~~APPARATUS FOR DETERMINING A TOUCH INPUT STIMULUS~~APPARATUS AND METHOD FOR DETERMINING A STIMULUS, INCLUDING A TOUCH INPUT AND A STYLUS INPUT

FIELD OF THE INVENTION

The present invention relates to an apparatus and method for detecting a stimulus, and more particularly, an apparatus and method for detecting a touch input and a stylus input.

BACKGROUND OF THE INVENTION

There exist numerous Human Machine Interface (HMI) devices designed to sense the presence of human touch today. In some cases these HMI interfaces include a stylus that is used to provide input from the human to the machine interface. A stylus may completely replace the direct human interface or may supplement the human interface. These HMI devices may use light, sound, mechanical-electro (switches) magnetic fields, electric fields, electromagnetic fields, or a combination of these stimuli.

Three prior and current touch technologies that exist today and that use electric fields are commonly referred to as projected capacitance, capacitive, and differential sensing. Projected capacitance is commonly associated with transparent touch screens that are used in conjunction with displays of the same approximate size and are assembled with such displays in a manner as to allow the light from the display to pass through the sensing elements of the projected capacitance touch screen sensing elements. Projected capacitance is usually implemented with high resolution capabilities where the selection of an area of touch can be much smaller than the actual size of a finger. Projected capacitance is widely used on personal electronic devices such as cell phones, personal digital assistants (PDAs), smart phones, notebooks, laptop computers, laptop monitors, and other user devices that have

CLAIMS

1. A capacitive sensor comprising:

a capacitive sensing circuit defining an output and including a plurality of electrodes;

a substrate overlying the capacitive sensing circuit for receipt of an object thereon; and

a processing unit electrically coupled to the capacitive sensing circuit and configured to detect placement of the object against the substrate based on the rate of change of the capacitive sensing circuit output, wherein the capacitive sensing circuit output is based on the self-capacitance of at least two of the plurality of electrodes.

~~2. The capacitive sensor of claim 1 wherein the capacitive sensing circuit includes a single electrode and wherein the capacitive sensing circuit output is based on the self-capacitance of the single electrode.~~

~~3. The capacitive sensor of claim 1 wherein the capacitive sensing circuit includes a plurality of electrodes and wherein the capacitive sensing circuit output is based on the mutual capacitance of at least two of the plurality of electrodes.~~

~~4. The capacitive sensor of claim 1 wherein the capacitive sensing circuit includes a plurality of electrodes and wherein the capacitive sensing circuit output is based on the self-capacitance of at least two of the plurality of electrodes.~~

2~~5~~. The capacitive sensor of claim 1 wherein the capacitive sensing circuit includes a sampling capacitor electrically coupled to the processing unit.

3~~6~~. The capacitive sensor of claim 1 wherein the plurality of electrodes ~~capacitive sensing circuit~~ include~~s~~ a sense electrode and a bias electrode spaced apart from the sense electrode.

4~~7~~. The capacitive sensor of claim 1 wherein the plurality of electrodes ~~capacitive sensing circuit~~ include~~s~~ a sense electrode and a strobe electrode spaced apart from the sense electrode.

5~~8~~. The capacitive sensor of claim 1 wherein the processing unit is a time domain differential processing circuit configured to determine the rate of change of the capacitive sensing circuit output.

6~~9~~. The capacitive sensor of claim 3~~6~~ wherein the time domain differential processing circuit is adapted to determine a touch signature based on the rate of change of the capacitive sensor circuit output and at least one of a capacitive value and a time domain.

7~~10~~. A capacitive sensor comprising:

a substrate for receiving a touch input thereon;

an electrode subjacent the substrate and including a capacitance adapted to vary in response to the touch input; and

a processing unit coupled to the electrode and adapted to determine a signature of the touch input based on the electrode capacitance, wherein the signature includes variations in the electrode capacitance corresponding to movement of a touch input generally perpendicular to the substrate and against the substrate.

8~~11~~. The capacitive sensor of claim 7~~10~~ wherein the processing unit is adapted to measure the rate of change of the electrode capacitance over a first time domain to determine the signature of the touch input.

9~~12~~. The capacitive sensor of claim 8~~11~~ wherein the processing unit is adapted to measure the rate of change of the electrode capacitance over a second time domain to determine the signature of the touch input, the second time domain being greater than the first time domain.

