A New Mode of Interaction to Explore All-sky Maps in Multiple Wavelengths

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To cite this article:

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Article Info	Abstract
	As the Museums and Interactivity-oriented Science Centres of the world are reinventing themselves more as creators of culture than just conservators of culture, they are getting keener to explore how various data retrieval and HCI technologies can symbiotically fit into the methods of museology. Museums, since their advent, have used spatial and temporal scanning to present stories that evolve either over time or through space. But these have always remained static timelines that are limited in content, lack interactive exploration, and miss any metaphorical interaction that allows one to have the experience of physically scanning a space or a timeline. In this work, we report how a new HCI technology was used to retrieve all-sky map data and present the multi-wavelength view of the universe to the uninitiated visitor having no skill to navigate through sophisticated astronomy instruments. We describe an intuitive interface that takes no training and learning for the visitors to operate. They can start analyzing multi-wavelength all-sky maps of our galaxy in no time – exactly as professional astronomers do. Stressing upon the ease of usability, reliability of data, and fail-safe operation, visitors are given access to additional layers of information that can be presented in myriad options chosen by the visitor. They can compare thin slices of galactic images in various wavelengths and look for essential radiation sources that are otherwise not apparent in the naked eye or simple optical observations. The public exhibit was based on duplex data communication between a computer and a PIC microprocessor controller using IEEE 1284 parallel port in ECP mode thus making it a generic technology for interactive displays

Introduction

Museums have been a suitable domain of study and design intervention for Human-Computer Interaction (HCI) for several decades. However, conscious study or development of generic technology in the HCI for Museums is rare. Hence, we present this system developed in the National Council of Science Museums, India that embodies Tangible User Interfaces (Ishii and Ullmer, 1997, 2000) and Tangible Interaction system (Hornecker and Buur, 2006) wherein the user interacts with a digital system by manipulating physical, tangible and digitally enhanced object as interface element.

The motivation for developing the exhibit 'Multiview-Universe' came from the urge to interactively communicate how astronomers use images and visualization techniques for studying the actual shape and character of the galaxy with an eye for the detail of manifold constituent objects in it. However, in the process of development of the technology the authors felt that development of a generic scheme of technology is possible that can present a whole class of problems in museum settings.

The specific problem was to make the Museum or Science Centre visitors understand that now we have a new window and dimension for us to observe and depict the two-dimensional sky. We can regard the electromagnetic spectrum as a third observable dimension as shown in figure 1(b) addition to the coordinates on the 2D Celestial sphere. Astrophysical objects have widely varied physical characteristics, and they manifest themselves in enormously different signatures in their electromagnetic emission features, intensities, and wavelengths. A given astrophysical object can be invisible in one wavelength range and while shining brilliantly in another. These interesting phenomena provide astronomers with significant hints about the origin, history, and behavior of astrophysical objects and materials. However, while developing this particular tangible HCI, we realized that the technology to be used is a generic problem solver that is tantamount to linear high-resolution scanning of a background in a spatial or temporal scale and presenting context-sensitive data contextually connected to the relative position of a marker on that scale.

The National Council of Science Museums recognized the issue of astronomical presentation long back. Even when astronomical objects are visible in different wavelengths, their brightness and shape vary in different wavelengths. Earlier this used to be presented through simple slides – one for each wavelength. But this new technique presented here uses dynamic scanning controlled by the visitor, which is far more engaging.

As of now, representing multi-wavelength data typically involves creating false-color images and comparing them side-by-side to search for significant features and their correlations. Since data with different wavelengths are produced by different research groups, a variety of color map schemes and different data mappings are applied to the raw data, where the raw data themselves are recorded in a variety of incompatible formats and units from different detector technologies. The differences make them unsuitable for visual comparison. In addition, with recent advances in measurement technology, both the quality and the quantity of all-sky surveys are on uptick; the most recent survey data have higher angular precision, a wider range and precision of wavelengths (Li, Fu & Hanson, 2008), and higher dynamic range .

Some very famous survey data contain stunningly beautiful images of our galaxy – the Milky Way, each covering a specific frequency band. These multispectral image data are so informative and visually attractive that they appeared to be appropriate items to be scientifically presented to the students and general people interested in astronomy. So, we investigated more efficient and effective visualization technique that is easy to operate, yet, helpful to form profound understanding.

The challenge in creating this museum technology was the fact that HCI had to adopt simplest operative technique that demands no learning time and matches the purpose of scanning over space metaphorically.
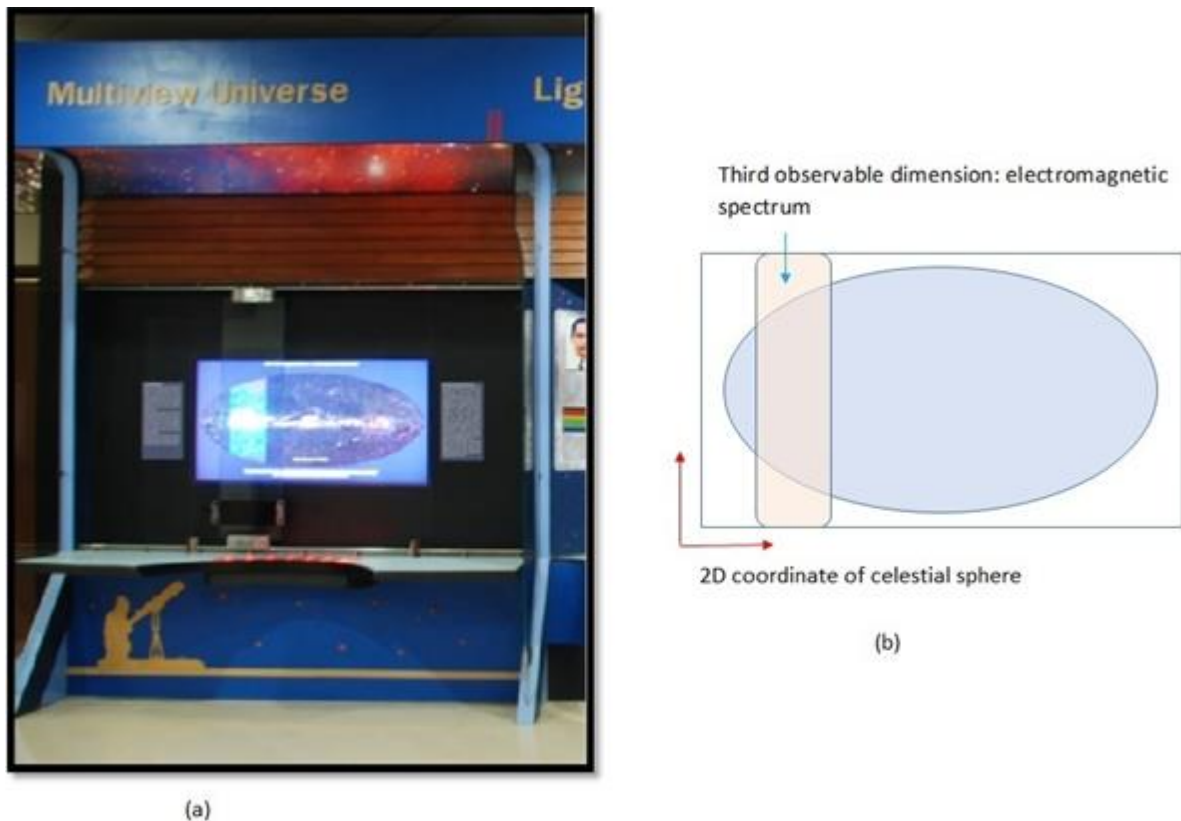
Mutiview Universe- The Exhibit

