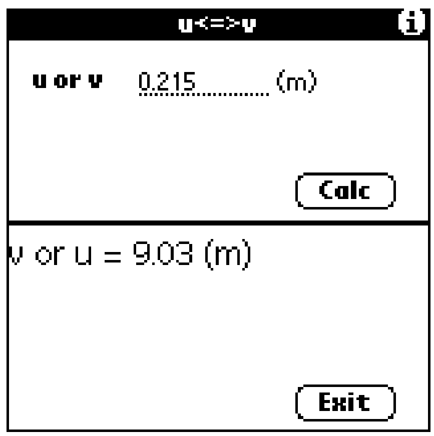
[11]Do not confuse u with u' which is used in connection with tilted lenses. Both represent distances from the lens to the subject, but only u for non-tilted lenses satisfies the lens

translates u into v or v into u. The others produce u and v from magnification, subject height, and $d/2$. The programs and their parameters are given in Table (6).

Program	Parameter
utofromv	u or v
uvh	height
uvm	magnification
uvd2	$d/2$

Table 6: u and v program parameters

The input and output for **utofromv** when v is input are shown below. Note that the input must always be in meters.



11 Bellows Factor

The F-number that is read from a light meter strictly applies to the situation when the lens is focused at infinity. When the focus point is closer to the lens, the lens must be extended and this decreases the amount of light reaching the film by the inverse square law. That is if the lens is moved twice as far out, the exposure will be one quarter of the original. To compensate for this, one should multiply the shutter speed by a factor. The factor is called the “bellows factor.” The programs in this section give the bellows factor as a function either of the magnification or of the lens extension. They also translate the bellows factor into stops so that one may adjust the F-number instead of the shutter speed if desired.

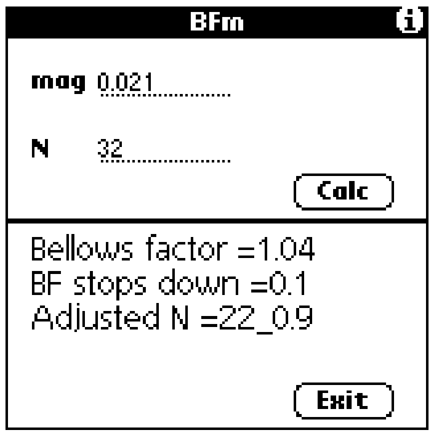
The programs and their parameters are given in Table (7).

equation. The lens equation may be used with tilted lenses, but u’ is not the quantity needed.

Program	Parameter
BFMag	magnification
BFext	extension

Table 7: bellows factor program parameters

The input and output for the **BFMag** program are shown below.

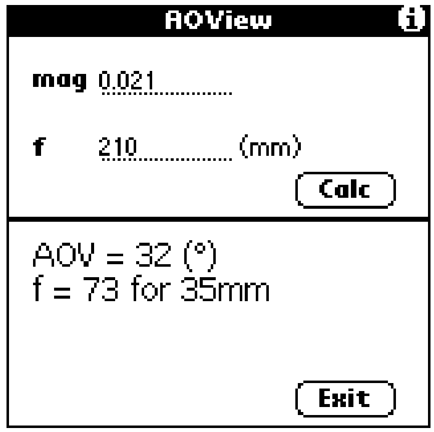


12 Miscellaneous programs

This section documents a number of miscellaneous programs such as **AOView** for finding the angle of view, and **StopMotion** for calculating the shutter speed required to stop motion.

12.1 AOView, from magnification and focal length

The input and output are as shown.

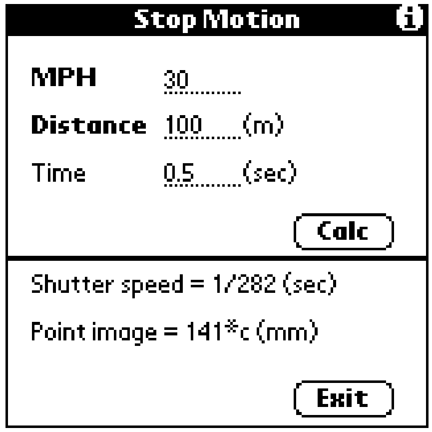


For reference, the last line of the output gives the focal length of a 35 mm lens with the same angle of view.

