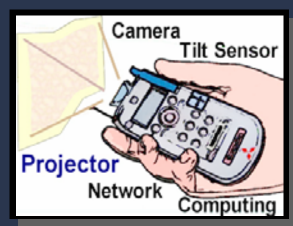
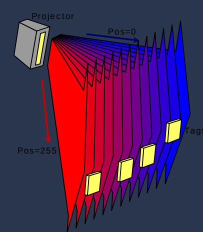
Mobile Projectors and Optical Communication





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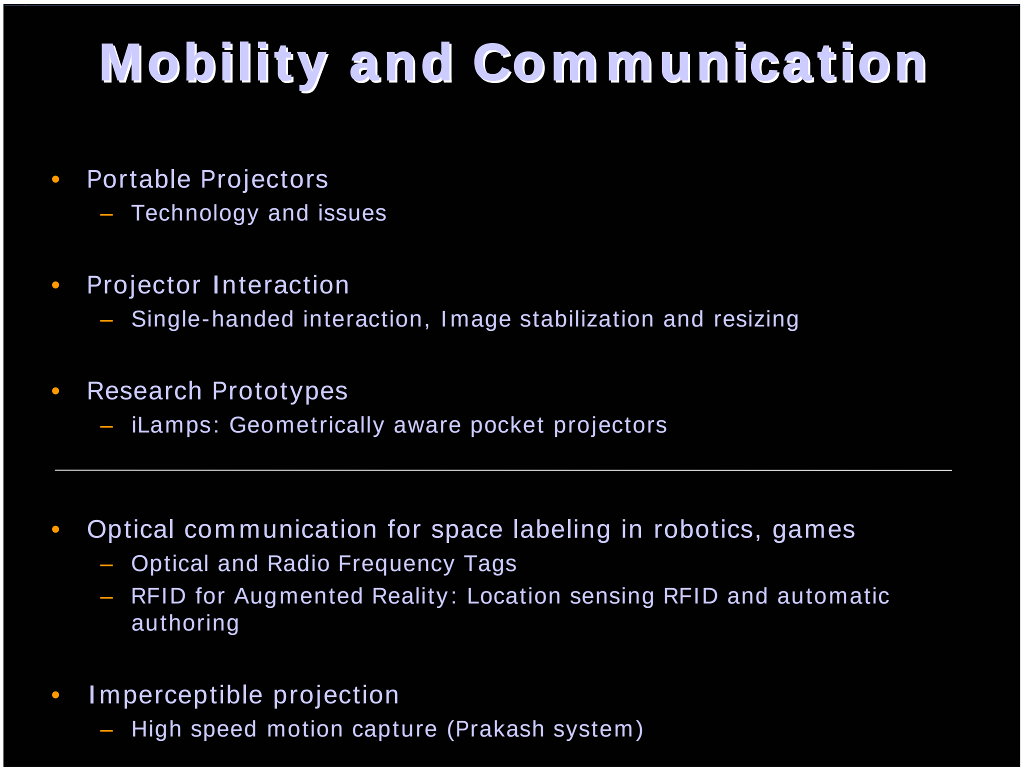
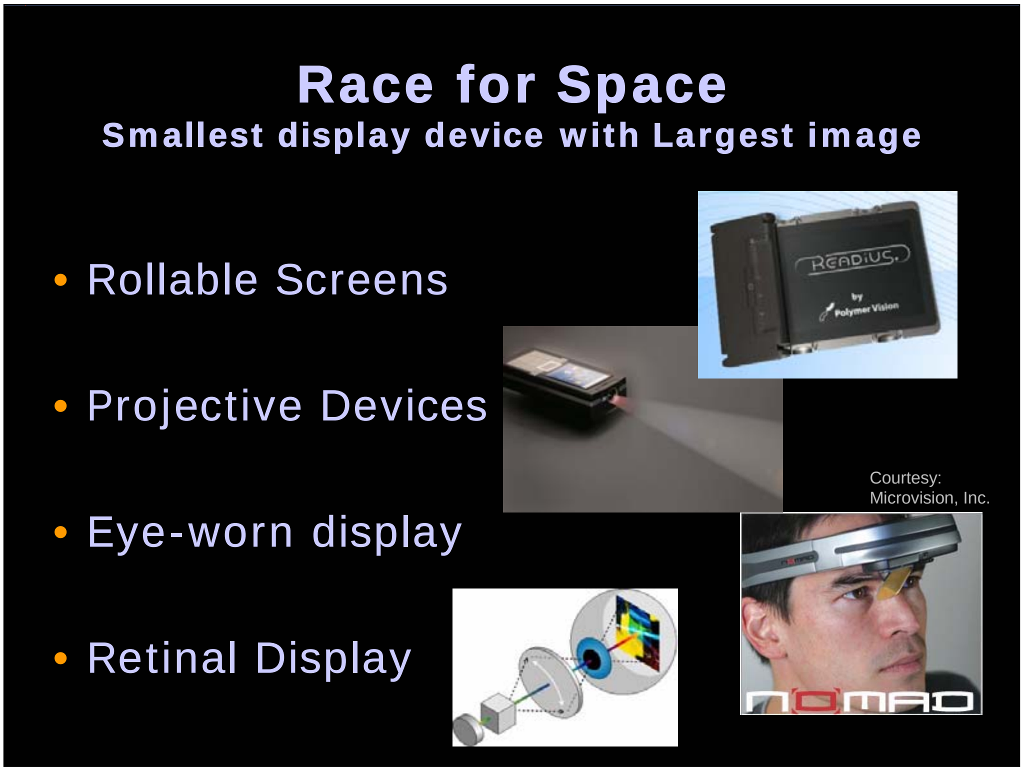
Mobile Projectors
and
Optical Communication



Micro and Pico portable projectors are still in development phase. Excellent review at http://www.economist.com/science/tq/displaystory.cfm?story_id=10789401. So called pocket projectors, e.g. from Mitsubishi Electric, are already available.

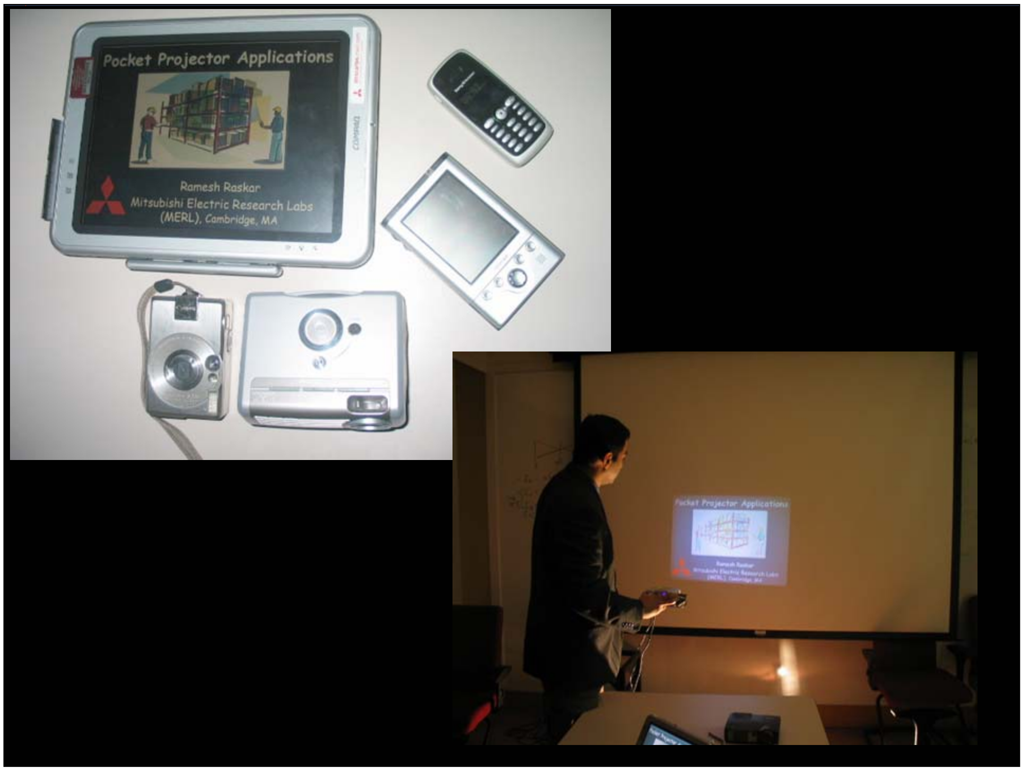
We will look at research in mobile projectors and the interaction with real world. Then we will explore the opportunities in optical communication with projectors.



There are only a limited solution to create a large display from a small device.

Projectors are showing the potential to create new ways of interacting with information in everyday life. Desktop screens, laptops and TVs have a basic constraint on their size – they can never be smaller than the display area. Hand-helds such as PDAs are compact but the display size is too limited for many uses. In contrast, projectors of the near future will be compact, portable, and with the built-in awareness which will enable them to automatically create satisfactory displays on many of the surfaces in the everyday environment.

Mitsubishi Pocket Projector


Pocket Projector Applications
Ramesh Raskar
Mitsubishi Electric Research Labs
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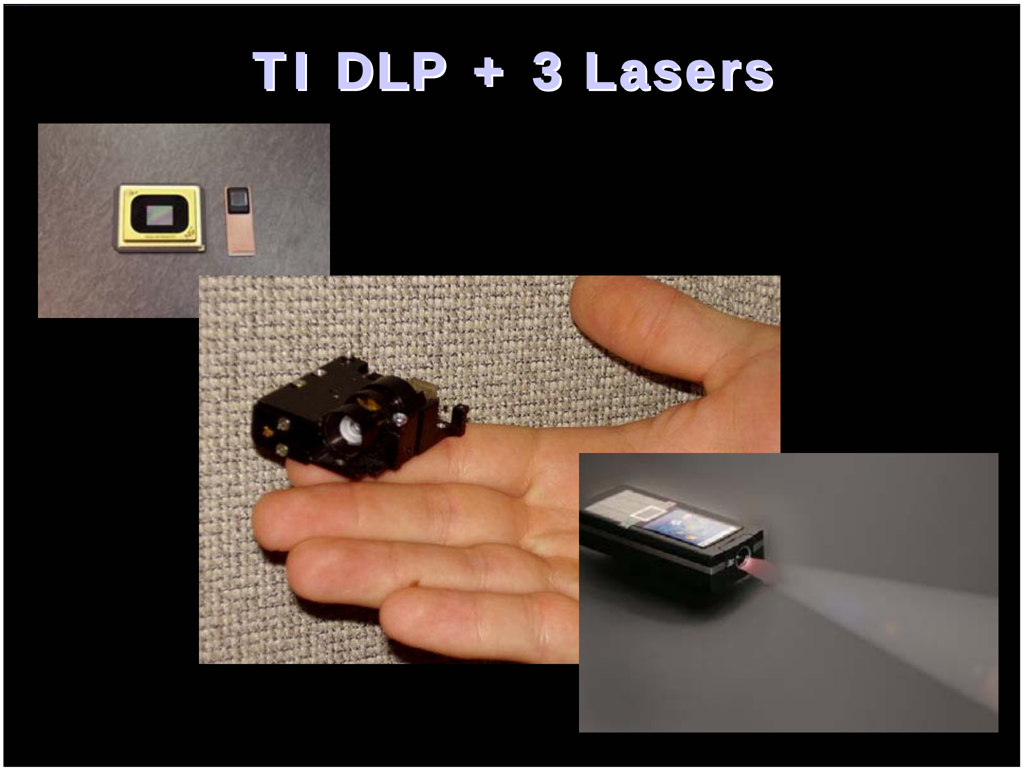
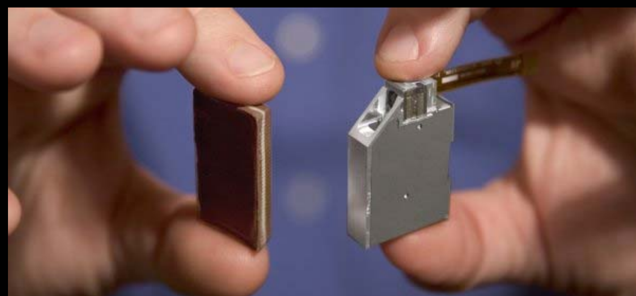