Figure 1. Multiview Universe: (a) Exhibit installed in the Astronomy gallery Nehru Planetarium, Delhi (b) HCI Based Observable Content Display

The exhibit developed is shown in Figure. 1, through its interfaces visitors can select, superpose, compare and analyze features revealed in 'false color' images of our galaxy photographed in different selected wavelength ranges by different specialized Telescopes. When the visitor approaches the exhibit, she notices a big all-sky map of our galaxy made from the image shot in the optical wavelength range. It is displayed in a large 65" LCD flat panel display. Visitors have access to a set of seven 'range-selection' switches on the front panel of the exhibit and one can move, on guided rails, a transparent slider put in front of the large display.

The galaxy, in general, is seen in optical wavelength. But, a slice of the image that is seen through the transparent glass slider is seen in another wavelength range which is selectable by the visitor. Considering that she has pressed the Radio continuum button, the sliced part of the all-sky map will show how the galaxy Milky Way looks like at that part seen in Radio wave of appropriate range. Rest of the image, however, still remains visible in optical range. Now, as the visitor moves the slider, the 'selected wavelength' view also follows the slider such that the slice seen through the slider immediately transforms and represents the galaxy observable in the wavelength range of choice.

Keeping the background in optical range and selecting any superposing range from the seven given options (Radio Continuum, 408 MHz; Molecular Hydrogen, 115 GHz; Infrared, 12, 60, 100 µm; Near Infrared, 1.25, 2.25, 3.5

μm; X-Ray, 0.25, 0.75, 1.5 KeV; Gamma Ray > 100 MeV; Cosmic Microwave background, COBE) the visitor can find out how the view of the galaxy changes in the selected wavelength. So, some objects that radiate only in the selected wavelength range come up, while those who does not radiate strongly in that range will become invisible. This enables the visitor to analyze, minutely, what is changing in the view and by how much intensity when the wavelength selection is changed at a particular location of the map. The UI here offers the visitor the choice of varying two independent parameters –one, selected range of wavelength and the other, smooth variation over different regions of the full-sky image of the galaxy. It follows exactly the earlier proposition of adding another dimension to scan the all-sky map in 2D image representation.

Working Principle and Design Details

In a way, human vision is color blind. We're color blind to wavelengths like ultraviolet and infrared, we're color blind to X-rays. But we can build instruments and sensors that are sensitive to these colors of EM wave and represent the data in a visual way that we can still interpret. This is where false-color imaging comes in.

In the first encounter with deep sky objects seen through a telescope, any observer would be shocked to see that everything is black and white and the beautifully colored images of galaxies and nebulae are missing. But one has to understand that these colored images featuring in our books are not real. They are called 'False Colour' images wherein the intensity of radiation in a particular range is represented using an artificial color-shade following a norm. Part of why we don't see colors in astronomical objects through a telescope is that our eye is not sensitive to colors when what we are looking at is faint. So, we need to enhance the colors for 'seeing' features that are present in them.The practice started when Radio Astronomers started interpreting their captured images accordingly. Radio waves are not seen by the naked eye. So, Radio Astronomers used to take photographs of their targets and they appeared on photograph as 'shades of grey' – ranging from pure black to pure white. They assigned red to the most intense radio emission and blue to the least intense emission recorded on the image. Intermediate colors got their places accordingly – so orange, yellow, and green were assigned to the intermediate levels of radio intensity. But human eyes can distinguish only 16 shades of grey visually. So, a better UI demands that if we can map 16 million colors with varied range of intensities, we can see extreme details in an image that we would miss otherwise.

