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The first successful application was the American Jet Propulsion Laboratory (JPL). They used image processing techniques such as geometric correction, gradation transformation, noise removal, etc. on the thousands of lunar photos sent back by the Space Detector Ranger 7 in 1964, taking into account the position of the sun and the environment of the moon. The impact of the successful mapping of the moon's surface map by the computer has been a huge success. Later, more complex image processing was performed on the nearly 100,000 photos sent back by the spacecraft, so that the topographic map, color map and panoramic mosaic of the moon were obtained, which achieved extraordinary results and laid a solid foundation for human landing on the moon.[4] The cost of processing was fairly high, however, with the computing equipment of that era. That changed in the 1970s, when digital image processing proliferated as cheaper computers and dedicated hardware became available. This led to images being processed in real-time, for some dedicated problems such as television standards conversion. As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and computer-intensive operations. With the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing, and is generally used because it is not only the most versatile method, but also the cheapest. Image sensors Main article: Image sensor The basis for modern image sensors is metal-oxide-semiconductor (MOS) technology,[5] which originates from the invention of the MOSFET (MOS field-effect transistor) by Mohamed M. Atalla and Dawon Kahng at Bell Labs in 1959.[6] This led to the development of digital semiconductor image sensors, including the charge-coupled device (CCD) and later the CMOS sensor.[5] The charge-coupled device was invented by Willard S. Boyle and George E. Smith at Bell Labs in 1969.[7] While researching MOS technology, they realized that an electric charge was the analogy of the magnetic bubble and that it could be stored on a tiny MOS capacitor. As it was fairly straightforward to fabricate a series of MOS capacitors in a row, they connected a suitable voltage to them so that the charge could be stepped along from one to the next.[5] The CCD is a semiconductor circuit that was later used in the first digital video cameras for television broadcasting.[8] The NMOS active-pixel sensor (APS) was invented by Olympus in Japan during the mid-1980s. This was enabled by advances in MOS semiconductor device fabrication, with MOSFET scaling reaching smaller micron and then sub-micron levels.[9][10] The NMOS APS was fabricated by Tsutomu Nakamura's team at Olympus in 1985.[11] The CMOS active-pixel sensor (CMOS sensor) was later developed by Eric Fossum's team at the NASA Jet Propulsion Laboratory in 1993.[12] By 2007, sales of CMOS sensors had surpassed CCD sensors.[13] Image compression Main article: Image compression An important development in digital image compression technology was the discrete cosine transform (DCT), a lossy compression technique first proposed by Nasir Ahmed in 1972.[14] DCT compression became the basis for JPEG, which was introduced by the Joint Photographic Experts Group in 1992.[15] JPEG compresses images down to much smaller file sizes, and has become the most widely used image file format on the Internet.[16] Its highly efficient DCT compression algorithm was largely responsible for the wide proliferation of digital images and digital photos,[17] with several billion JPEG images produced every day as of 2015.[18] Digital signal processor (DSP) Main article: Digital signal processor Electronic signal processing was revolutionized by the wide adoption of MOS technology in the 1970s.[19] MOS integrated circuit technology was the basis for the first single-chip microprocessors and microcontrollers in the early 1970s,[20] and then the first single-chip digital signal processor (DSP) chips in the late 1970s.[21][22] DSP chips have since been widely used in digital image processing.[21] The discrete cosine transform (DCT) image compression algorithm has been widely implemented in DSP chips, with many companies developing DSP chips based on DCT technology. DCTs are widely used for encoding, decoding, video coding, audio coding, multiplexing, control signals, signaling, analog-to-digital conversion, formatting luminance and color differences, and color formats such as YUV444 and YUV411. DCTs are also used for encoding operations such as motion estimation, motion compensation, inter-frame prediction, quantization, perceptual weighting, entropy encoding, variable encoding, and motion vectors, and decoding operations such as the inverse operation between different color formats (YIQ, YUV and RGB) for display purposes. DCTs are also commonly used for high-definition television (HDTV) encoder/decoder chips.[23] Medical imaging Further information: Medical imaging In 1972, the engineer from British company EMI Housfield invented the X-ray computed tomography device for head diagnosis, which is what is usually called CT (computer tomography). 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