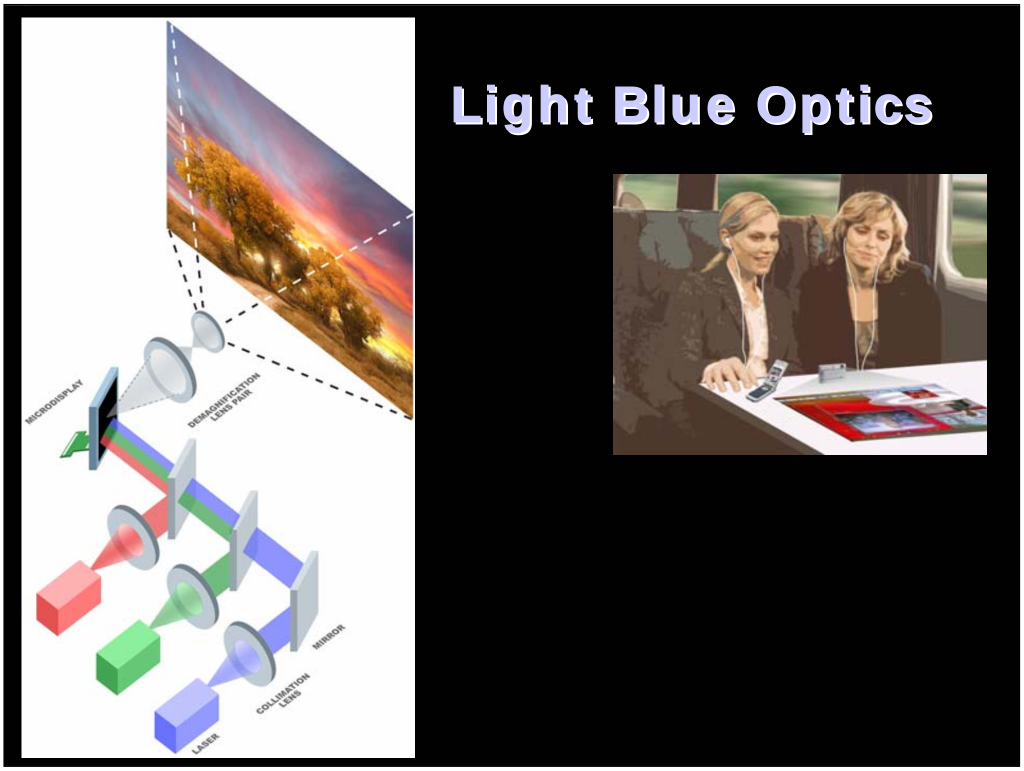
On the left is a standard DLP chip that you might find in a large-screen TV. On the right is a DLP for a projector phone. Although smaller, the chip can still project fairly large images. By putting these chips into phones, TI hopes to make watching video on phones more pleasing and, of course, sell more chips. A complete pico projector. It fits into a phone. The projector contains three lasers, a DLP chip and a power supply and measures about 1.5 inches in length. A mock-up of TI's functioning projector in a phone. Granted, the phone's a little larger than a lot of the phones on the market today, but those don't have projectors in them.
http://www.news.com/TI-demos-its-movie-projector-in-a-phone/2100-1041_3-6170619.html?tag=ne.gall.related

Microvision: Rotating mirror + Lasers



Microvision's ultra-miniature full-color digital projection display approximately the size of a Thin Mint candy, designed to be embedded into handheld electronic devices such as cellphones, PDAs, or multimedia handhelds. (January 2007 Consumer Electronic Show). The projector developed at Microvision is composed of two main parts: a set of red, blue, and green lasers made of semiconductor material, such as gallium indium arsenide, and a mirror--one millimeter across--that tilts on two axes. The lasers shine on the mirror, and the mirror reflects the pixel of light onto a wall or other surface. The intensities of the lasers change to produce different colors: when all three are pumping out light full blast, the pixel is white; when all three are off, the pixel is black. Other colors are produced from various combinations in between.

As the lasers flash on the mirror, the mirror gimbals on its two axes, flickering to produce 30 million pixels a second, each illuminating a surface for 20 nanoseconds. Using this laser and single-mirror setup, the projector paints a scene onto a surface one pixel at a time, says Sprague. It does this so quickly that our eyes perceive a static image or a continuous movie. One of the challenges is to design a rapidly gyrating mirror that can coordinate with the lasers that turn on and off 100 million times a second. Integrated into the Microvision mirror are silicon mechanical structures that measure strain on the mirror, detecting what position it's in. This information is fed back into the laser modulator--the device that determines when a laser is emitting light or not--and the feedback loop allows the system to constantly adjust, depending on the demands of the projected image. The mirror, its mount, and the other mechanical components are all made of silicon, putting the projector in a class of device called MEMS (microelectromechanical systems). http://www.technologyreview.com/Biztech/17860/

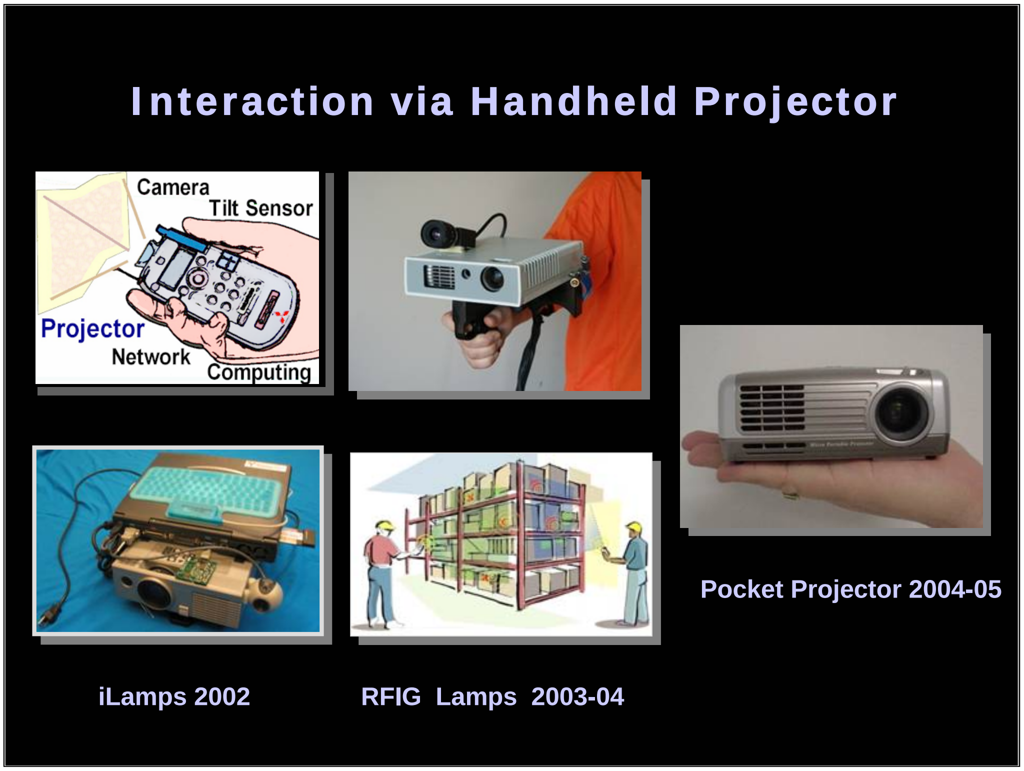


LBO's approach to miniature projection has a range of differentiating features and benefits. The term "holographic" refers not to the projected image,

but to the method of projection. A diffraction pattern of the desired 2D image, calculated using LBO's patented holographic algorithms, is displayed on a

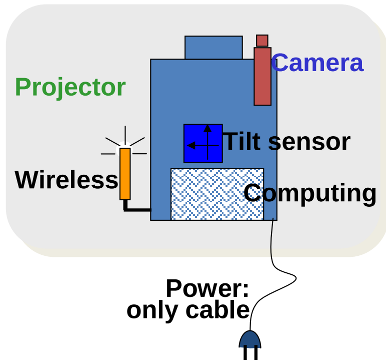
custom-designed phase-modulating reflective Liquid Crystal on Silicon (LCOS) microdisplay. When illuminated by coherent laser light, the desired 2D image is projected. The projector uses a reflective LCoS array to create a constantly varying diffraction pattern that is carefully calculated to produce the desired two-dimensional image when illuminated by red, green and blue lasers.

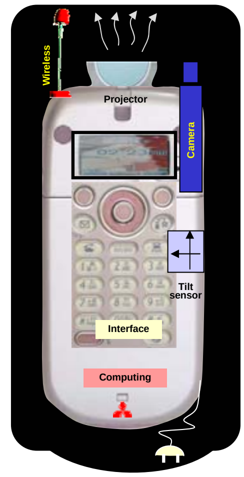
The resulting image is in focus at all distances from the projector, and the projector has no moving parts. The drawback of this approach is that the LCoS array takes up more space than a single mirror. But the nature of the technology means that the size of the array can be kept to a minimum. Because the array displays a diffraction pattern, not the actual image, the resolution of the projected image can be higher than that of the array. LBO's current prototype projects a 1,600-by-1,024-pixel image using an 864-by-480-pixel array.