12.2 StopMotion, shutter speed to stop motion

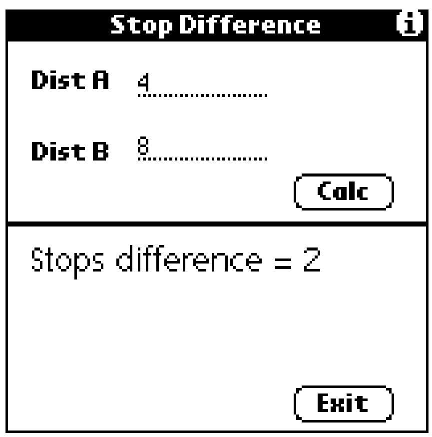
The screen shows input for a 30 mph hour object 100 meters away. The direction of motion is assumed to be at right angles to the lens axis. The output indicates that a shutter speed of 1/282 seconds will stop this motion.

One may not always be able to shoot at the indicated speed, and some idea of the degree of blurring is useful. If the desired shutter speed, in seconds is input in *Time*, then the degree of blurr is shown on the output screen. The output gives the distance the image of the subject moves in units of c, the diameter of the circle of confusion. A time of 1/2 second was input on the screen on the left and the output screen shows that the image of a subject will cover a distance of 141 times c during the 1/2 second exposure. It will be very blury. As a rule a subject that moves only two or three times c may be acceptable.



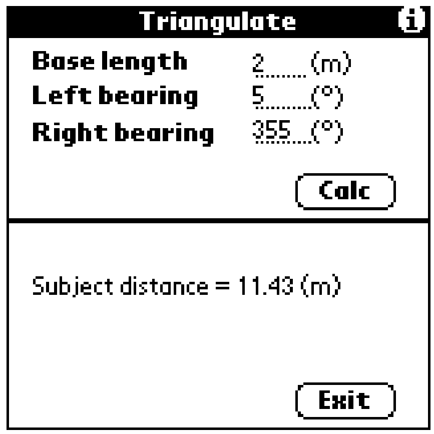
12.3 Stopdiff, stop difference for light movement

If the lights in a studio are moved or the flash distance is changed, the F-number will change. This program gives the stop difference required to make the adjustment. The lights are at 4 m and they are to be moved to 8 m, and the output shows that the F-number must be increased by 2 stops.



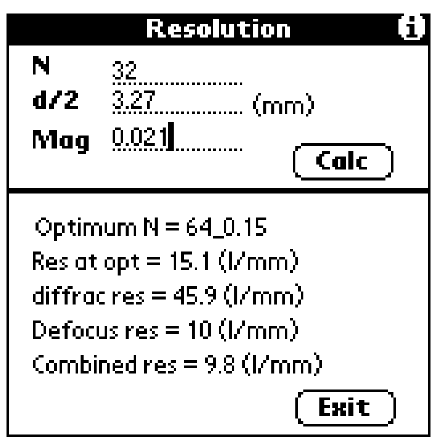
12.4 Triangulate, triangulation

The distance to an object may be found by triangulation. The input requires the base distance and two compass readings. I generally choose a two meter base, since I carry a retractable pocket measure and it is easy for me to hook the end on the camera and move out one meter on each side. My compass is shown among the gadgets in Figure (2).



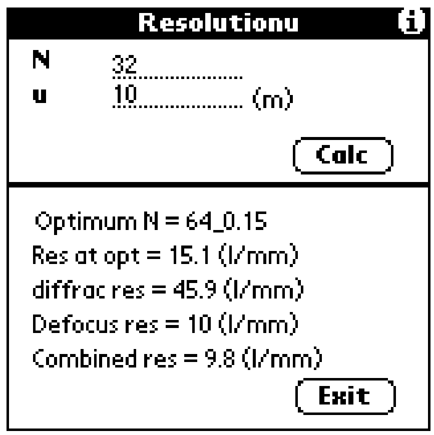
12.5 Resolution

This is a theoretical calculation of little practical use in the field, but included for completeness. With it one may calculate the resolutions shown in Figure (9). The input screen shows $d/2$ entered as 3.27. The output screen shows the resolution at the optimum for $d/2 = 3.27$. Below this are the resolutions from two different sources which combine to produce the final resolution. The first of these is the diffraction resolution, and the second is the defocus resolution at a $d/2$ distance from the plane of exact focus. The two resolutions are combined using root mean square on their inverses – this is strictly an empirical combination since there is no simple theoretical way to combine them. It is interesting to note that the resolution due to diffraction is actually the largest resolution shown, which should give pause to those who ascribe poor quality to diffraction – in this case, the principal cause is extreme defocus.