For the optically visible objects if the objects were much brighter, we would indeed see them in color through telescope. However, the still photo wouldn't necessarily be the same colors we see in the images, because most images are indeed 'false color'. But what the false color means really depends on the data in question. What wavelengths an image represents depends on what filter that was being used (if any) when the image was taken, and the sensitivity of the detector (e.g., CCD) being used. So, different images of the same object may look very different. In our exhibit we chose maps of the Milky Way Galaxy representing the galaxy in seven wavelength (color) regions as shown in Figure 2 above.Even though, in actual exhibit, we have used high resolution versions of each image separately, here we present a combined view for space constraint and easier comparison of the scenarios.
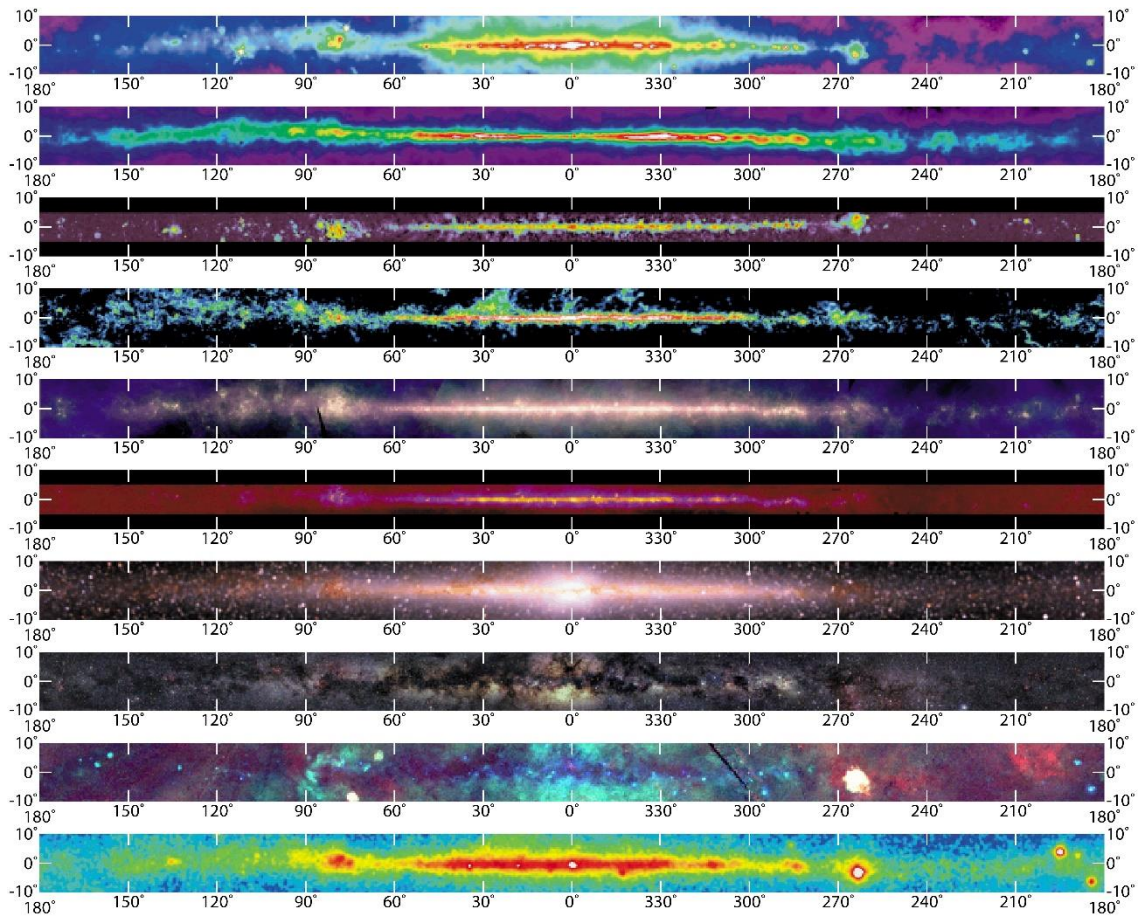
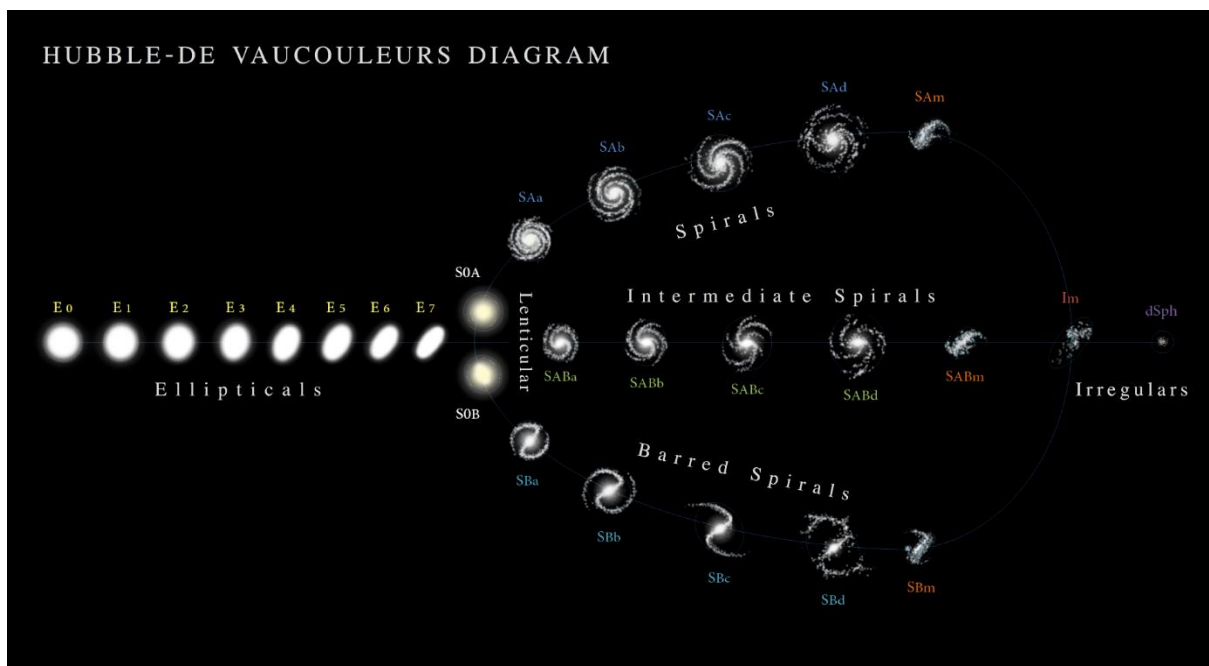Figure 2. Combined View of Multi-wavelength Galactic Map

Figure. 3. Hubble - de Vaucouleurs Diagram for galaxy Morphology Featuring Ellipticals, Lenticulars, Spirals, Intermediate Spirals, Barred Spirals And Irregulars. Antonio Ciccolella/M. De Leo –

The Milky Way Galaxy is generally considered an SBc-type galaxy Figure. 3 (Wikimedia Commons ,

2011),where the SB represents Spiral Barred and the c is a subclass among the o, b and c type. In SBc galaxies, both the arms and the bar are highly resolved into star clouds and stellar associations. The arms are open in form and can start either at the ends of the bar or tangent to a ring. The Milky Way has a central bulge of stars and spiral arms of gas and stars in a disk (What was new at the NSSDC? (n.d.-b);Multiwavelength All-Sky Images. (n.d.);Radio Continuum images.(n.d);Reich, Fürst, Reich, & Reif, 1990;Hartmann & Burton,1997; Dame, Hartmann & Thaddeus,2001;Wheelock, Gautier, Chillemi, Kester, McCallon, Oken, & Good, 1994;Hauser, Kelsall, Leisawitz, & Weiland,1998;Snowden, Egger, Freyberg, McCammon, Plucinsky,Sanders, & Voges,1997;Esposito, Bertsch, Chen, Dingus, Fichtel, Hartman,& Willis,1999; Multiwavelength astronomy. (n.d.)).