There has been significant research in modifying and interfacing projectors for novel scenarios and applications. Two of the projects we will discuss : iLamps and RFIG lamps.

iLamps : Intelligent Locale-aware Mobile Projectors

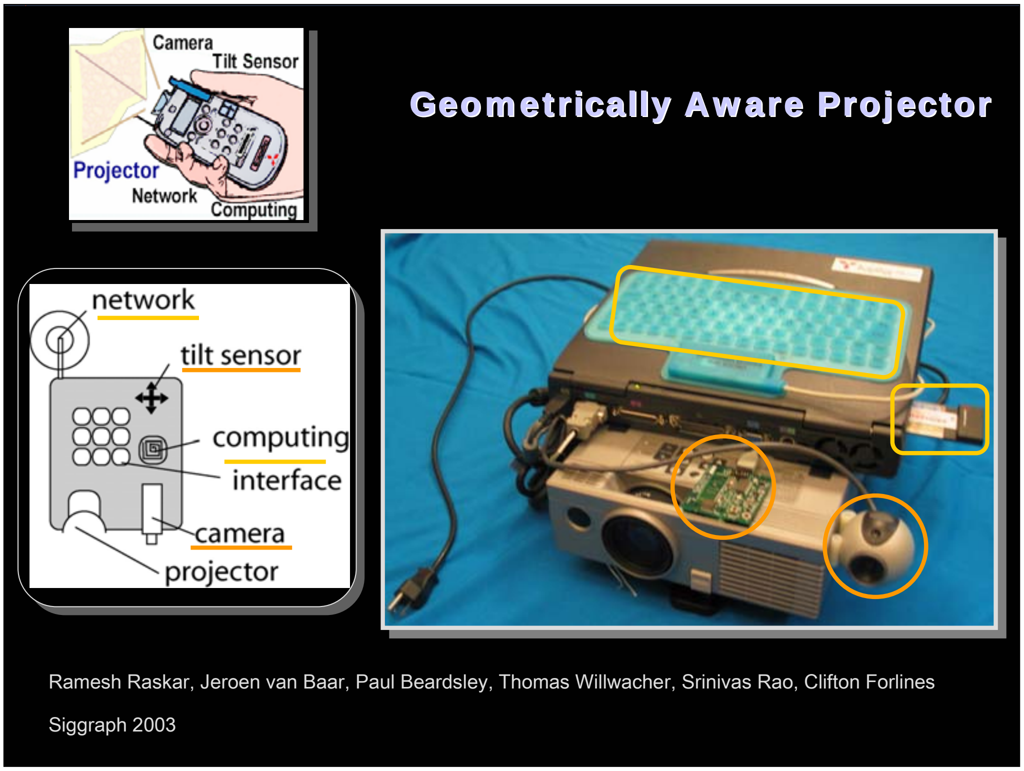




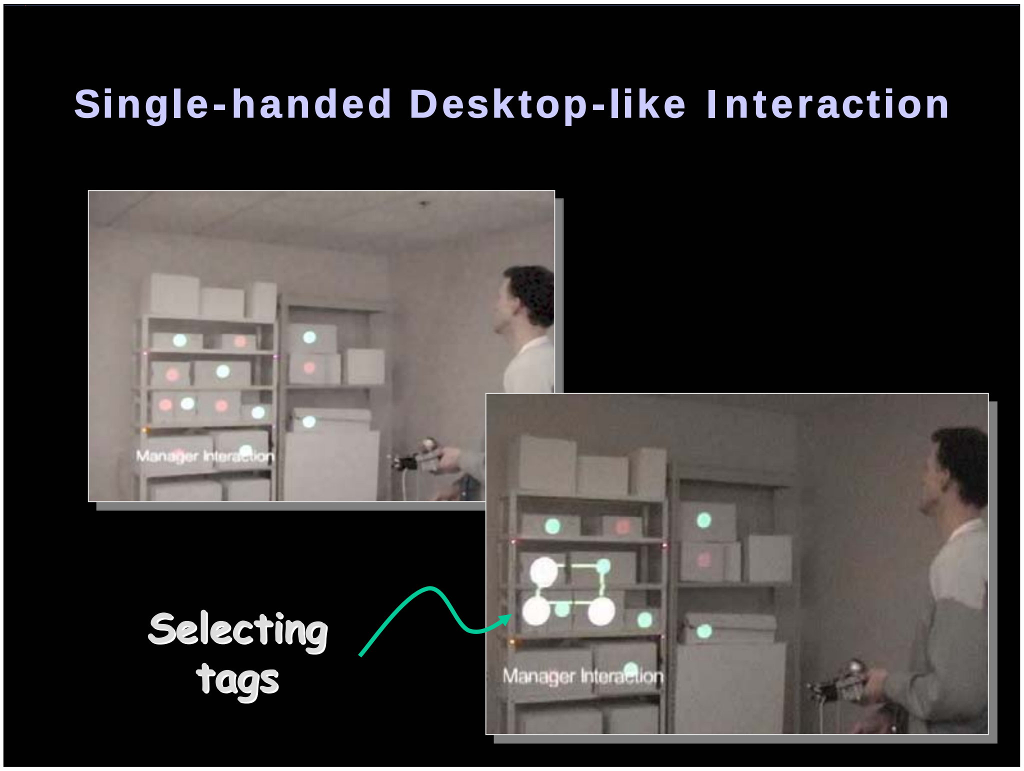
Ramesh Raskar, Jeroen van Baar,
Paul Beardsley, Thomas Willwacher,
Srinivas Rao, Clifton Forlines

Siggraph 2003

iLamps stands for Intelligent Locale-aware Mobile Projectors. The idea is to augment a mobile phone with a projector, camera and tilt sensor.

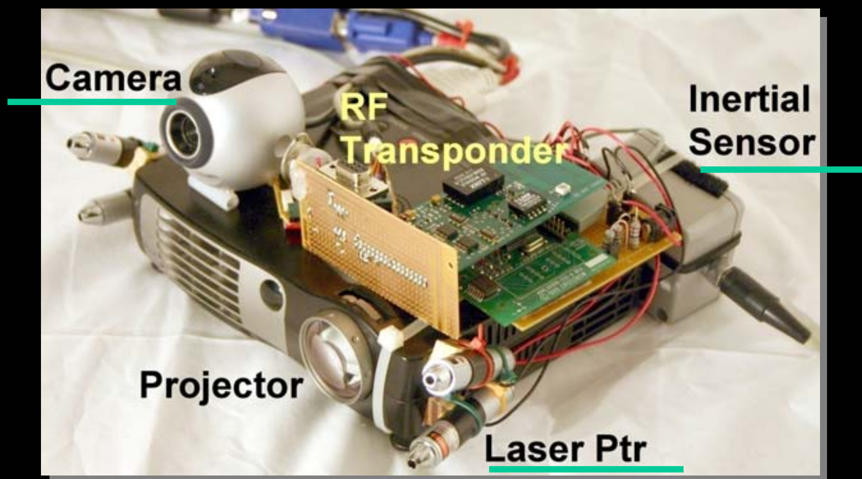


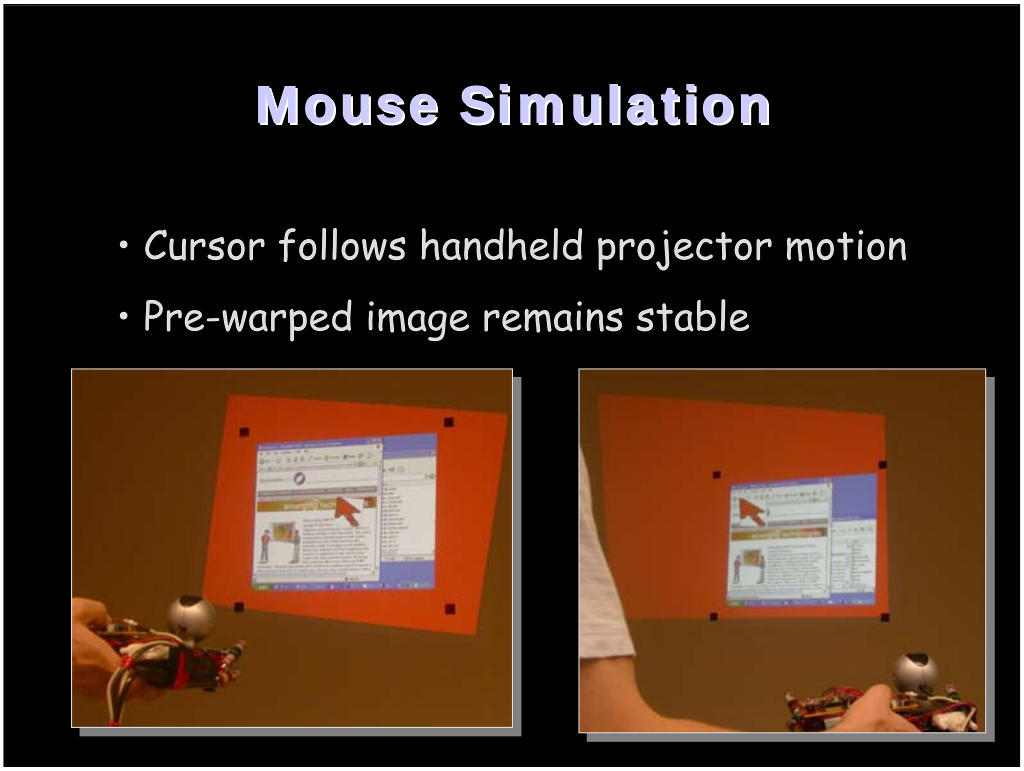
Projectors are currently undergoing a transformation as they evolve from static output devices to portable, environment-aware, communicating systems. An enhanced projector can determine and respond to the geometry of the display surface, and can be used in an ad-hoc cluster to create a self-configuring display. Information display is such a prevailing part of everyday life that new and more flexible ways to present data are likely to have significant impact. This project examines geometrical issues for enhanced projectors, relating to customized projection for different shapes of display surface, object augmentation, and co-operation between multiple units.



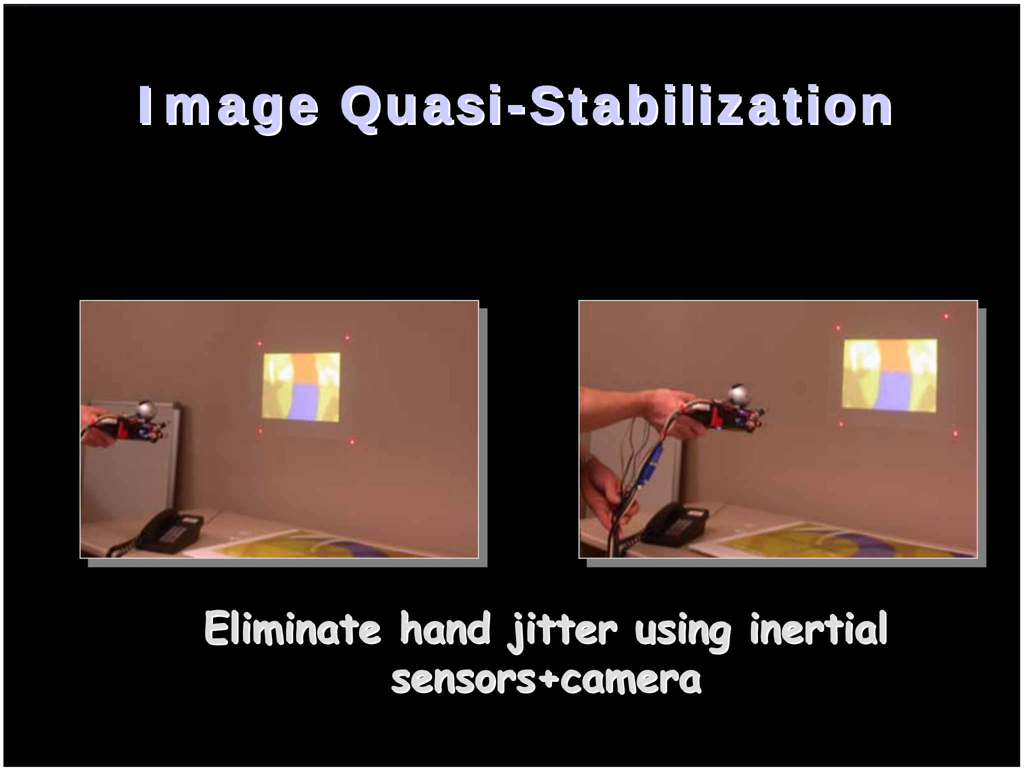
Consider interactive projection to allow a user to interact with projected information e.g. to navigate or update the projected information. A single-handed desktop-like interaction with projected illumination is possible.