10~~13~~. The capacitive sensor of claim 7~~10~~ wherein the processing unit is adapted to measure a change in the electrode capacitance relative to ground.

11~~14~~. The capacitive sensor of claim 7~~10~~ wherein the touch signature includes fluid movement of an object toward the capacitive sensor.

12~~15~~. The capacitive sensor of claim 7~~10~~ wherein the touch signature includes staggered movement of an object toward the capacitive sensor.

13~~16~~. The capacitive sensor of claim 7~~10~~ wherein the touch signature includes fluid movement of an object toward and away from the capacitive sensor.

14~~17~~. The capacitive sensor of claim 7~~10~~ wherein the touch signature includes staggered movement of an object toward and away from the capacitive sensor.

15~~18~~. The capacitive sensor of claim 7~~10~~ wherein the touch signature includes a flattening of the touch input against the substrate.

~~19. The capacitive sensor of claim 10 wherein the electrode is elongate and defines a length, the elongate electrode including a width that varies with the length to provide a varying capacitance as a touch input is moved along the length of the electrode.~~

~~20. A capacitive sensor comprising:~~

~~first and second electrodes defining a capacitive coupling therebetween; and~~

~~a processing unit electrically coupled to at least one of the first and second electrodes and configured to determine the rate of change of the capacitive coupling to indicate the presence of a stimulus.~~

~~21. The capacitive sensor of claim 20 wherein determining a rate of change of the capacitive coupling is in response to the capacitive coupling achieving a predetermined criteria.~~

~~22. The capacitive sensor of claim 20 wherein the processing unit is further adapted to compare the self-capacitance of the first electrode to the self-capacitance of the second electrode.~~

~~23. The capacitive sensor of claim 22 wherein determining a rate of change of the capacitive coupling is in response to the self-capacitance of the first electrode being substantially dissimilar from the self-capacitance of the second electrode.~~

~~24. The capacitive sensor of claim 22 wherein the processing unit is adapted to simultaneously measure the self-capacitance of the first and second electrodes.~~

~~25. The capacitive sensor of claim 22 wherein the processing unit is adapted to sequentially measure the self-capacitance of the first and second electrodes.~~

~~26. The capacitive sensor of claim 20 wherein:~~

~~the first electrode is an inner electrode; and~~

~~the second electrode is an outer electrode surrounding a substantial portion of the inner electrode, the inner and outer electrodes being substantially coplanar.~~

~~27. The capacitive sensor of claim 26 wherein:~~

~~the inner electrode includes an outer periphery defining spaced apart segments; and~~

~~a portion of the outer electrode is interposed between the spaced apart segments.~~

~~28. The capacitive sensor of claim 20 further including a first substrate overlying the first and second electrodes and a second substrate underlying the first and second electrodes, wherein the first substrate is movable relative to the first and second electrodes.~~

~~29. The capacitive sensor of claim 28 further including a plurality of substantially non-compressible spacers interposed between the first and second substrates, wherein the first substrate is flexible toward the second substrate in response to a downward deflection of the first substrate.~~

~~30. The capacitive sensor of claim 28 wherein the first and second substrates are substantially rigid and further including a plurality of collapsible spacers interposed between the first and second substrates, wherein the first substrate is moveable toward the second substrate in response to a downward deflection of the first substrate.~~

~~31. A method for detecting a stimulus comprising:~~

~~providing first and second electrodes defining a capacitive coupling;~~

~~measuring a rate of change of the capacitive coupling; and~~

determining the presence of a stimulus based on the measured rate of change of the capacitive coupling.

32. The method according to claim 31 wherein the stimulus corresponds to an object as proximate the first and second electrodes.

33. The method according to claim 31 further including detecting an object in proximity to the first and second electrodes in response to the capacitive coupling achieving a predetermined criteria.

34. The method according to claim 31 wherein the first and second electrodes include an inner electrode an outer electrode surrounding a substantial portion of the inner electrode, the inner and outer electrodes being substantially coplanar.

35. The method according to claim 34 further including a providing bias electrode spaced apart from the first and second coplanar electrodes.