To incorporate authentic dataset, we chose the images from the Multi Wavelength Milky Way (MWMW) project's Education Section "intended primarily for use by educators, students, and the general public." The digital artefacts displayed in this exhibit are maps of the Milky Way galaxy at ten wavelength regions. The maps show the central part of Milky Way galaxy in a band extending from 10° north to 10° south of the Galactic plane. Following description of the images is also taken from the Multi Wavelength Milky Way (MWMW) Education page of NASA and reproduced as is for accuracy and compliance (Multiwavelength All-Sky Images. (n.d.); Multiwavelength astronomy. (n.d.)) Use of the Multi Wavelength Milky Way (MWMW) is demonstrative. Any set of images can be loaded into the system and compared for features. For example we can load the images of Crab Nebula Figure 4 (Multiwavelength astronomy. (n.d.)), for comparing features.
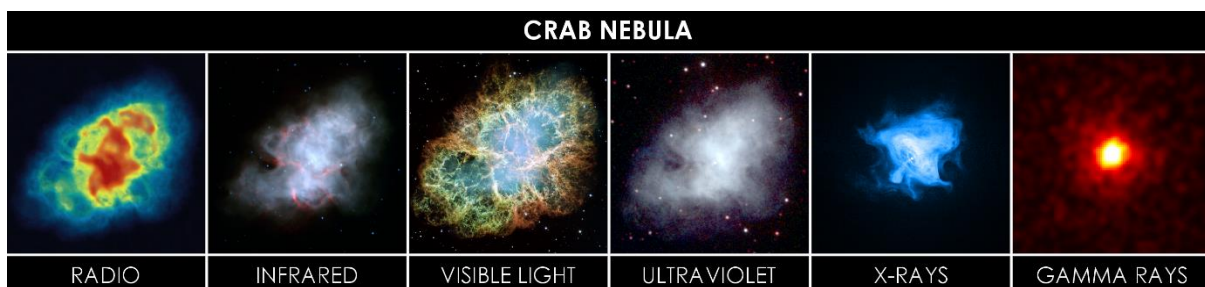

Figure 4. Optical – Crab Nebula in multi wavelength

The Radio image reveals a bright white spot that is the core of the star that collapsed into a neutron star and this event gave birth to this nebula. In the infrared image the blue-white region is emitted by a cloud of energetic electrons that are trapped in the pulsar's magnetic field. The red features follow the nebula's filaments. The blue core of the nebula in optical view comes from electrons within the nebula that are deflected and accelerated by the magnetic field of the central neutron star. The UV image shows a nebula little bigger than the X-ray nebula. That means that the slower electrons stretch a little more than the hot electrons responsible for X-ray emissions (Multiwavelength astronomy. (n.d.)). With reference to the galactic coordinates shown in Figure 2, similar comparison of the galactic features is possible.

Anyway, it is understood that studying these features are easier when they are overlayed as in our system than they are presented as frames either aligned horizontally as in Figure 4 or vertically as is customary in standard educational set up. While this method is tedious, the advanced image comparison via image processing (Misra,

Mishra & Appasani, 2018) and photometry are time intensive. But while our system facilitates a first level visual inspection and feature identification, Image Processing systems (Misra, Mishra & Appasani, 2018) or even other advanced methods like advanced STSDAS (Space Telescope Science Data Analysis System), StarLink Project etc. Much improve the analytical pipeline.

i)   Optical. Visible light photomosaic taken with a very wide-field camera at northern and southern observatories.

Figure 5. Optical – Milky Way

ii)   Radio Continuum (408 MHz). Radio continuum emission from surveys with ground-based radio telescopes (Jodrell Bank MkI and MkIA, Bonn 100 meter, and Parkes 64 meter).
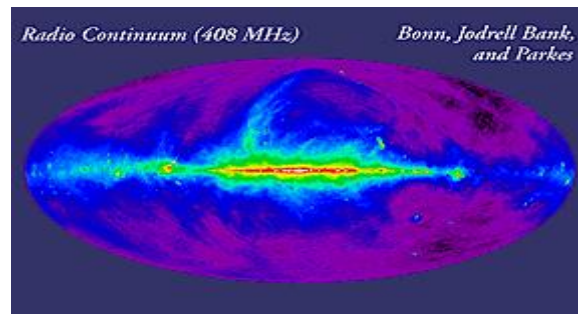

Figure 6. Radio Continuum (408 MHz) – Milky Way

iii)   Atomic Hydrogen. From radio surveys of the 21-cm transition of hydrogen. The data are a composite of several surveys with ground-based telescopes in the northern and southern hemispheres.
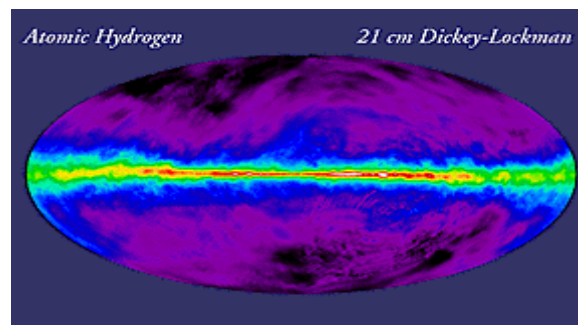

Figure 7. Atomic Hydrogen – Milky Way

iv)   Molecular Hydrogen. The data shown here are a composite of surveys taken with twin 1.2-m millimeter-wave telescopes, one in New York City and the other on Cerro Tololo in Chile.
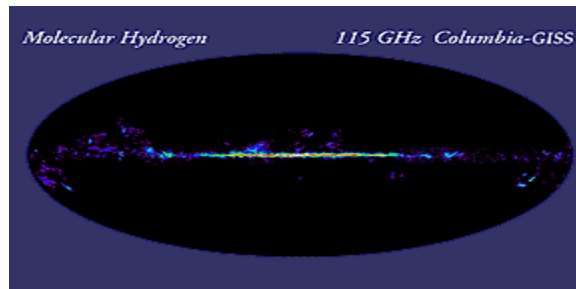