Support for handheld projection



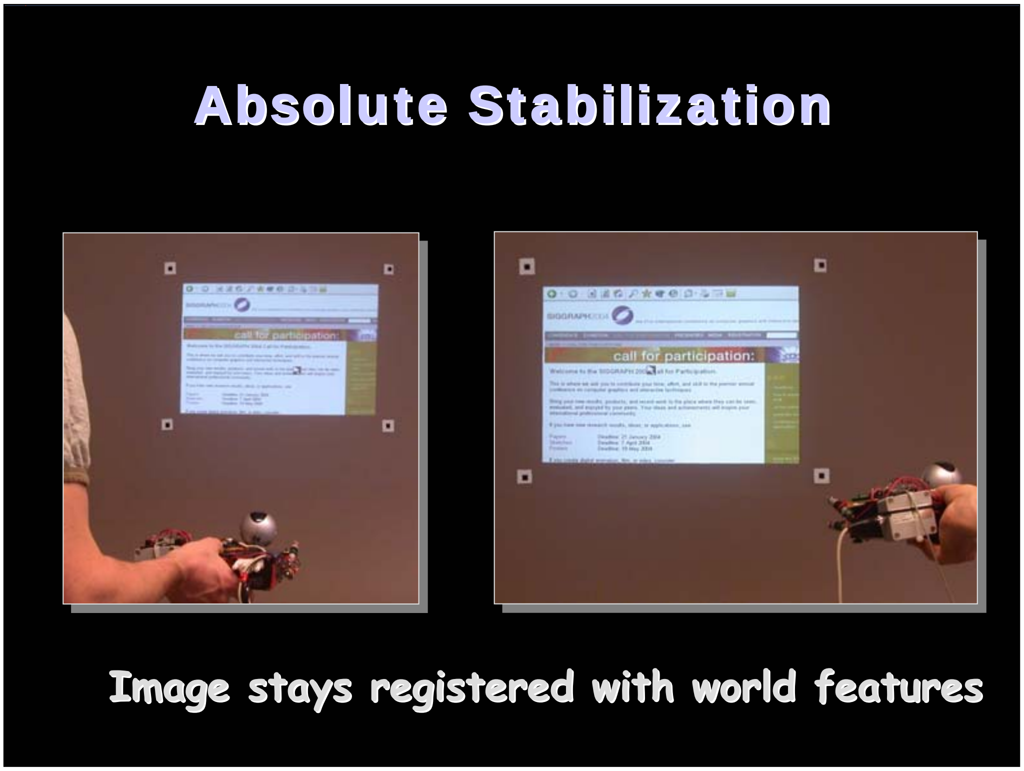


Here we introduce interactive projection, allowing a user with a handheld projector to do mouse-style interaction with projected information. This is achieved by treating a projection as conceptually having two parts – a stabilized component that is static in the display surface, and a cursor that follows any user pointing motion of the projector – effectively allowing the user to track a cursor across a projection. Accompanying mouse buttons are used to do selection. Interactive projection is not specific to a tagged environment, but the technologies meld well.

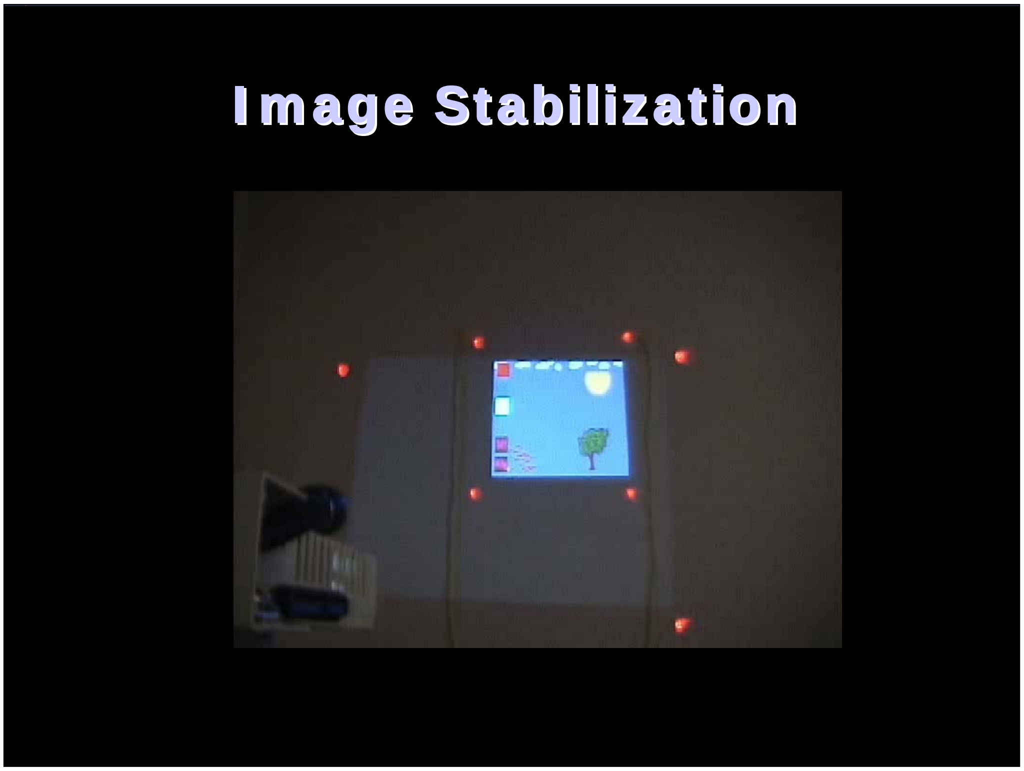


In creating a handheld projector, an immediate problem that arises is that hand-jitter results in jitter in the projection. The core requirement to deal with this problem is to compute the pose of the projector relative to the display surface.

Quasi-stabilization
preserves the form of the projection up to an unknown translation in the plane i.e. it preserves projection shape, size and orientation. But the projection translates in the display plane in accordance with projector motion parallel to the plane.



Absolute stabilization is possible when the camera is viewing four or more fixed surface points in general position, or the equivalent, on a planar display surface. Our goal is to find a homography H *between* the projector image plane and a fixed coordinate frame on the surface. Homography H *specifies the mapping between each pixel* on the projector image plane and the fixed surface coordinate frame. Hence we can use its inverse inv(H) *to transform from a desired (fixed)* projection on the surface to the projector image plane, thereby determining the required projector image to give the fixed projection.

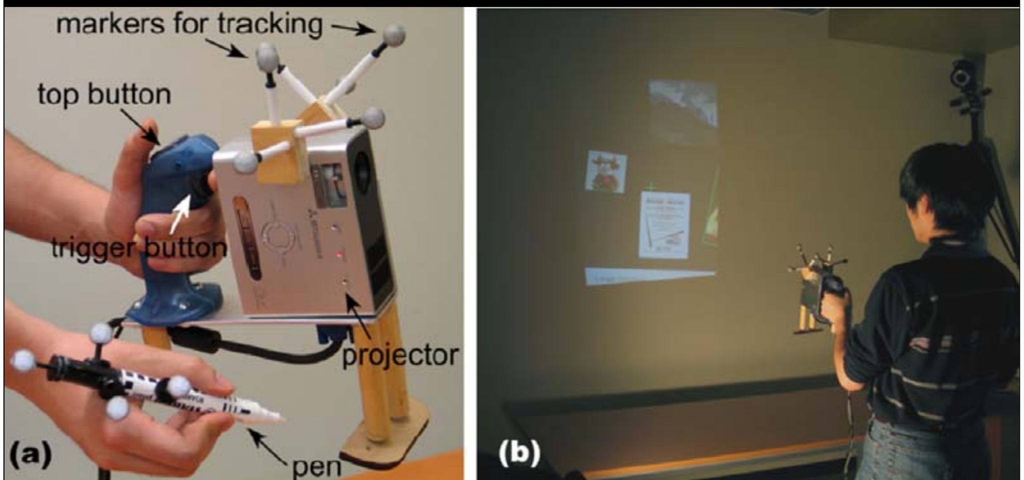


Video

A new way to play tic-tac-toe

- Handheld projector.
- Grid projects to a fixed position on the wall.
- Cursor is guided by pointing the projector.

Playing game is a nice way to demonstrate various functionalities.



Xiang Cao, Ravin Balakrishnan. (2006). Interacting with dynamically defined information spaces using a handheld projector and a pen. Proceedings of UIST 2006, ACM Symposium on User Interface Software and Technology

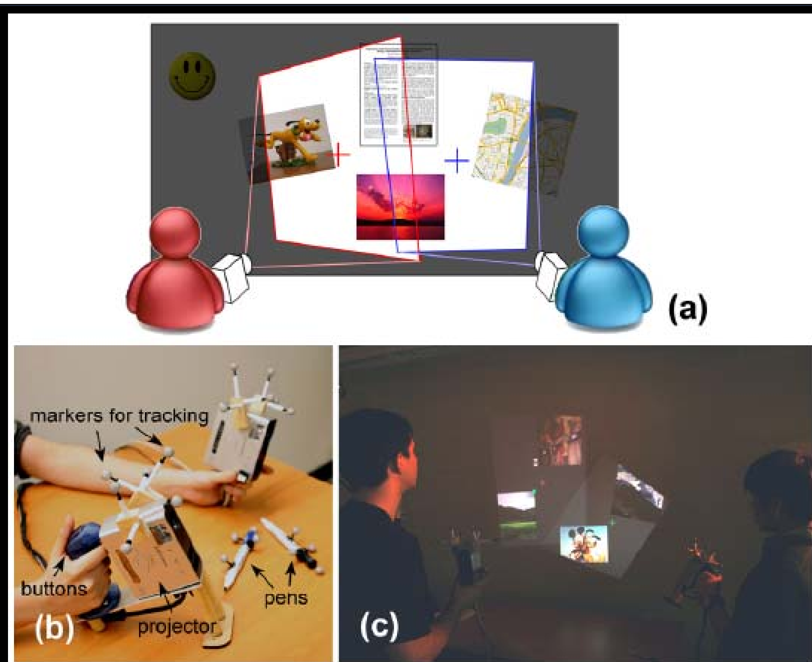
Handheld devices will soon have the ability to project information onto any surface, thus

enabling interfaces that are not possible with current handhelds. The authors in Toronto explore the design space of dynamically

defining and interacting with multiple virtual information spaces embedded in a physical environment using a handheld projector and a passive pen tracked in 3D. They

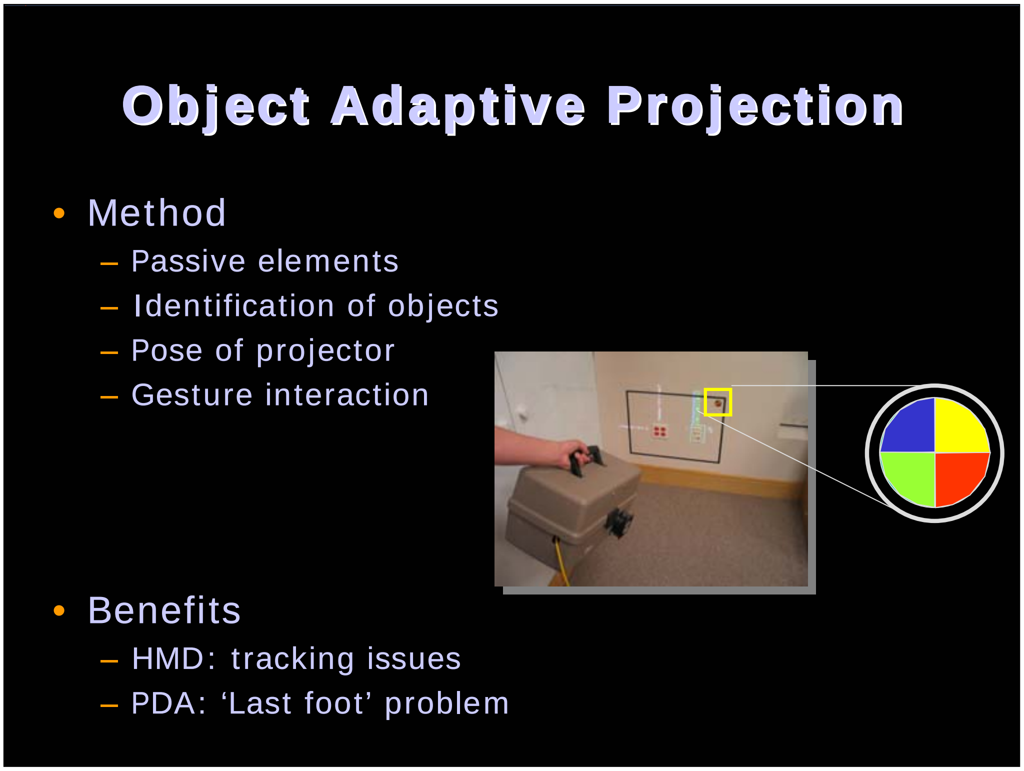
develop techniques for defining and interacting with these

spaces.