12.6 Resolutionu, at the DOF limits

Although diffraction is often thought of as an important source of image degradation, it is not in fact. This calculation shows the diffraction and defocus resolutions as was done in the previous subsection, but this time the resolutions are in terms of practical camera settings. The calculations are made at the DOF limits, which represent a worst case – resolutions for any distances closer to u than these DOF limits will be higher[12].It may be seen that for such practical settings, diffraction is always so much larger than defocus resolution, that it has little effect on the combined resolution. The maximum N engraved on a lens is chosen so that diffraction has an effect only in extreme cases. An extreme case would be one with N at the maximum and u just slightly larger than the focal length.



[12]This may be checked using the previous program by decreasing $d/2$. The value of $d/2$ at the DOF limits may be obtained from any of the DOF programs.

BIBLIOGRAPHY

1. Bond, H. (1998). *Photo Techniques*, May/June

2. Merklinger, Harold, M. (1992) *The ins and outs of focus.* Ottawa, Canada.

3. Merklinger, Harold, M. (1993) *Focusing the view camera.* Ottawa, Canada.

4. Jacobson, R.E.; Ray, S.F.; and Attridge, G.G. (1988). *The manual of photography.* Eighth Ed. Focal Press, Boston.

5. bib:Kingslake) Kingslake, R. (1989) *A history of the photographic lens.* Academic Press, Boston.

6. Ray, Sidney F. (1994) *Photographic optics.* Focal Press, Boston.

7. Sears, F.W. (1958) *Optics*, Addison Wesley, Reading MA.

8. Stroebel, Leslie; Compton, John; Current, Ira; and Zakia, Richard. (1986) *Photographic materials and processes.* Focal Press, Boston.

9. Stroebel, Leslie. (1993). *View camera technique.* Focal Press, Boston.

Directory	Program Name	Page	Description
	Params	8	Set and display parameters
View			Viewframe information
	Viewv	10	u,FrontDOF,BackDOF from v
	Viewu	10	u,FrontDOF,BackDOF from u
Tilt			Calculates tilt angle
	Tiltb	12	By back focusing
	Tiltd	14	From distances and angles
	TilJ	16	From u and J
	Tiltg	16	From subject plane slope
DOF			Depth of field
	DOFu	18	From u
	DOFTilt	19	From ray angle, for tilted lens
	DOFv	21	From v
	DOFht	22	From height of the subject
	DOFmag	23	From magnification
	DOFd2	23	From $d/2$
	d2DOF	24	$d/2$ from DOF
	Hyperfocal	25	The hyperfocal distance
	Fuzz	25	Blurred subject size
Height			Subject height
	Hu	27	From u
	Hv	27	From v
	Hm	27	From magnification
	HDOF	27	From DOF
	Hd2	27	From $d/2$
N			Calculates F-numbers
	NNearFar	29	From near and far values
	Nd2u	28	From $d/2$ and u
	NDOFu	30	From DOF and u
Focal			Focal length
	FNearFar	30	From near and far DOF limits
	Fd2u	30	From $d/2$ and u
	FDOF	30	From DOF and u
	Fmu	30	From DOF and magnification
	Fmv	30	From v and magnification
Mag			Magnification
	Magu	31	From u
	Magv	31	From v
	Magh	31	From subject height
	Magd2	31	From $d/2$
u <=> v			u and v
	utofromv	32	u to v or v to u
	uvh	32	u and v from subject height
	uvm	32	u and v from magnification
	uvd2	32	u and v from $d/2$
Bellows			Bellows factors
	BFm	33	From magnification and N
	BFext	33	From extension and N
Misc			Various utilities
	AOView	35	Angle of view from magnification and focal length
	StopMotion	35	Shutter spread to stop motion
	StopDifference	36	Stop difference for two light distances
	Ttianuglate	36	Triangulates to find subject distance
	Resolution	37	Theoretical resolution
	Resolutionu	38	Resolution at the DOF limits