Figure 8. Molecular Hydrogen – Milky Way

v)   Infrared. Composite of mid and far-infrared images taken by the Infrared Astronomical Satellite (IRAS) in 12-, 60-, and 100-micron wavelength bands.
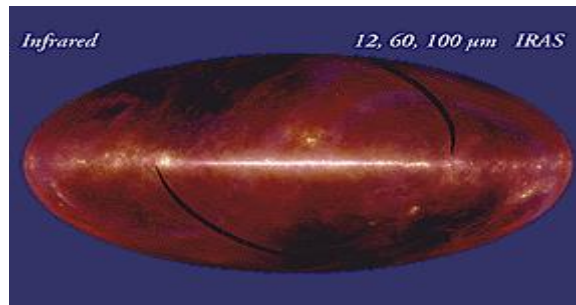

Figure 9. Infrared – Milky Way

vi)   Near Infrared. Composite near-infrared signals observed by the Diffuse Infrared Background Experiment (DIRBE) instrument on the Cosmic Background Explorer (COBE) in the 1.25-, 2.2-, and 3.5-micron wavelength bands.
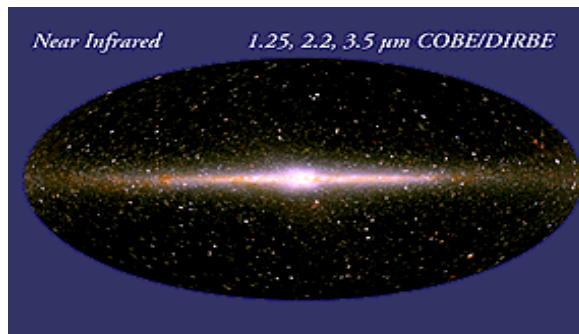

Figure 10. Near Infrared – Milky Way

vii)   X-Ray. Composite X-ray signals observations by an instrument on the Roentgen Satellite (ROSAT) in three broad, X-ray bands centered at 0.25 keV, 0.75 keV, and 1.5 keV.
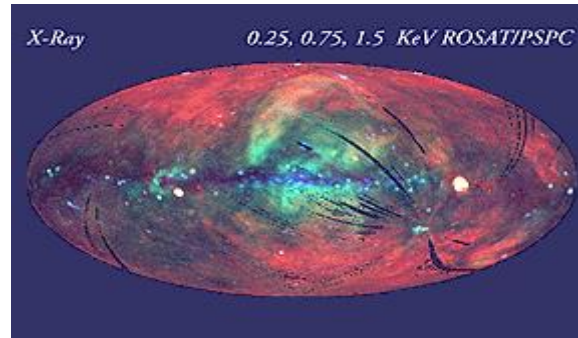
Figure 11. X-ray – Milky Way

viii)   Gamma Ray. Signals of high-energy gamma-ray emission observed by the Energetic Gamma-Ray Experiment Telescope (EGRET) instrument on the Compton Gamma-Ray Observatory (CGRO).
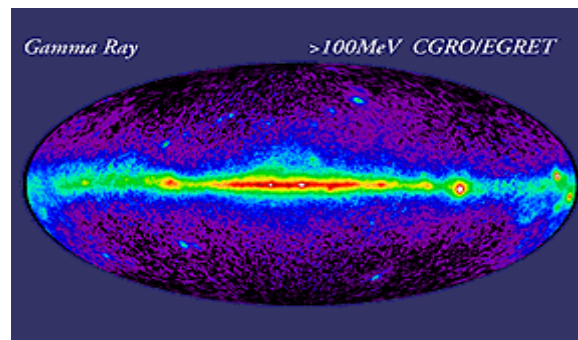
Figure 12. Gamma Ray – Milky Way

These chosen digital artefacts, rendered to proper dimensions (1920 x 1080 pixels), were stored in computer secondary storage. An application package (Multiview - Universe) was developed in Microsoft Visual Basic 2008 (.NET) platform so that all component units of the exhibit shown in Figure 4 are coordinated and controlled through this application. The PIC unit communicates with the computer through IEEE 1284 parallel port in ECP mode such that the application can either read the data supplied by the PIC unit or it may write data to the same unit.

Figure 13. Schematic Arrangement of Data Flow within Components of the Exhibit Multiview Universe

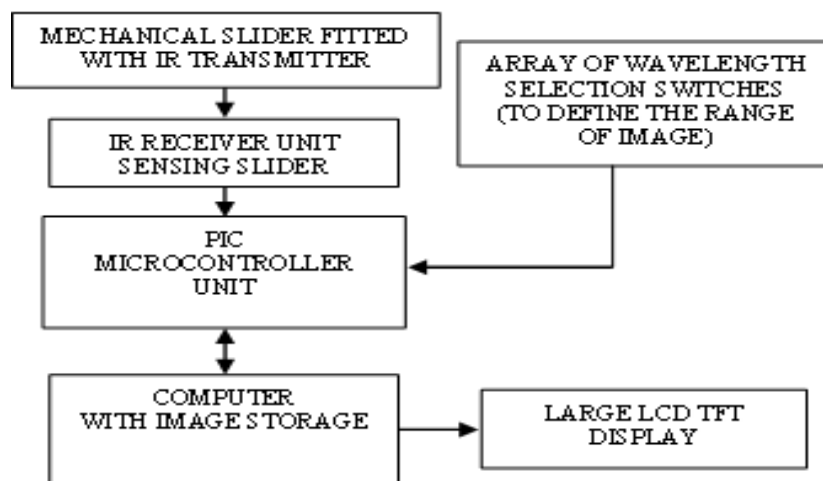The computer sends image data to the display through DVI-D port. At such resolutions, or even in a higher resolution, comparison by juxtaposition is not a good method as at the scale of the Milky Way to spot same object in multiple wavelengths demands that we exactly superpose them with exact matching of the superimposed images by their registration points. This may be considered an improvement over the methods described in (Lobo, Pietriga & Appert, 2015; Hornecker & Buur, 2006). For map comparison, Human-Computer Interaction researchers focus on how users interact with maps such as, e.g., techniques to select specific items in dense sets, techniques to visualize off-screen content, and techniques to navigate more efficiently in both space and scale. This method help in all these counts.