36. The method according to claim 31 further including providing a flexible substrate overlying the first and second electrodes and supported by a plurality of spacers, wherein the flexible substrate is deflectable toward the inner and outer electrodes.

37. The method according to claim 31 further including providing a substantially rigid substrate overlying the first and second electrodes and supported by a plurality of collapsible spacers, wherein the substantially rigid substrate is deflectable toward at least one of the inner and outer electrodes.

38. A capacitive sensor comprising:

first and second coplanar electrodes;

a third electrode spaced apart from the first and second electrodes, wherein the third electrode defines a first capacitive coupling with the first electrode and a second capacitive coupling with second electrode; and

~~a processing unit electrically coupled to at least one of the first, second and third electrodes and configured to determine the rate of change of the first and second capacitive couplings to indicate the presence of a stimulus.~~

~~39. The capacitive sensor of claim 38 wherein the processing unit is adapted to simultaneously measure the first and second capacitive couplings.~~

~~40. The capacitive sensor of claim 38 wherein the processing unit is adapted to sequentially measure the first and second capacitive couplings.~~

~~41. The capacitive sensor of claim 38 wherein second electrode surrounds a substantial portion of the first electrode.~~

~~42. The capacitive sensor of claim 42 wherein the third electrode is coextensive with the first and second electrodes.~~

~~43. The capacitive sensor of claim 38 wherein the processing unit is adapted to determine the rate of change of the first and second capacitive couplings in response to the first or second capacitive couplings being greater than a threshold capacitance.~~

~~44. A capacitive sensor comprising:~~

~~a strobe electrode;~~

~~first and second sense electrodes spaced apart from the strobe electrode; and~~

~~a processing unit electrically coupled to the first and second sense electrodes and configured to determine the presence of a stimulus based on the capacitance of the first and second sense electrodes.~~

~~45. The capacitive sensor of claim 44 wherein:~~

~~the strobe electrode and the first sense electrode define a first mutual capacitance;~~

~~the strobe electrode and the second sense electrode define a second mutual capacitance; and~~

~~the processing unit is adapted to determine the presence of a stimulus based on the first mutual capacitance and based on the second mutual capacitance.~~

~~46. The capacitive sensor of claim 45 wherein the processing unit is adapted to simultaneously measure the first mutual capacitance and the second mutual capacitance.~~

~~47. The capacitive sensor of claim 45 wherein the processing unit is adapted to sequentially measure the first mutual capacitance and the second mutual capacitance.~~

~~48. The capacitive sensor of claim 45 wherein the processing unit includes a time domain differential sensing circuit adapted to determine the rate of change of the first mutual capacitance and the second mutual capacitance.~~

~~49. The capacitive sensor of claim 45 wherein:~~

~~the first sense electrode is an inner electrode; and~~

~~the second sense electrode is an outer electrode surrounding a substantial portion of the inner electrode, the inner and outer electrodes being substantially coplanar.~~

~~50. The capacitive sensor of claim 45 further including a first dielectric substrate overlying the strobe electrode for receipt of a touch input thereon.~~

~~51. The capacitive sensor of claim 50 further including a second dielectric substrate underlying the strobe electrode and interposed between the strobe electrode and the first and second sense electrodes.~~

~~52. The capacitive sensor of claim 51 further including a plurality of spacers interposed between the dielectric substrates, wherein first dielectric substrate is adapted to flex downwardly toward the second dielectric substrate.~~

~~53. The capacitive sensor of claim 51 further including a plurality of collapsible spacers interposed between the dielectric substrates, wherein first dielectric substrate is adapted to translate downwardly toward the second dielectric substrate.~~

~~54. The capacitive sensor of claim 45 further including a first dielectric substrate overlying the first and second sense electrodes for receipt of a touch input thereon.~~

~~55. The capacitive sensor of claim 54 further including a second dielectric substrate underlying the first and second sense electrodes and overlying the strobe electrode.~~

~~56. The capacitive sensor of claim 55 further including a plurality of rigid spacers interposed between the first and second dielectric substrates, wherein first dielectric substrate is adapted to flex downwardly toward the second dielectric substrate.~~

~~57. The capacitive sensor of claim 55 further including a plurality of collapsible spacers interposed between the dielectric substrates, wherein first dielectric substrate is adapted to translate downwardly toward the second dielectric substrate.~~