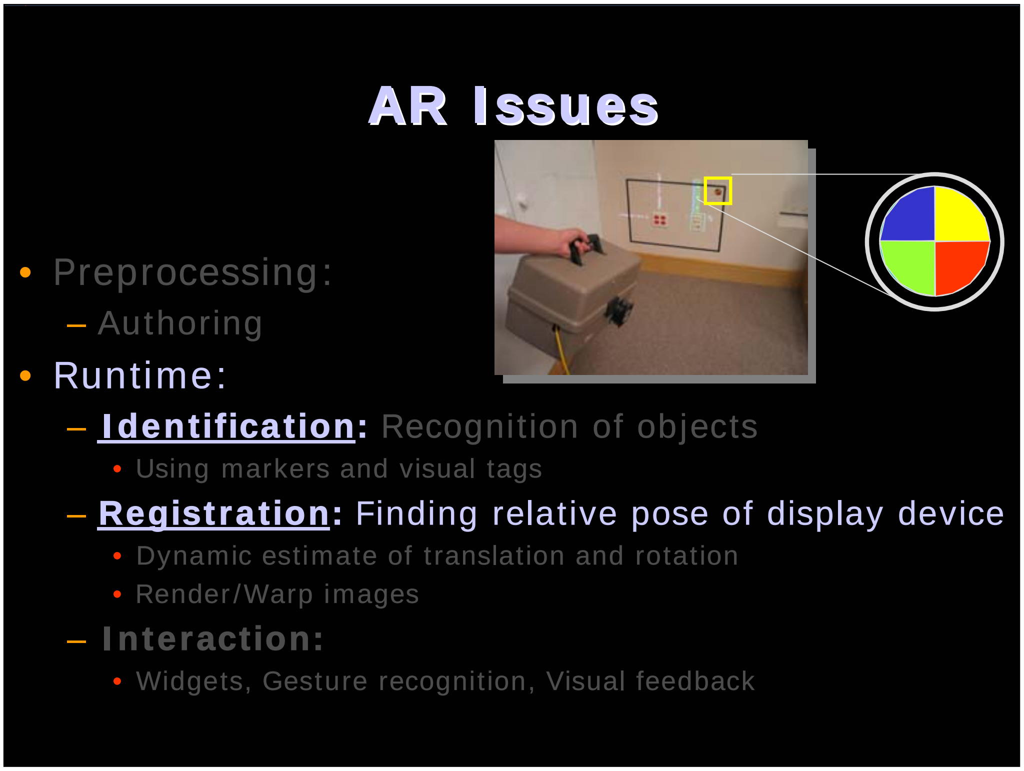
Xiang Cao, Clifton Forlines, Ravin Balakrishnan. (2007). Multi-user interaction using handheld projectors. Proceedings of UIST 2007, ACM Symposium on User Interface Software and Technology. p. 43-52.

They extend the prior single-user research to co-located multi-user interaction using multiple handheld projectors. They present a set of interaction techniques for supporting co-located collaboration with multiple handheld projectors, and discuss application scenarios enabled by them. Handheld projectors provide interesting design challenges compared to other co-located collaborative settings such as a shared tabletop display. For example, users can create their individual displays with their projectors, allowing for easy support of personalized views, which is seldom the case in other settings.



Let us look at object augmentation using a hand-held projector, including a technique for doing mouse-style interaction with the projected data. Common to some previous approaches, we do object recognition by means of fiducials attached to the object of interest. Our fiducials are 'piecodes', colored segmented circles, which allow thousands of distinct colorcodings.

As well as providing identity, these fiducials are used to compute camera pose (location and orientation) and hence projector pose since the system is fully calibrated. With projector pose known relative to a known object, content can be overlaid on the object as required.

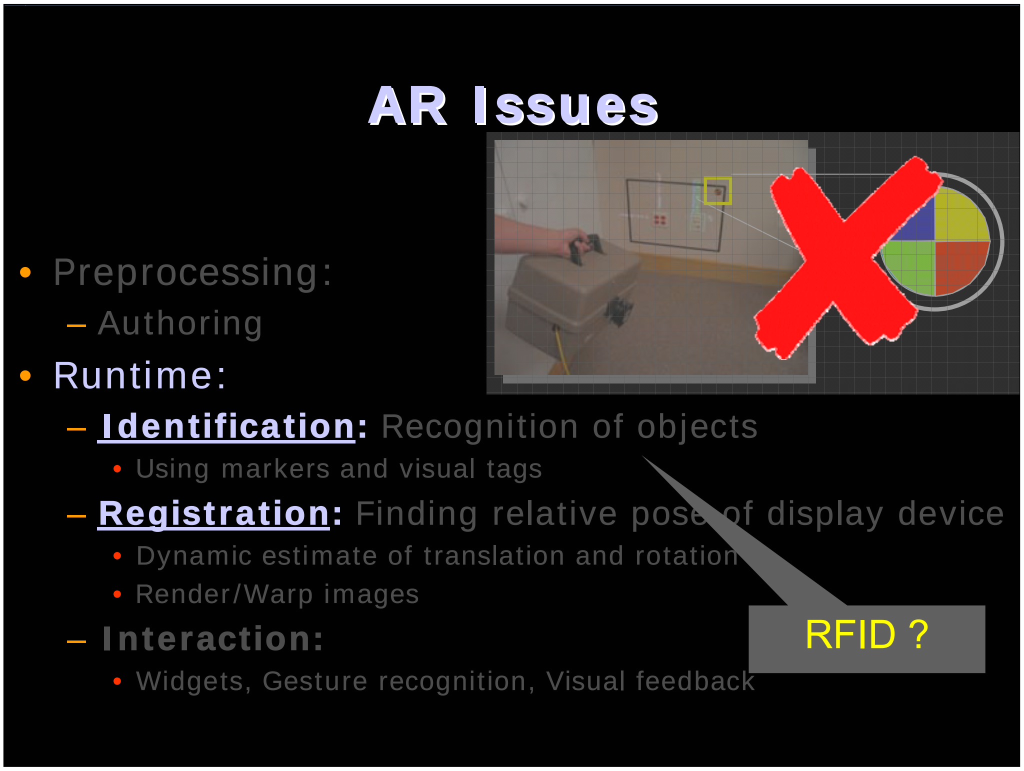


The pie-codes help us solve two critical run-time components of an AR system.

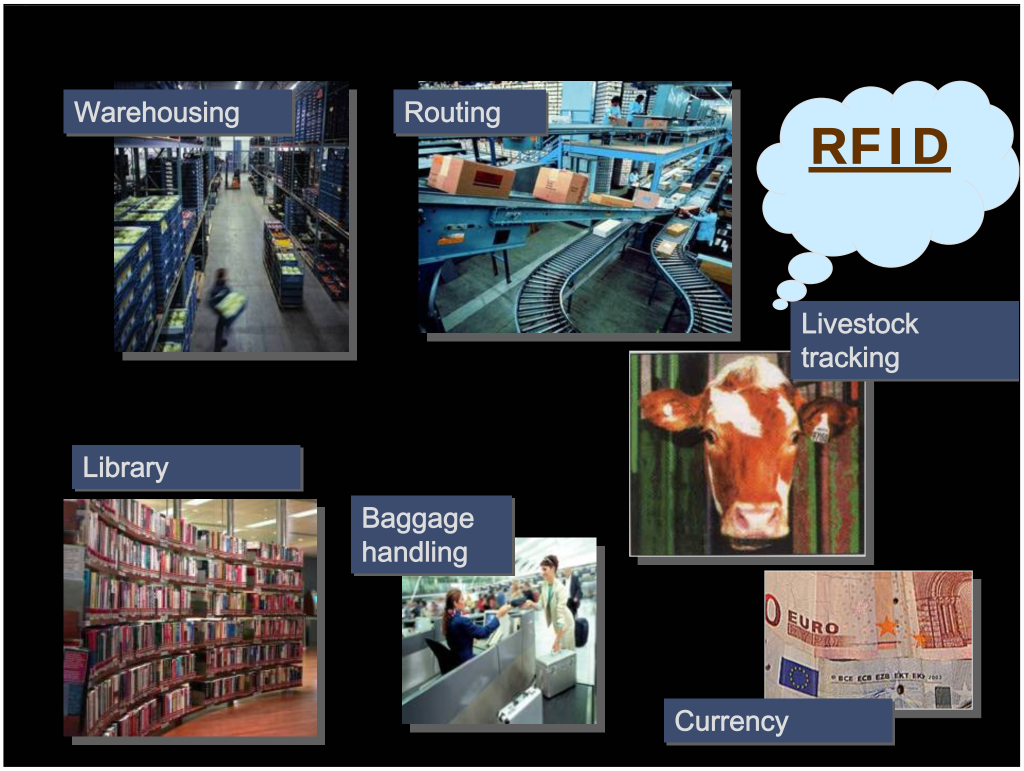
Raskar, vanBaar, Beardsley, Willwacher, Rao, Forlines
‘iLamps: Geometrically Aware and Self-Configurable Projectors’,
SIGGRAPH 2003

