as parts of the monolithic structure by means of a double-silicon-on-insulator process developed at NASA's Jet Propulsion Laboratory. The tops of the bundles of carbon nanotubes would lie below the plane of the tops of the gate electrodes. The particular choice of shapes, dimensions, and relative positions of the electrodes and bundles of carbon nanotubes would provide for both field emission of electrons from the bundles of carbon nanotubes and control of the electron current to obtain the inverse majority function, as described next.

The application of a positive bias potential to the anode would cause emission of electrons from the bundles of carbon nanotubes and, if no bias potential were applied to the gate electrodes, the electrons would travel to the anode, giving rise to an anode current. Relative to the anode, the gate electrodes would be much closer to the bundles of carbon nanotubes, such that the application of a smaller positive bias potential to a gate electrode would suffice to divert, to that electrode, the electrons emitted by the adjacent bundles of carbon nanotubes.

If the positive bias potential were not applied to another gate electrode, then the anode would continue to draw an electron current from the bundles of carbon nanotubes not adjacent to the positively biased gate electrode. However, if the positive bias potential were applied to any two or all three of the gate electrodes, then all of the electrons emitted by all the bundles of carbon nanotubes would be diverted to the positively biased gate electrodes, causing the anode current to fall to zero. In terms of binary logic, if one regards nonzero anode current as representing output state 1, zero anode current as representing output state 0, positive gate-electrode bias as representing input state 1, and zero gate-electrode bias as representing input state 0, then logical 0 inputs to two or all three of gate terminals would result in output of logical 1, and logical 1 inputs to two or all three of the gate terminals would result in output of logical 0. This relationship among input and output states constitutes a NAND and a NOR gate combination. This is the inverse majority function.

This work was done by Harish Manohara and Mohammad Mojarradi of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Reduced-Order Kalman Filtering for Processing Relative Measurements

A Kalman filter can be propagated using fewer computations.

NASA's Jet Propulsion Laboratory, Pasadena, California

A study in Kalman-filter theory has led to a method of processing relative measurements to estimate the current state of a physical system, using less computation than has previously been thought necessary. As used here, "relative measurements" signifies measurements that yield information on the relationship between a later and an earlier state of the system. An important example of relative measurements arises in computer vision: Information on relative motion is extracted by comparing images taken at two different times.

Relative measurements do not directly fit into standard Kalman filter theory, in which measurements are restricted to those indicative of only the current state of the system. One approach heretofore followed in utilizing relative measurements in Kalman filtering, denoted state augmentation, involves augmenting the state of the system at the earlier of two time instants and then propagating the state to the later time instant. While state augmentation is conceptually simple, it can also be computationally prohibitive because it doubles the number of states in the Kalman filter.

In many practical applications, relative measurements are not functions of entire earlier states but rather may be a function of only a subset of elements of the earlier state. A relative measurement that can be thus characterized is denoted a partial relative measurement. For example, in computer vision, relative-measurement information is usually a function of position rather than velocity, acceleration, or other elements of the state.

When processing a relative measurement, if one were to follow the state-augmentation approach as practiced heretofore, one would find it necessary to propagate the full augmented state Kalman filter from the earlier time to the later time and then select out the reduced-order components. The main result of the study reported here is proof of a property called reduced-order equivalence (ROE). The main consequence of ROE is that it is not necessary to augment with the full state, but, rather, only the portion of the state that is explicitly used in the partial relative measurement. In other words, it suffices to select the reduced-order components first and then propagate the partial augmented state Kalman filter from the earlier time to the later time; the amount of computation needed to do this can be substantially less than that needed for propagating the full augmented Kalman state filter.

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