

meric keys and a "\*" key and "#" key as shown in FIG. 4-FIG. 7D2. Each projection can be explored and pressed with a fingertip.

[0046] FIG. 1A shows the front of a Personal Digital Assistant 2 with a display screen 3 and antenna 30. FIG. 1B shows the present input device on the back of the PDA of FIG. 1A being used for input by exploring and pressing with a fingertip the position of a projection for producing input. FIG. 8 shows a side sectional view of some projections 12, 15, 18, and 21 on such an input device, which will be described later.

[0047] As shown in FIGS. 1A and 1B, a PDA is held with one hand in a position that allows the index finger to reach the home position of the input device. The input device is small enough to operate by moving only a finger, while the wrist is fixed. The size and shape for input device is designed shown in FIGS. 2A and 2B. A first egg-shaped area C1 can be reached by the index finger of the right or left hand, whichever hand is holding the PDA. This area C1 is the tactile sense recognition feasible region.

[0048] According to experiments, the area in which a fingertip of either hand can move reasonably freely and fully without moving the wrist is less than 1 to 2 times the fingertip breadth. A second egg-shaped curve C2 shows this area as 19 mm-22 mm high and 17 mm-20 wide. Area C2 is about 5 mm-8 mm less than C1 in every direction.

[0049] As shown in FIG. 2B, a preferred vertical pitch of the projections is 4.0 mm to 7.0 mm and a preferred lateral pitch is 4.5 mm to 8.0 mm. This allows 12 projections to fit completely within C2 in four rows with 3 projections per row.

[0050] Areas C1 and C2 are preferably laterally bisymmetric to allow equal use with the right or left hand. FIG. 3 shows how areas C1 and C2 are formed. A user normally holds a PDA as shown. In this holding position, the index finger has an angle  $\theta$  of about 30 degrees from vertical. For this reason, the feasible input area C3 and the preferred input area C4 are laterally asymmetric about the vertical centerline of the PDA for a given hand. For a right hand, the area is larger on the right side of FIG. 3, as shown. For a left hand the area is larger on the left (not shown). However if the larger sides of C3 and C4 are eliminated, and smaller sides are mirrored across the vertical centerline, the resulting areas will be laterally symmetric and equally accessible for a right or left hand. This is how C1 and C2 are formed from the smaller lateral portions of C3 and C4 respectively.

[0051] As shown in FIG. 8, plural projections 12, 15, 18, and 21 are preferably formed integrally in input plate 4. The plate and projections are made of an electrically insulating material. A substrate 5 is located behind the input plate. An electrical contact 7 is printed on the substrate 5 behind each projection. A pressure sensitive variable resistance layer 6 is printed on the electrical contact 7 behind each projection. An electrical conductor 8 is formed as a thin film on the input plate 4 behind each projection to raise conductivity. When pressure is applied to a projection, the variable resistance layer is compressed causing its resistance to decrease, and current flows.

[0052] The pressure-sensitive variable resistance layer 6 is made of a mixture of a compressible material such as silicone rubber with a conductive material such as carbon

black, carbon fiber, or graphite. This material has high resistance or is non-conductive when pressure is not applied, but it is conductive in proportion to pressure applied.

[0053] As shown in FIGS. 4 and 5A, twelve projections 11-22 are made by integral molding in the input plate 4. When the input array is used on the back of a PDA, the twelve projections correspond respectively to "3", "2", "1", "6", "5", "4", "9", "8", "7", "#", "0", "\*". This is because the array will be operated facing away from the user, so the inputs are laterally mirrored to match their normal positions as seen from the front of the PDA. If the input array is used on the front of a PDA, the twelve projections 11-22 correspond respectively to "1", "2", "3", "4", "5", "6", "7", "8", "9", "\*", "0", "#". These two preferred layouts are not essential, but are desirable because users are familiar with this convention.

[0054] FIG. 6 shows an example of preferred dimensions for an input plate. The lateral pitch of the projections is 7.0 mm, which is within the previously mentioned range of 4.5 mm to 8.0 mm, and the vertical pitch is 6.5 mm, which is within the previously mentioned range of 4.0 mm to 7.0 mm. The width of the input plate is 20 mm and the height is 25 mm. The projections 11-22 are generally hemispherical with a height  $h$  of 1.0 mm and a diameter of 2.5 mm. Projection 15 is smaller, with a height  $h$  of 0.5 mm and a diameter of 1.8 mm. Projections 15 provides a home position for the fingertip that can be recognized by the tactile sense of the user. The projections need not be perfect hemispheres.

[0055] FIGS. 7A1-7D2 show the projections protruding through individual holes in the back of the case of a Personal Digital Assistant. The back surface of the case need not be perfectly flat. It may have a curved or featured surface. Using this approach, an input plate does not necessarily need to be customized to conform to an existing curved surface of a given PDA.

[0056] A home position on the projections can be recognized by a surface feature on the input plate or on the back surface of a PDA, rather than by a smaller projection 15. FIGS. 7A1 and 7A2 show a circular depression S1 around a home position. FIGS. 7B1 and 7B2 show an oval depression S2. FIGS. 7C1 and 7C2 show the whole projection array mounted in a sunken area with a raised circumference S3. FIGS. 7D1 and 7D2 show a ridge S4 along the top row of projections, which are longer than the other projections. Any of these types of surface features are easily sensed by the user to guide the fingertip position. The last version S4 has the additional advantage of providing a higher row of projections where the finger is extended, making operation easy.

[0057] FIG. 6 shows a fingertip with a width  $D$  centered on input projection 15. Width  $D$  will be termed herein the fingertip representation size. This is the average breadth of an index fingerprint of a given of a given population. Fingerprint sizes differ by age, sex, race, and other demographic factors. Adult Asians have an index fingertip representation size  $D$  of 10 mm to 18 mm for men, and 10 mm to 15 mm for women.

[0058] For example, an average width  $D$  of 12 mm for adult Asian women can be used. The width of curve C1 for the input plate must be within 2 to 3 times this size. The usable curve C1 should have a width of 22 mm to 28 mm and