Video

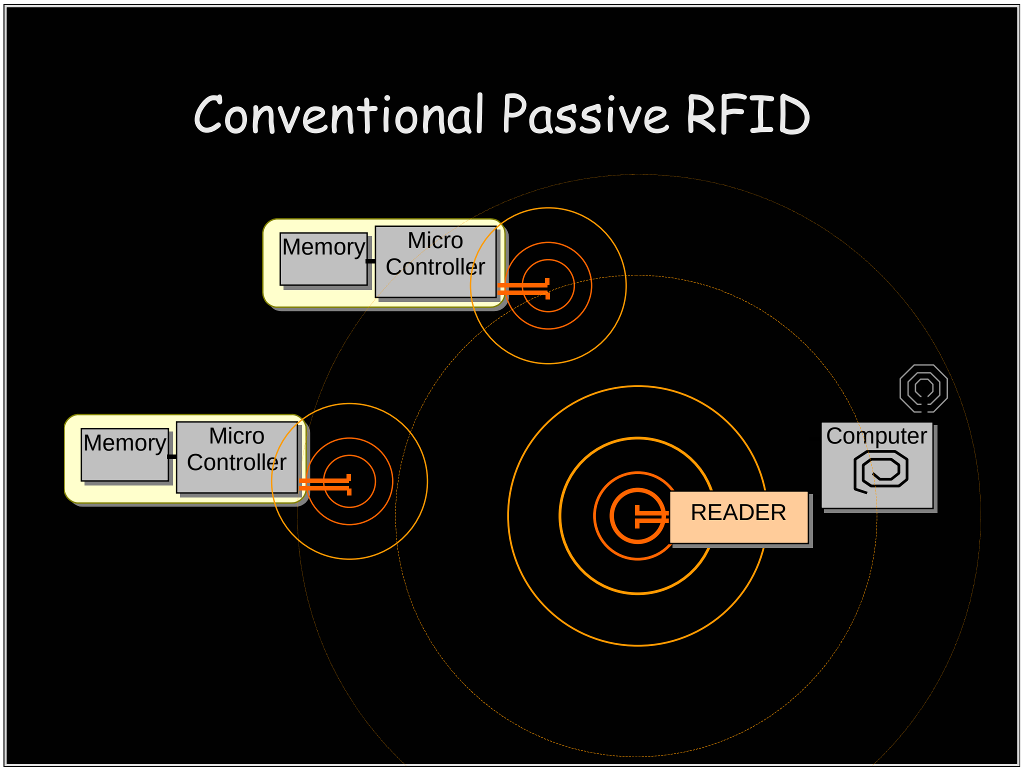
A hand-held projector can use various aspects of its context when projecting content onto a recognized object. We use proximity to the object to determine level-of-detail for the content. Other examples of context for content control would be gestural motion, history of use in a particular spot, or the presence of other devices for cooperative projection. The main uses of object augmentation are (a) information displays on objects, either passive display, or training applications in which instructions are displayed as part of a sequence; (b) physical indexing in which a user is guided through an environment or storage bins to a requested object; (c) indicating electronic data items which have been attached to the environment. Related work includes the Magic Lens [Bier et al. 1993], Digital Desk [Wellner 1993], computer augmented interaction with real-world environments [Rekimoto and Nagao 1995], and Hyper mask [Yotsukura et al. 2002].



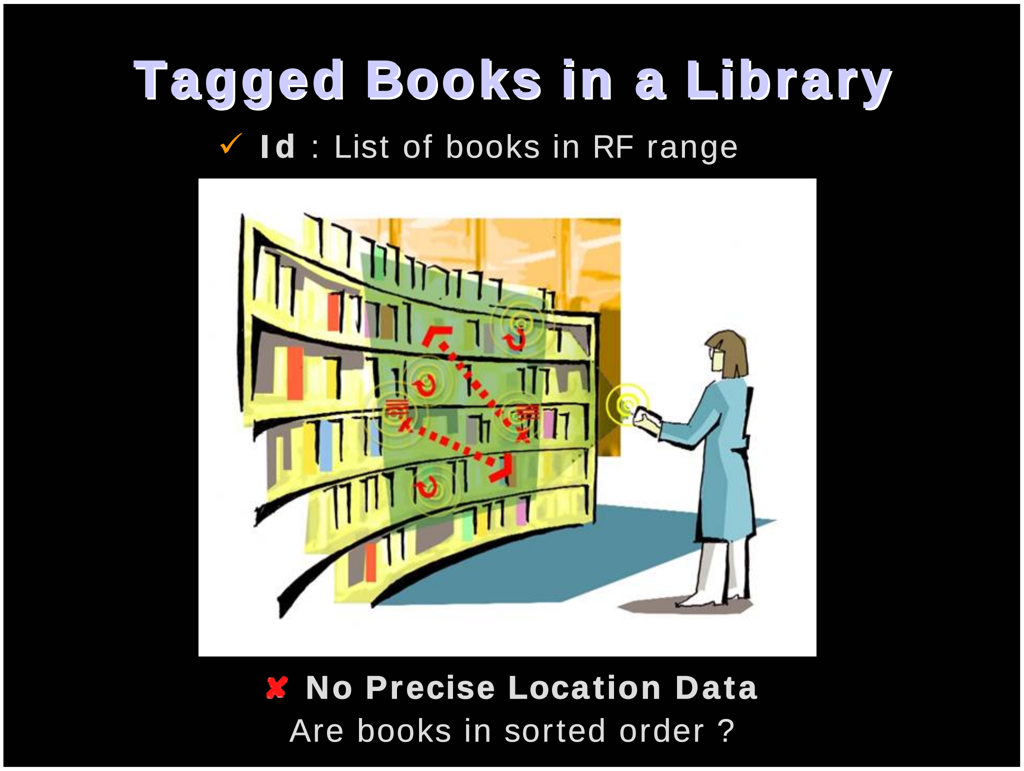
The pie-codes however can be replaced with radio frequency identification tags (RFID tags).



The first large-scale use of passive-RFID tags is expected to be for inventory control as part of logistics (a US$900 billion industry), so we turn to a scenario in a warehouse - locating objects with a required property and annotating them.

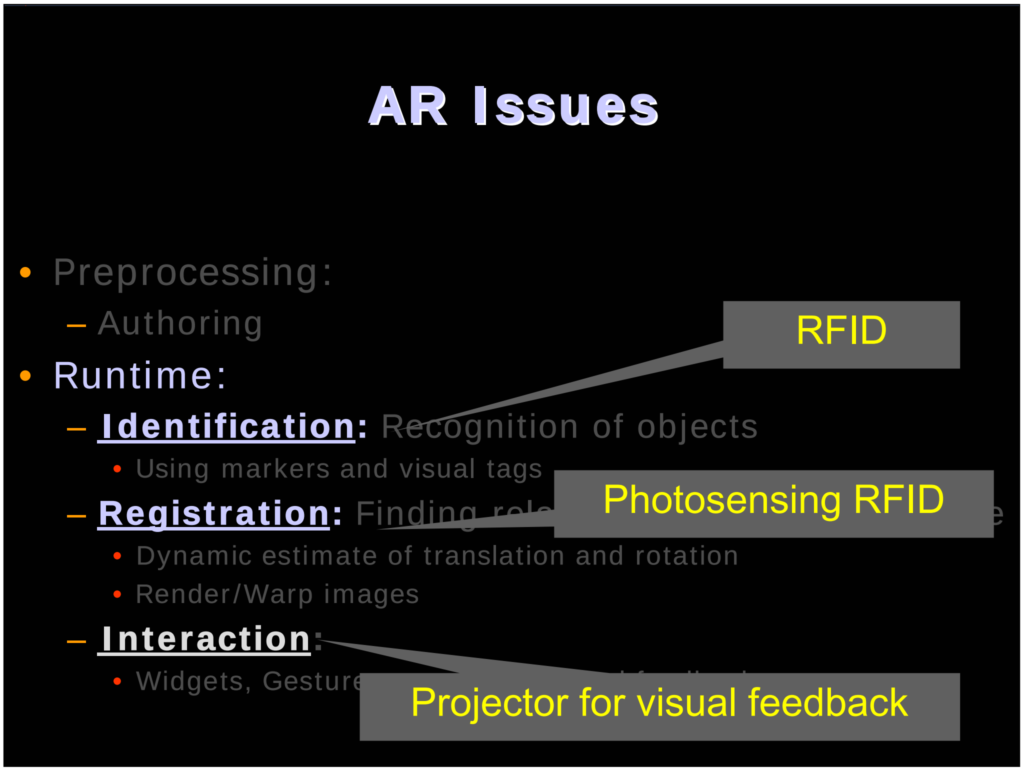


Conventional tag communication works by broadcast from an RFreader, with response from all in-range tags. Limiting the communication to a required tag is traditionally achieved using a shortrange tag-reader and close physical placement with the tag.
Powered radio-frequency tags currently use a battery that is about the size of a watch-battery, have a lifetime of a few years, and have a cost of a few dollars. In contrast, passive RFID tags are unpowered, can be as small as a grain of rice, and cost tens of cents [Want 2003]. Prices of both are dropping but the price differential will remain. The size and cost properties are such that RFID is showing signs of being adopted as a mass-deployment technology. Current commercial applications including embedding of RFID tags in packaging for inventory control, non-contact access control, and ear tags for livestock. Despite the interest in RFID, the available functionality is very limited – an RF-reader broadcasts a request, and in-range tags (collect energy from the RF pulse and) reply. The work is motivated by the observation that RFID is showing the potential to be a ground-breaking, pervasive technology, yet current functionality is limited.

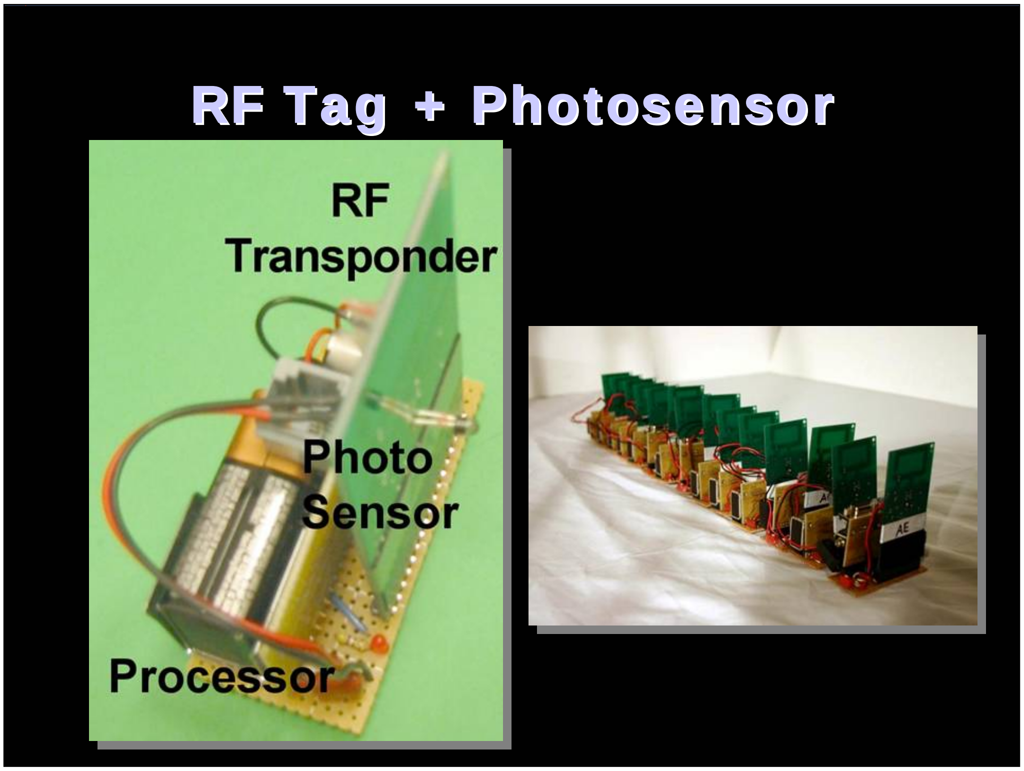


RF beacons or tag transmit devices references but without the ability to point and without visual feedback.