Circuit Description

The architecture shown in Figure 14 was designed considering simplicity and ease of maintenance. There are three functional blocks:
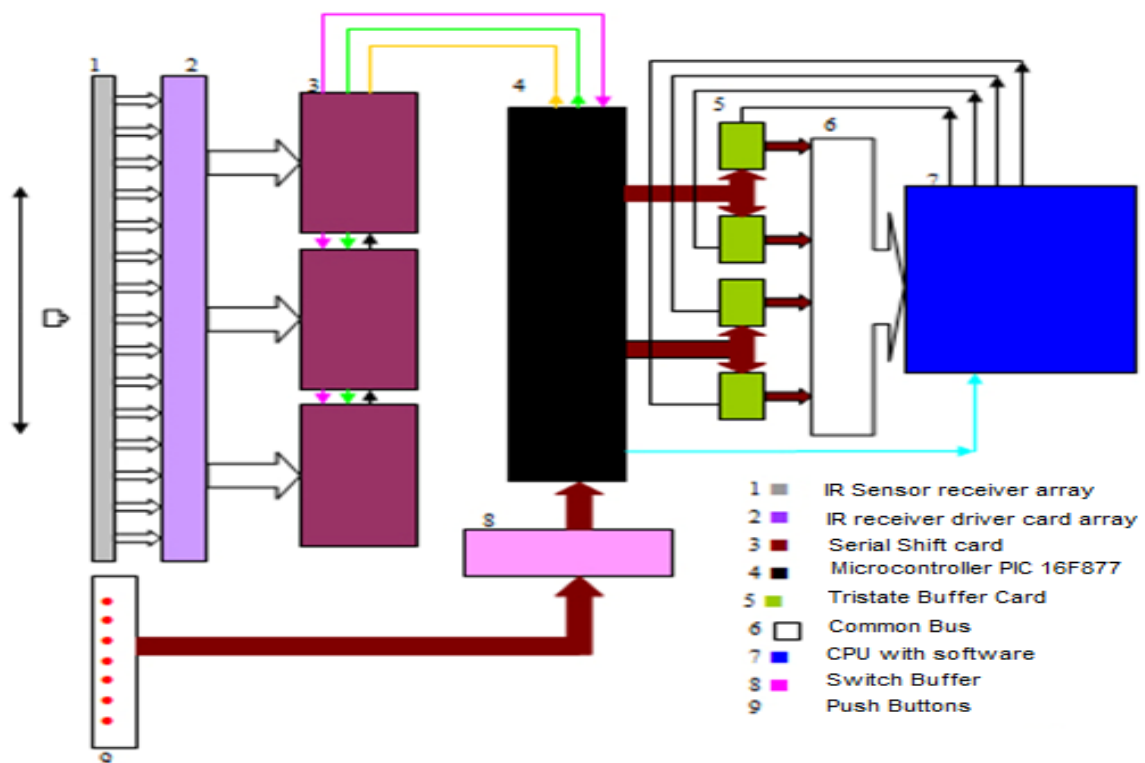
Figure 14. Block Diagram of the Multi-View System Architecture

Sensor and its driver

The Sensor array block is the sensing block which senses the signal from the IR transmitter. There is a linear array of 120 IR receivers and output of each receiver is connected to its corresponding driver. Whenever the transmitter is positioned in front of any of the 120 IR receivers, the receiver senses its position and output of the respective receiver is set high which subsequently sets the output of its driver at high as well.

Logic Circuit and Microcontroller

a.   Serial shift register block: Each of the receiver output, via respective driver, is connected to the input of serial shift registers array. The array of serial shift register stores the value at its input pin and thus the momentary scanned data gets stored.

b.   Microcontroller block: It controls the overall operation by sending Shift/load, clock pulse and end of conversion signal. Microcontroller sends out pulse to the shift/load pin of the serial shift register which results in loading of the value at the input pin of serial shift register. After certain delay, microcontroller sends out 120(no of receivers) clock pulse to the clock input of serial shift register to shift out the values stored in shift register. Microcontroller sends out the binary value of the corresponding clock count out of 120 at which it receives a high value at the serial out pin and also sends-out end of conversion signal.

c.   Tristate buffer: Four tri-state ICs have been used. Each IC, when enabled, places a nibble onto the data bus, which is 4-bit wide.

Computer and its Software

The computer senses end of conversion signal and sends out two pulses in sequence to enable tri-state IC 74125, and it reads the upper nibble and Lower nibble of data byte from the microcontroller, which corresponds to the transmitter position. Thus, the computer reads the transmitter position and, since this is attached with the glass slider, it represents the glass slider position as well (centre line is considered as its position). Once again sending two pulses in sequence to the other two set of tristate buffer IC 74125, the computer reads the upper nibble and Lower nibble corresponding to the data representing the selected wavelength. Algorithm of the Multi-View application process is shown in the flowchart Figure 15.
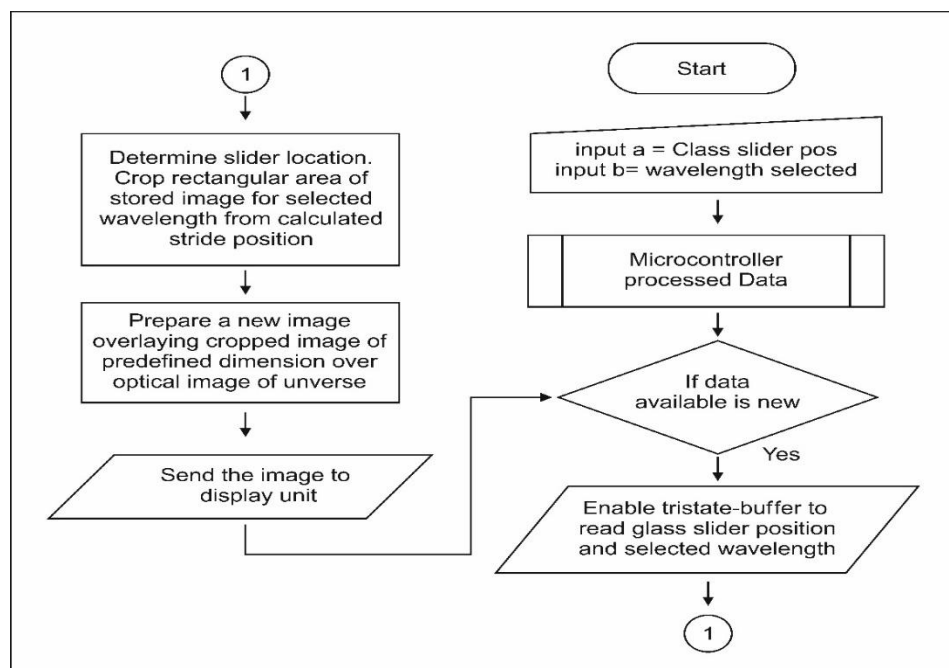

Figure 15 Algorithm of the Multi-View Application

The image manipulation module of the application checks the selected-wavelength image and slices out an image part of appropriate dimension from it, which it sends to the display superposing the same on the base optical image, positioning it exactly where the glass slider is. Even when the slider is moved faster by the visitor, the processing speed and its subsequent display time lag is taken care of by the following strategy to ensure smooth movement of the selected view of the image in sync with the speed of the movement of the slider.