~~58. A capacitive sensor comprising:~~

~~a plurality of electrode rows extending a first direction;~~

~~a plurality of electrode columns extending in a second direction transverse to the first direction; and~~

~~a processing unit electrically coupled to each of the plurality of electrode rows and electrode columns, wherein the processing unit is adapted to determine a rate of change of the capacitance of the plurality of electrode rows and the plurality of electrode columns to indicate the presence of a stimulus in two dimensions.~~

~~59. The capacitive sensor of claim 58 wherein electrodes from adjacent electrode rows form a capacitive coupling, the processing unit being further adapted to measure a rate of change of the capacitive coupling to detect the presence of a stimulus.~~

~~60. The capacitive sensor of claim 58 wherein electrodes from adjacent electrode columns form a capacitive coupling, the processing unit being further adapted to measure a rate of change of the capacitive coupling to detect the presence of a stimulus.~~

~~61. The capacitive sensor of claim 58 wherein one of the plurality of electrode rows and one of the plurality of electrode column for a capacitive coupling, the processing unit being further adapted to measure a rate of change of the capacitive coupling to detect the presence of a stimulus.~~

~~62. The capacitive sensor of claim 58 further including a non-conductive substrate interposed between the plurality of electrode rows and the plurality of electrode columns.~~

~~63. The capacitive sensor of claim 58 wherein the plurality of electrode rows and the plurality of electrode columns are in substantially non-overlapping alignment.~~

~~64. A capacitive sensor comprising:~~

~~a substrate for receiving a touch input thereon;~~

~~a plurality of electrode rows and electrode columns subjacent the substrate and each including an electrode capacitance adapted to vary in response to a touch input; and~~

~~a processing unit coupled to the plurality of electrode rows and electrode columns and adapted to determine a signature of a touch input based on at least one electrode capacitance, wherein the signature includes variations in at least one electrode capacitance corresponding to movement of a touch input generally perpendicular to the substrate while remaining in contact with the substrate.~~

~~65. The capacitive sensor of claim 64 wherein the processing unit is adapted to measure the rate of change of an electrode capacitance relative to a first time domain to determine the signature of the touch input.~~

~~66. The capacitive sensor of claim 65 wherein the processing unit is adapted to measure the rate of change of an electrode capacitance relative to a second time domain to determine the signature of the touch input.~~

~~67. The capacitive sensor of claim 64 wherein the processing unit is adapted to measure a change in an electrode capacitance relative to ground.~~

~~68 The capacitive sensor of claim 64 wherein the signature includes movement of an object toward and away from the plurality of electrode rows and electrode columns.~~

~~69. The capacitive sensor of claim 64 wherein the signature includes a flattening of the touch input against the substrate.~~

~~70. The capacitive sensor of claim 64 wherein the signature includes a deflection of the substrate in response to the touch input.~~

16~~71~~. A method comprising:

providing a plurality of electrodes including electrode rows and electrode columns;

measuring the rate of change of the capacitance of at least one of the plurality of electrodes; and

determining the presence of a stimulus based on the measured rate of change.

17~~72~~. The method according to claim 16~~71~~ wherein the measuring step includes:

strobing one of the electrode rows; and

sampling the voltage on an adjacent electrode row.

18~~73~~. The method according to claim 20~~75~~ wherein the measuring step includes:

strobing one of the electrode columns; and

sampling the voltage on an adjacent electrode column.

19~~74~~. The method according to claim 16~~71~~ wherein the measuring step includes:

strobing one of the electrode rows; and

sampling the voltage on at least one of the electrode columns.

20~~75~~. The method according to claim 19~~74~~ wherein the measuring step includes:

strobing one of the electrode columns; and

sampling the voltage on at least one of the electrode rows.

21~~76~~. The method according to claim 16~~71~~ wherein at least two of the electrode rows define a first mutual capacitance, the method further including measuring the rate of change of the first mutual capacitance.

22~~77~~. The method according to claim 21~~76~~ wherein at least two of the electrode columns define a second mutual capacitance, the method further including measuring the rate of change of the second mutual capacitance.

~~78. The method according to claim 71 further including providing a rigid substrate for supporting the plurality of electrode rows on a first side thereof.~~

~~79. The method according to claim 71 further including providing a dielectric material between the electrode rows and the electrode columns.~~

80. The method according to claim 71 wherein the electrode rows and the electrode columns are substantially transparent to visible light.