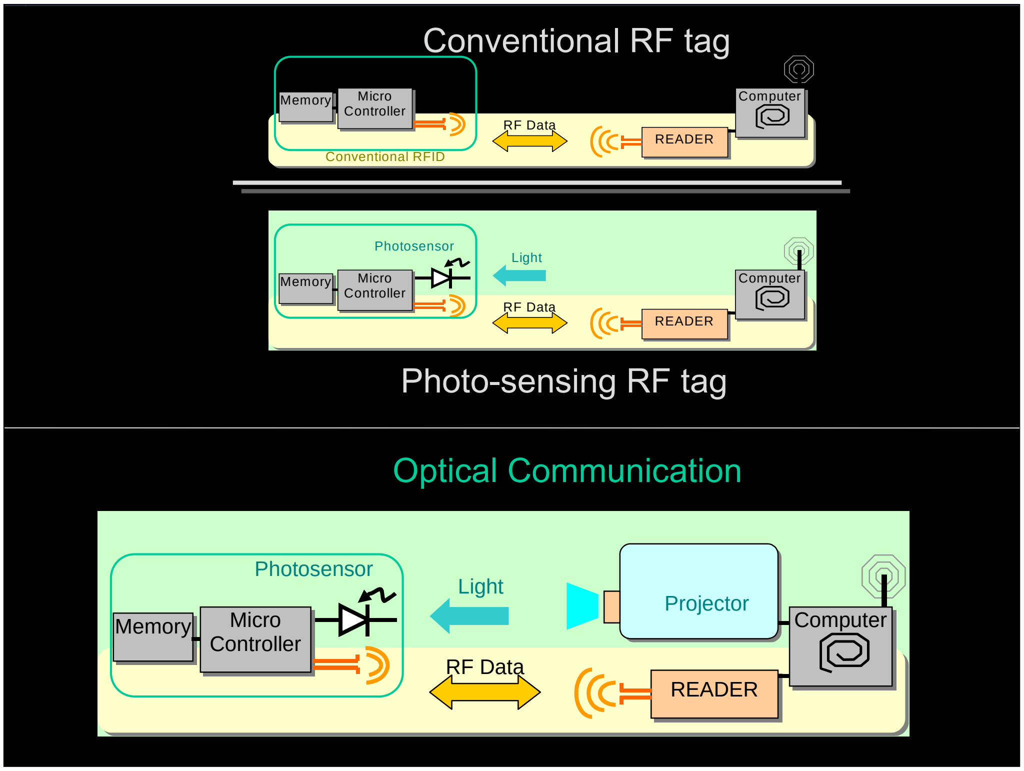
A library scenario: Finding which books are on the shelf within the RF range is easy with a traditional (handheld) RF reader. But how can one find out which books are out of the alphabetically sorted order ? With passive photosensing RFID attached to each book we can find the exact location of each book. So, one can verify if there is a mismatch between the list of books sorted by title versus list of books sorted by position coordinates. The mismatch can also be indicated by projecting the arrows back on the shelf indicating the correct position. (Green arrows.) We can also find out if any book is placed upside down. We attach two tags, one at the top and one at the bottom. Books for which the location of the two tags is reversed is marked as upside down. This is indicated visually with red arrows.



Let us see how a combination of photosensing RFID tags and pocket projectors allows us to solve AR problems in a new imperceptible way.



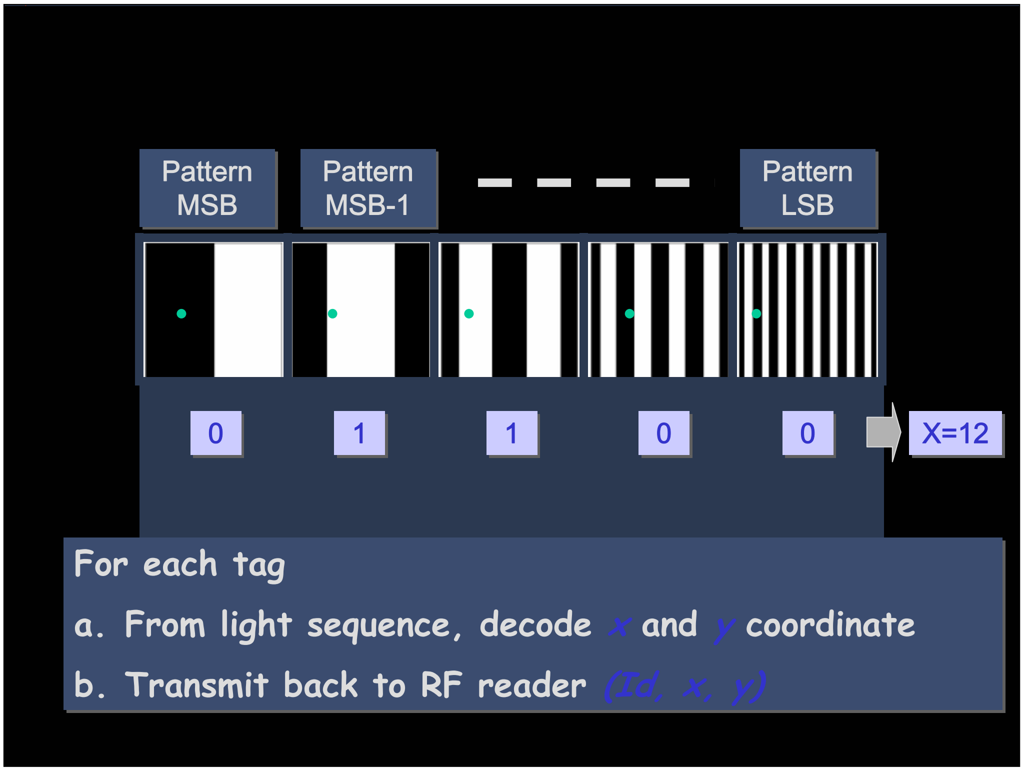
We augment each tag with a photo-sensor to significantly extend the current functionality and support radio frequency identity and geometry (RFIG) discovery. The ability to address and wirelessly access distributed photosensors creates a unique opportunity. We recover geometric information, such as 3D location of tags or shape history of tagged objects, and exploit the associated geometric operations to bring the RF tags into the realm of computer vision and computer graphics.



The key issue in evolving our active tag system to passive tags would be power. We only allow computation and sensing consistent with the size and power levels we felt were achievable on a passive RFID system. For example, (a) tags are not photo-sensing or computing until woken up by the RF reader and (b) we do not have a light emitting diode (LED) on the tag as a visual beacon to a human or camera-based system because it would be power-hungry. Also note that the tags incorporate a photo-sensor, so a passive version could draw power not just from the RF channel, but also from the incident light. Of course, there would be significant engineering challenges in moving from active to passive RFID.

For example, a warehouse
employee identifies food products that are close to expiry date and annotates an instruction to trash them. If these products were items on a computer desktop, this could be done with a few clicks. Our goal is to craft a scheme in the physical world that maintains the simplicity of the computer environment. In the computer, the items are files, and the interface is via keyboard, mouse, and display. In the physical world, the items are tagged objects, and the interface uses a handheld projector and user interaction directly through the projected information.

Video


Pattern MSB
Pattern MSB-1
Pattern LSB
0
1
1
0
0
X=12
For each tag
a. From light sequence, decode x and y coordinate
b. Transmit back to RF reader (Id, x, y)

Visual feedback of 2D position

a. Receive via RF $\{(Id_1, x_1, y_1), (Id_2, x_2, y_2), \ldots\}$

b. Illuminate those positions

RFID

(Radio Frequency Identification)

↓

RFIG

(Radio Frequency Id and Geometry)

Projector =
Optical Communication + Display + Interaction

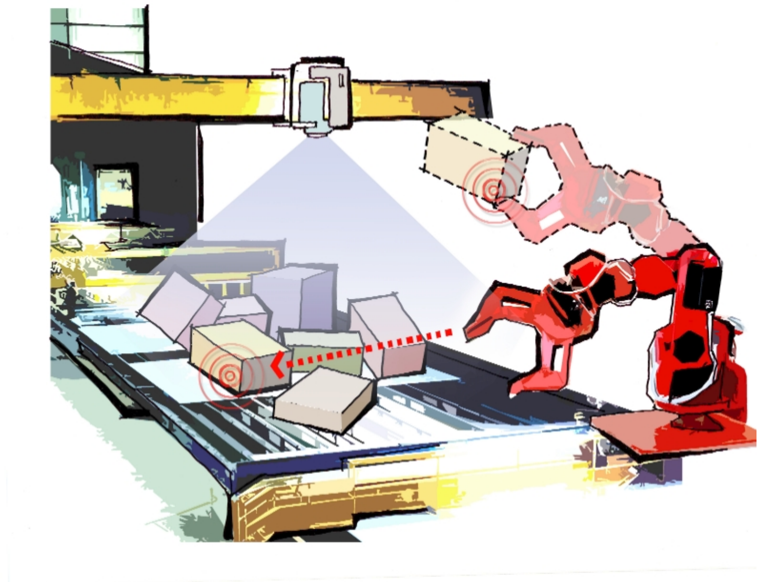
Find tag location using optical communication

Stabilized projection display

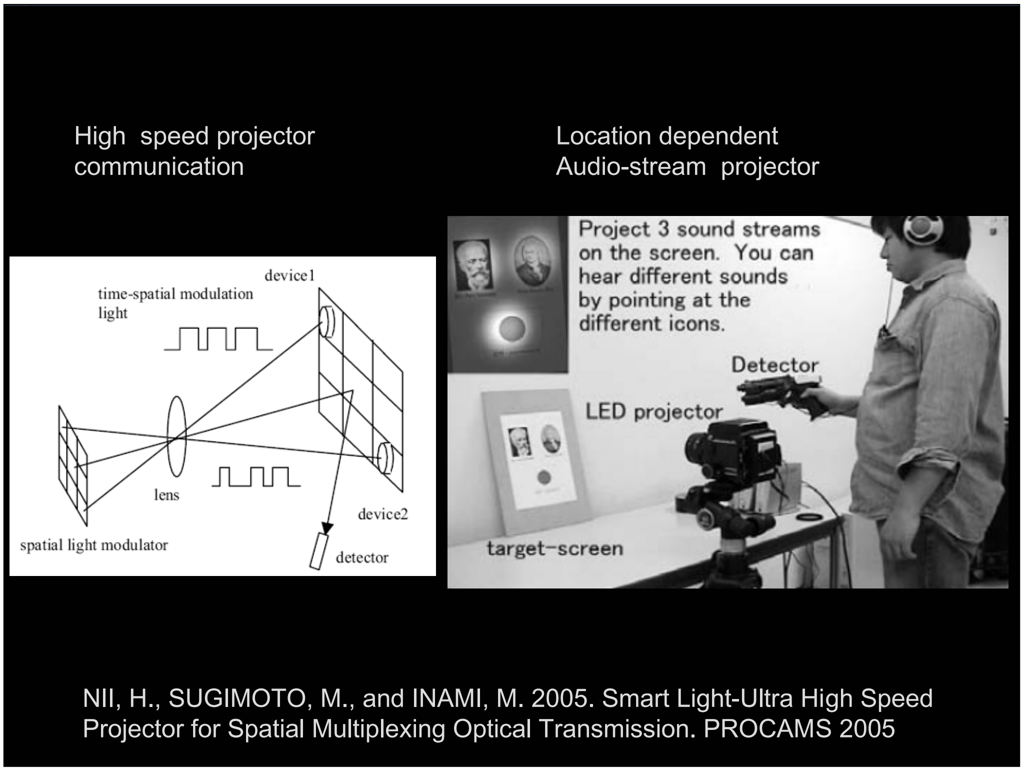
Select tags using desktop like interaction