The image manipulation module is pivoted primarily on four algorithmic constructs:

a.   The Bitmap cropping module: The module declares an empty bitmap object and another bitmap object with reference to the selected- bitmap image (selected-wavelength image that is). It scoops out a section of the same width as the width of the slider out of the selected-wavelength image and assigns the rectangle reference to the empty bitmap. The bitmap object referring to the rectangle is returned to any calling module.

b.   The wavelength data reading module: The module scans the Printer port to check if the seventh bit is high. If so, it writes a binary string 1111 1011which enables data reading from the status port, the number read is converted to a binary string and, by masking non-relevant pins, only S3, S4, S5& S6 bit positions are read as the LSB of the wavelength selection. Similarly, sending 1111 0111 to the data port pins and masking out other pins but the S3, S4, S5& S6, the MSB of the wavelength selection, switch is read. These two are concatenated and converted to decimal to deduce the wavelength selection.
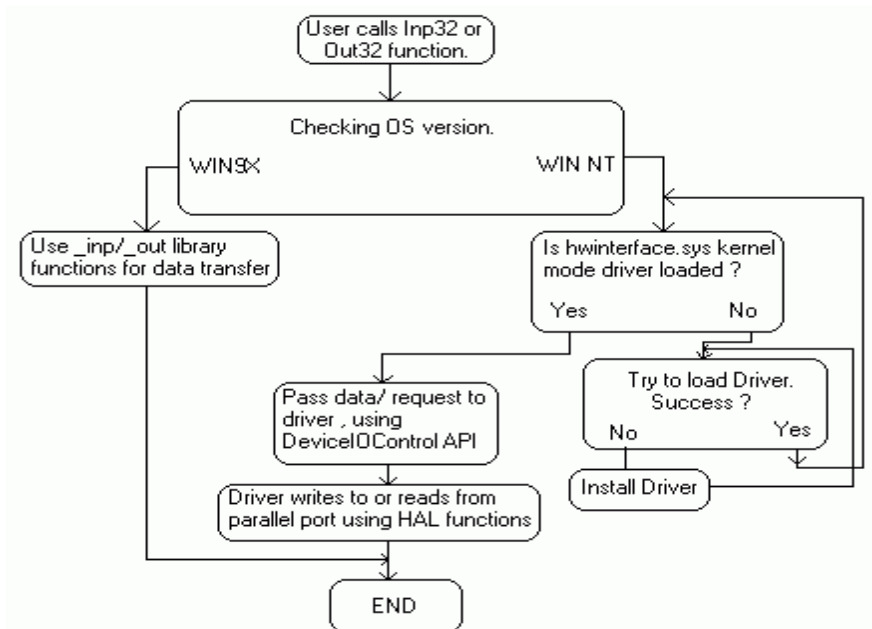
Figure 16. Inpout32 DLL Flow

c.   The position data reading module: Employing the same technique as elaborated in the previous module, the PIC system is made to return the LSB and MSB of the position data by sending two strings 1111 1110 and 1111 1101 respectively. These are read and concatenated to return the slider position.

d.   The timer module: A precision timer module was developed to fire every millisecond. This module read slider position and switch selection every millisecond and changed spectrum image of the chosen wavelength and aligned the sliced overlay image with glass slider position as and when the slider changed. Reading from Status

pins of IEEE 1284 and writing to the data pins of the same port was accomplished through creating an object with invocation of the inout32.dll for Windows XP distributed by logix4u. This dynamic link library works according to the flow diagram Figure 15. The '.dll' user interface consists of the following functions that are called at convenience from the user code once the object is declared in .NET code:

i.   Inp32(), reads data from a specified parallel port register.

ii.   Out32(), writes data to specified parallel port register.

iii.   DllMain (), called when dll is loaded or unloaded. When the .dll is loaded, it checks the OS version and loads hwinterface.sys if needed.

iv.   Closedriver (), close the opened driver handle. Called before unloading the driver.

v.   Opendriver (), open a handle to hwinterface driver.

vi.   Inst () , Extract 'hwinterface.sys' from binary resource to 'systemroot\drivers' directory and creates a service. This function is called when 'Opendriver' function fails to open a valid handle to 'hwinterface' service.

vii.   Start (), starts the hwinterface service using Service Control Manager APIs.

viii.   SystemVersion() Checks the OS version and returns appropriate code.

Adoption of the HCI as Generic Museum Technology

Traditional museums have played an important role in making connections between different objects across time and space. Future museums will continue to build on this, adding multiple layers of meaning and placing greater emphasis on brokering different perspectives. In doing so, networks of objects and subjects, story narratives, themes and metaphors will become important. Metaphors are useful to illustrate complex ideas. Unfortunately, there is not yet any 'best practice', nor are there many published studies on metaphor use in museums. One recent study sought to examine metaphor use in text labels in museums to further mindful theories and future quantitative data collection but while developing this technology, the authors felt that technology and metaphors can form a great effective synergy for the museums.

This paper attempted to bring in basis of Human Computer Interaction on technique of false colour rendering used in the interpretation of the data of all-sky galaxy viewed through different wavelength to an easier understanding for general visitor. However, the same technology can be used to present a generic class of stories always necessary for the narratives used in the museums. The technology used here can be used to present a metaphor that the visitor is scanning through a scale of time, space or thematic flow of subjects and consuming information (rendered into stories) anchored on the contextual position of the scale. Y understanding the idea that this information-seeker technology can metaphorically harness information related to temporal or spatial evolution, we in the National Council of Science Museums have developed several technologies where the hardware varied but the scheme of HCI presentation remained the same. For example, in the Regional Science Centre Kottayam, the following exhibit scans over different milestones in Digital Transformation Trends observed over the recent In this narrative the metaphor is discrete and hence in the underlying technology, we popularly call "visual seeker", the resolution of scanning is kept coarse (10 points of transition). However, in the Multiview technology the resolution of the marker movement is 2mm. To have even better resolution a color metrology-based technology was developed and patented by NCSM [1162/KOL/2014 (Color Metrology)]

In public display system users value convenience and layered information access as critical factors. A presentation system is always coveted wherein user or viewer would be able to grasp the overview right away and then, by themselves, explore and experience cascades of text, pictures, motion pictures and contextual audio that make up the subject matter to whatever depth they choose.