81. The method according to claim 71 wherein the electrode rows and the electrode columns are substantially translucent to visible light.

82. The method according to claim 71 wherein the electrode rows and the electrode columns are substantially opaque.

83. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit, the capacitive sensing circuit having an output;

measuring a rate of change of the capacitive sensing circuit output;

comparing the measured rate of change against a predetermined rate of change attributable to electromagnetic noise; and

in response to the measured rate of change being less than the predetermined rate of change, determining the presence of a stimulus.

84. The method according to claim 83 wherein the capacitive sensing circuit output is based on the capacitance of a single electrode.

85. The method according to claim 83 wherein the capacitive sensing circuit output is based on the capacitive coupling between a first electrode and a second electrode.

86. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit, the capacitive sensor having an output;

measuring a rate of change of the capacitive sensing circuit output;

comparing the measured rate of change against a predetermined rate of change attributable to environmental variations; and

in response to the measured rate of change being greater than the predetermined rate of change, determining the presence of a stimulus.

87. The method according to claim 86 wherein the capacitive sensing circuit output is based on the capacitance of a single electrode.

88. The method according to claim 86 wherein the capacitive sensing circuit output is based on the capacitive coupling between a first electrode and a second electrode.

89. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit, the capacitive sensing circuit having an output;

measuring a rate of change of the capacitive sensing circuit output; and

comparing the measured rate of change against a predetermined minimum rate of change and against a predetermined maximum rate of change; and

in response to the measured rate of change being between the predetermined minimum and the predetermined maximum, determining the presence of a stimulus.

90. The method according to claim 89 wherein the capacitive sensing circuit output is based on the capacitance of a single electrode.

91. The method according to claim 89 wherein the capacitive sensing circuit output is based on the capacitive coupling between a first electrode and a second electrode.

92. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit defining an output;

measuring a rate of change of the capacitive sensing circuit output; and

determining the presence of a stimulus in response to an increase in the measured rate of change of the capacitive sensing circuit output.

93. The method according to claim 92 wherein the stimulus corresponds to the measured rate of change transitioning from below a lower threshold value to above an upper threshold value.

94. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit defining an output;

measuring a rate of change of the capacitive sensing circuit output; and

determining the presence of a stimulus in response to a decrease in the measured rate of change of the capacitive sensing circuit output.

95. The method according to claim 94 wherein the stimulus corresponds to the measured rate of change transitioning from above an upper threshold value to below a lower threshold value.

96. A method for detecting a stimulus comprising:

providing a capacitive sensing circuit defining an output;

measuring a rate of change of the capacitive sensing circuit output; and

determining the presence of a stimulus in response to a sequential increase and decrease in the measured rate of change of the capacitive sensing circuit output.

97. The method according to claim 96 wherein the capacitive sensing circuit includes a sampling capacitor and at least one of a single electrode and an electrode pairing.

98. A method comprising:

providing a capacitive sensing circuit having an output;

measuring the capacitive sensing circuit output over successive intervals to determine a rate of change of the capacitive sensing circuit output; and

determining a touch signature based on the rate of change of the capacitive sensing circuit output.

99. The method according to claim 98 wherein the capacitive sensing circuit includes a sampling capacitor coupled to at least one of a single electrode and an electrode pairing.

100. The method according to claim 98 wherein the touch signature corresponds to placement of an object proximate to the capacitive sensing circuit.

101. The method according to claim 98 wherein the touch signature corresponds to the fluid movement of an object toward the capacitive sensing circuit.

102. The method according to claim 98 wherein the touch signature corresponds to the staggered movement of an object toward the capacitive sensing circuit.

~~103. The method according to claim 98 wherein the touch signature corresponds to the fluid movement of an object toward and away from the capacitive sensing circuit.~~

~~104. The method according to claim 98 wherein the touch signature corresponds to the staggered movement of an object toward and away from the capacitive sensing circuit.~~

~~105. The method according to claim 98 wherein the capacitive sensor includes first and second electrodes and the determining step includes:~~

~~comparing the capacitance of the first electrode against the capacitance of the second electrode.~~

~~106. The method according to claim 98 wherein the capacitive sensing circuit includes first and second electrodes and the determining step includes:~~

~~comparing the rate of change of capacitance of the first electrode against the rate of change of capacitance of the second electrode.~~

~~107. A capacitive sensor comprising:~~

~~a touch substrate adapted to receive a touch input thereon;~~

~~a sense electrode subjacent the touch substrate; and~~

~~a processing unit electrically coupled to the sense electrode and configured to detect deflection of the substrate in response to a touch input on the touch substrate.~~

~~108. The capacitive sensor of claim 107 further including a rigid substrate spaced apart from the touch substrate.~~

~~109. The capacitive sensor of claim 107 further including a collapsible spacer interposed between the touch substrate and the rigid substrate.~~

~~110. The capacitive sensor of claim 107 further including a substantially rigid spacer interposed between the touch substrate and the rigid substrate.~~

~~111. The capacitive sensor of claim 107 wherein the touch substrate is adapted to flex downwardly toward the rigid substrate.~~

~~112. The capacitive sensor of claim 107 wherein the sense electrode is coupled to the touch substrate.~~

~~113. The capacitive sensor of claim 107 wherein the sense electrode is coupled to the rigid substrate.~~

~~114. The capacitive sensor of claim 107 further including an air gap between the touch substrate and the rigid substrate.~~

~~115. The capacitive sensor of claim 107 wherein the sense electrode is an inner electrode in an electrode pair including an outer electrode.~~

~~116. The capacitive sensor of claim 107 wherein the sense electrode is a column electrode in a two-dimensional electrode matrix.~~

~~117. The capacitive sensor of claim 107 wherein the sense electrode is a row electrode in a two-dimensional electrode matrix.~~

~~118. A capacitive sensor comprising:~~

~~an upper substrate for receipt of a touch input thereon;~~

~~a first and second spaced apart electrodes subjacent the upper substrate;~~

~~a processing unit electrically coupled to the first and second electrodes and configured to detect a touch input based on the capacitance of the first and second electrodes; and~~

~~a haptics driver coupled to the first and second electrodes, the haptics driver being operable to induce an electrostatic force between the first and second electrodes to vibrate the upper substrate in response to a touch input detected by the processing unit.~~

~~119. The capacitive sensor of claim 118 wherein the processing unit and the haptics driver comprise a single integrated circuit.~~

~~120. The capacitive sensor of claim 118 wherein the processing unit and the haptics driver comprise a single micro-controller.~~

~~121. The capacitive sensor of claim 118 further including a lower substrate supporting the second electrode thereon.~~

~~122. The capacitive sensor of claim 121 wherein the upper and lower substrates are substantially rigid.~~

~~123. The capacitive sensor of claim 118 wherein:~~

~~the first electrode includes a plurality of electrode rows; and~~

~~the second electrode includes a plurality of electrode columns.~~

~~124. The capacitive sensor of claim 118 wherein the processing unit includes a time domain differential sensing circuit.~~

~~125. An apparatus comprising:~~

~~an optical sensor having an output; and~~

~~a processing unit electrically coupled to the optical sensor, wherein the processing unit is adapted to determine a rate of change of the optical sensor output to indicate the presence of an object in proximity to the optical sensor.~~

~~126. The apparatus of claim 125 further including a first light emitting diode operable to illuminate the object in proximity to the optical sensor.~~

~~127. The apparatus of claim 126 further including a second light emitting diode operable to illuminate the object in proximity to the optical sensor.~~

~~128. The apparatus of claim 127 wherein the first and second light emitting diodes are fixed in relation to the optical sensor.~~

~~129. The apparatus of claim 125 wherein determining a rate of change of the optical sensor output is in response to the optical sensor output achieving a predetermined criteria.~~

~~130. The apparatus of claim 125 wherein the processing unit is further adapted to determine the object is stationary relative to the optical sensor in response to the measured rate of change of the optical sensor output being substantially zero.~~

~~131. The apparatus of claim 125 wherein the processing unit is further adapted to determine the object is moving relative to the optical sensor in response to the measured rate of change of the optical sensor output being substantially non-zero.~~

~~132. The apparatus of claim 125 further including a capacitive touch member fixed in relation to the optical sensor to receive a touch input thereon.~~