"Visual Seeker" – stemming out of the same HCI that we describe here – in which a digital display moves over a background graphic, putting a "magic lens" onto otherwise static material has become a standard technology for all metaphorical scanning and story-telling interfaces. Using the combination of a printed background collage of graphics (or vitrines containing artifacts) with a glowing user-movable high-resolution LFD, the visitor is able to access dynamic and progressively revealed content. This allows the visitor to explore at ease and the Curator to include a very large amount of information in a small space. The moving display can amplify and magnify details of static printed information, or display alternate, animated information. Instead of linear scanning, a circular space can also be scanned metaphorically giving an idea to the visitor in being a cylindrically immersive space.

Figure 17 Linear Timeline Slider Based Human Computer Interaction

Figure 18 Circular timeline slider based Human computer Interaction

The same HCI technique was used in the following exhibit in Science City, Kolkata. Here the angular scanner scans over the 30o West to 60o West longitude of the earth surface and presents the major geomorphological, economic and historical evolution that unfolded over this part of the earth.The Multiview spectrum scanning UI technique described here may be used by the astronomers for visually comparing the large data received through different sensors for different wavelength. The choice-based image slicing of the all-sky map of universe can also be a utility tool in class room teaching of astronomy. Further integrating with real time images of different observatories, this exhibit could enhance its usefulness as research tool.

Future Scope

To keep the presentation simple, the package now gives short textual tips on the observables which are pre-coded in the unit. But the same system, enabled with further image processing muscle, may be used to incorporate multiple zoom levels, transparent superposition with control of opacity and object and object selection tools. Our Multiview universe tool interaction has one difficulty that moving the slider by a kid might be difficult due to the force required to move the slider. However, if we have a gesture-controlled method of moving the slider it is going to be interesting and easier interaction. We intend to present a series of other metaphorical HCI adopted for the museums elsewhere very soon.

Such metaphorical HCI help information to transcend into stories – stories that can be used to make sense of the world. While we will see ourselves exploring through them, it is through stories that we will encounter new interdisciplinary and scientific perspectives that will change how we think and feel.

References

Central Research & Training Laboratory, NCSM.(2019). A Colour Metrology Based Selectıve Informatıon/content Dısplayıng System and Method" (India/ Kolkata Patent No.324574: Patent Application No. 1162/KOL/2014 dated 12.11.2014)

Dame, T. M., Hartmann, D., & Thaddeus, P. (2001). The Milky Way in molecular clouds: a new complete CO survey. The Astrophysical Journal, 547(2), 792.

Esposito, J. A., Bertsch, D. L., Chen, A. W., Dingus, B. L., Fichtel, C. E., Hartman, R. C., ... & Willis, T. D. (1999). In-flight calibration of EGRET on the compton gamma-ray observatory. The Astrophysical Journal Supplement Series, 123(1), 203.

File:Hubble-Vaucouleurs.png - Wikimedia Commons. (2011, September 17). https://commons.wikimedia.org/wiki/File:Hubble-Vaucouleurs.png

Hornecker, E., & Buur, J. (2006, April). Getting a grip on tangible interaction: a framework on physical space and social interaction. In Proceedings of the SIGCHI conference on Human Factors in computing systems (pp. 437-446).

Hauser, M. G., Kelsall, T., Leisawitz, D., & Weiland, J. (1998). COBE Diffuse Infrared Background Experiment Explanatory Supplement, version 2.1. COBE reference publication.

Hartmann, D., & Burton, W. B. (1997). Atlas of galactic neutral hydrogen. Cambridge University Press.

Li, H., Fu, C. W., & Hanson, A. (2008). Visualizing multiwavelength astrophysical data. IEEE Transactions on Visualization and Computer Graphics, 14(6), 1555-1562.

Lobo, M. J., Pietriga, E., & Appert, C. (2015, April). An evaluation of interactive map comparison techniques. In Proceedings of the 33rd annual ACM conference on human factors in computing systems (pp. 3573-3582).

Multiwavelength All-Sky Images. (n.d.). https://asd.gsfc.nasa.gov/archive/mwmw/mmw_allsky.html

Multiwavelength astronomy. (n.d.). https://imagine.gsfc.nasa.gov/science/toolbox/multiwavelength2.html

Misra, D., Mishra, S., & Appasani, B. (2018). Advanced image processing for astronomical images. arXiv preprint arXiv:1812.09702.

Radio Continuum images.(n.d) http://home.arcor-online.de/axel.mellinger/

Reich, W., Fürst, E., Reich, P., & Reif, K. (1990). A radio continuum survey of the Galactic Plane at 11 CM wavelength. II-The area L= 358-76 deg, B=-5 to 5 deg. III. Astronomy and Astrophysics Supplement Series (ISSN 0365-0138), vol. 85, no. 1, Oct. 1990, p. 633-690., 85, 633-690.

Snowden, S. L., Egger, R., Freyberg, M. J., McCammon, D., Plucinsky, P. P., Sanders, W. T., & Voges, W. (1997). ROSAT survey diffuse X-ray background maps. II. The Astrophysical Journal, 485(1), 125.

Ullmer, B., & Ishii, H. (2000). Emerging frameworks for tangible user interfaces. IBM systems journal, 39(3.4), 915-931.

Ullmer, B., & Ishii, H. (1997, October). The metaDESK: models and prototypes for tangible user interfaces. In Proceedings of the 10th annual ACM symposium on User interface software and technology (pp. 223-232).

What was new at the NSSDC? (n.d.-b). https://nssdc.gsfc.nasa.gov/nssdc/what_was_new.html

Wheelock, S. L., Gautier, T. N., Chillemi, J., Kester, D., McCallon, H., Oken, C., ... & Good, J. (1994). IRAS sky survey atlas: Explanatory supplement (No. NAS 1.26: 197335).

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