Machine AR

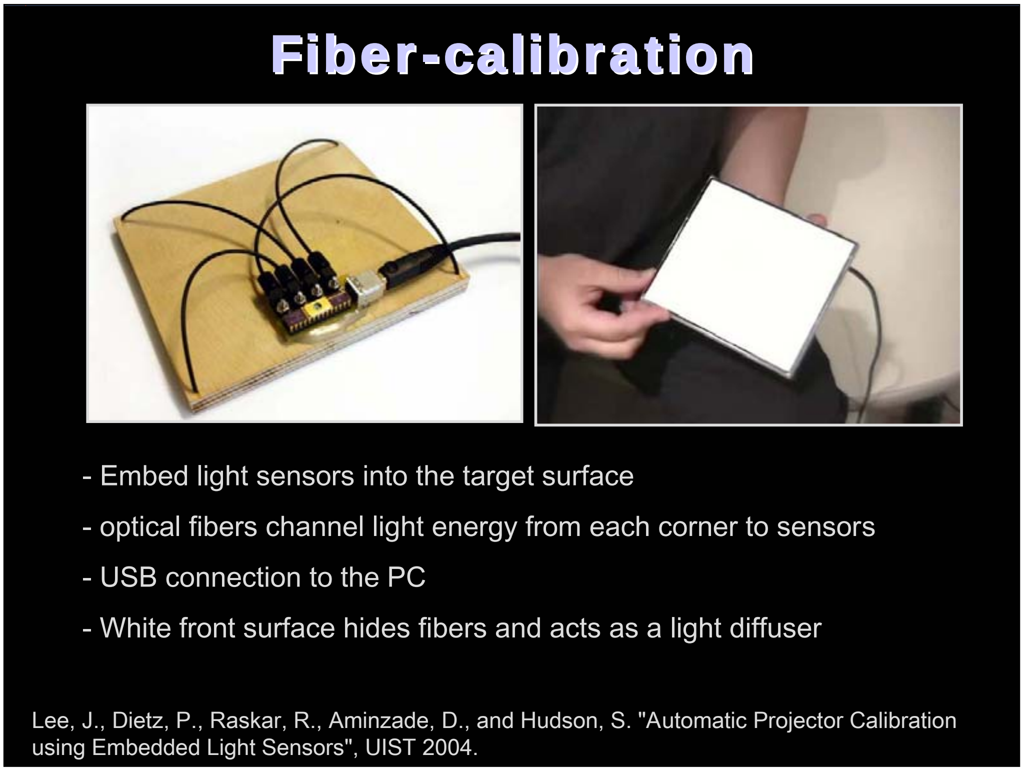
Robot 'Laser' Guidance
Picking and Sorting Tagged Objects



Laser-guided robot. Guiding a robot to pick a certain object in a pile of objects on a moving conveyor belt, the projector locates the RFIG-tagged object, illuminating it with an easily identifiable temporal pattern. A camera attached to the robot arm locks onto this pattern, enabling the robot to home in on the object.

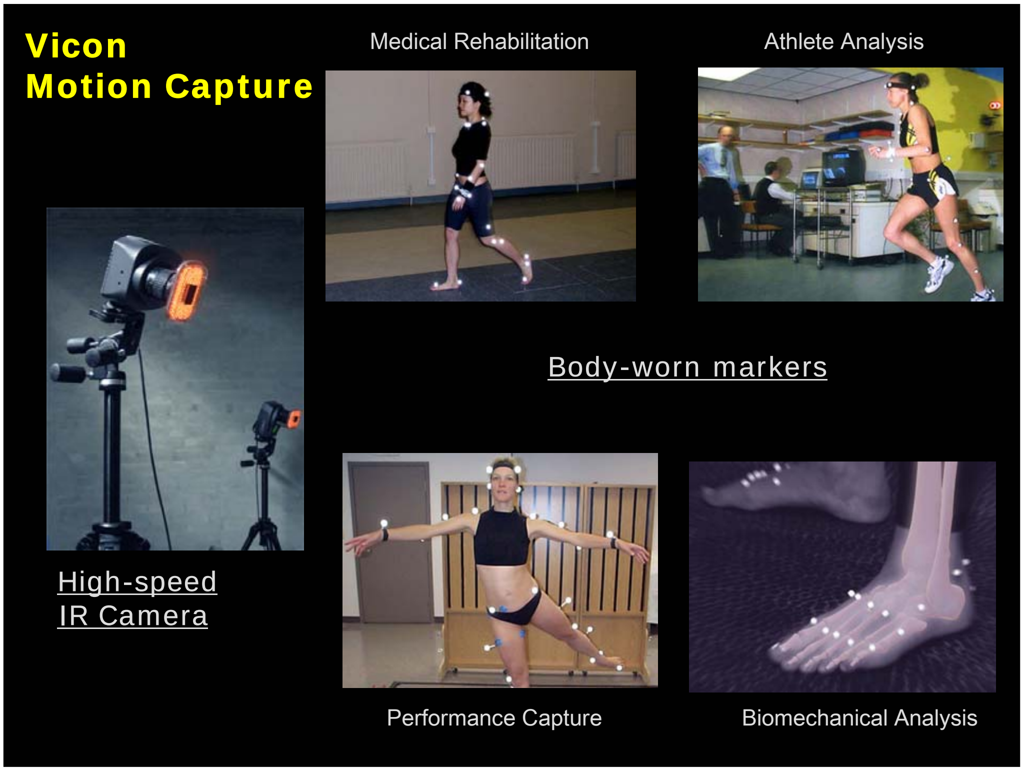


The system built by Hideaki Nii and Masahiko Inami projects 3 different audio streams to different icons on the screen. They made a LED array board that was embedded in the camera and can project 3 different sounds simultaneously. If a subject changes a direction of the detector to a different icon, he/she can hear a different sound.



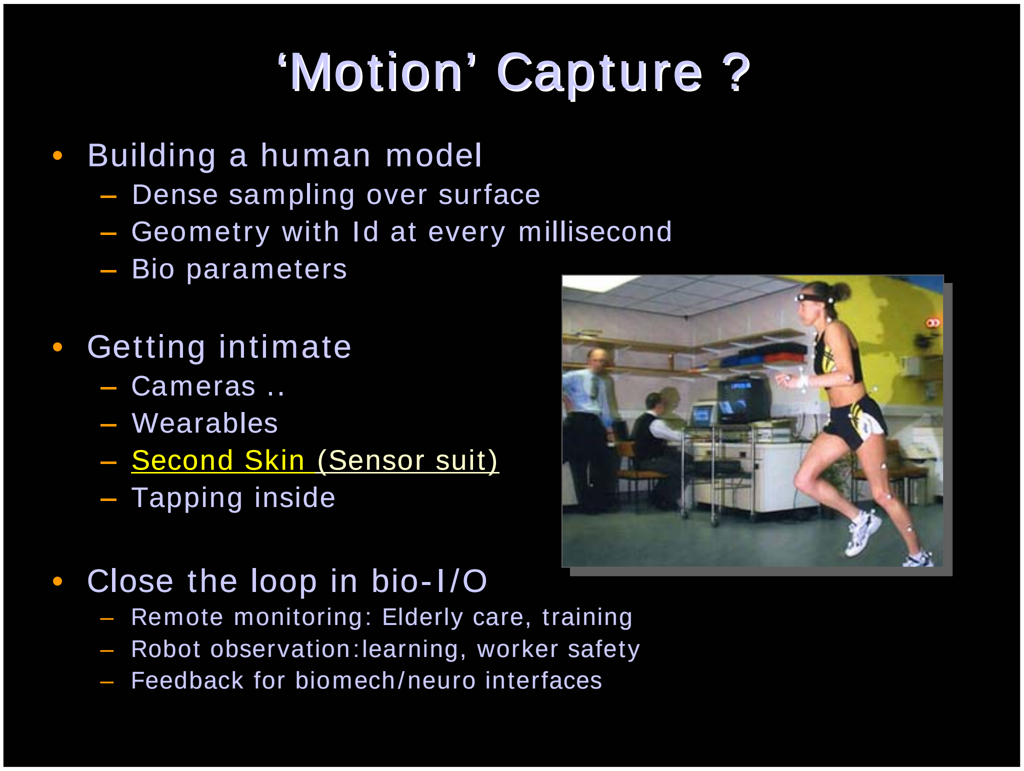
The fundamental concept is to: 1) Embed optical sensors into the projection surface. 2) Project a series of Gray-coded binary patterns. 3) Decode the location of the sensors for use in a projected application. This video demonstrates this idea in the form of a target screen fitting application. It goes on to demonstrate how this approach can be used in multi-projector applications such as stitching (creating a large display using tiled projection) or layering (multiple versions of content on the same area for view dependent displays). Additionally, it can be used to automatically register the orientation of 3D surfaces for augmenting the appearance of physical objects.

This technique is also useful for performing automatic touch calibration of interactive whiteboards or touch-tables.

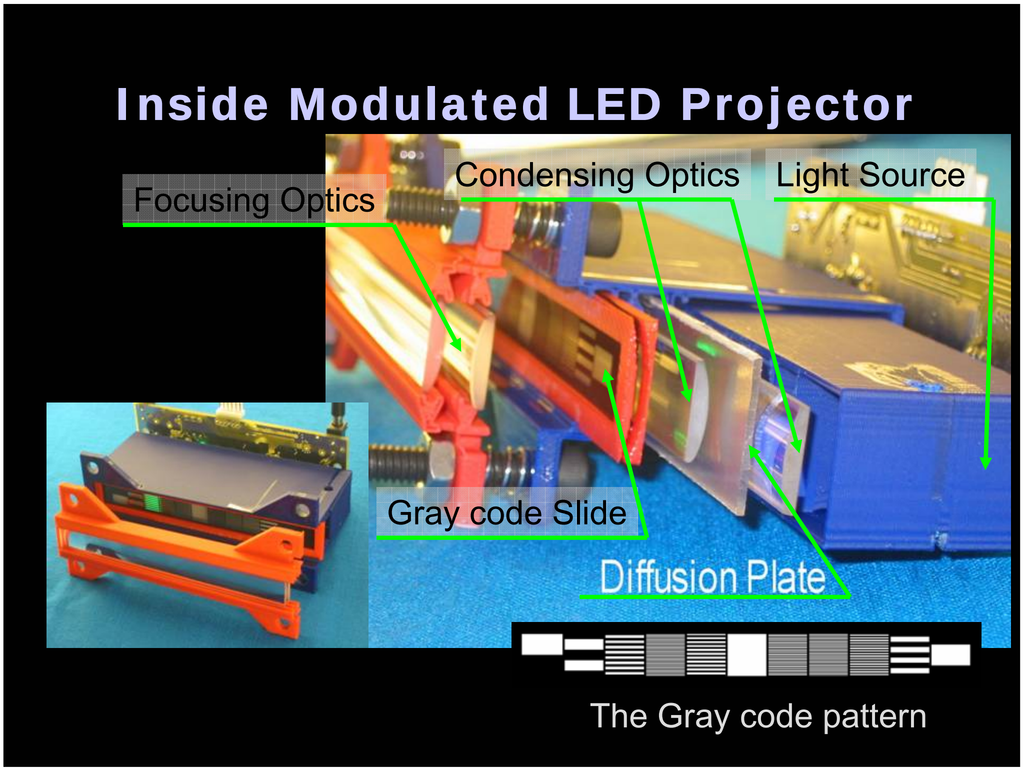


Consider how optical communication can be used to built motion capture systems.

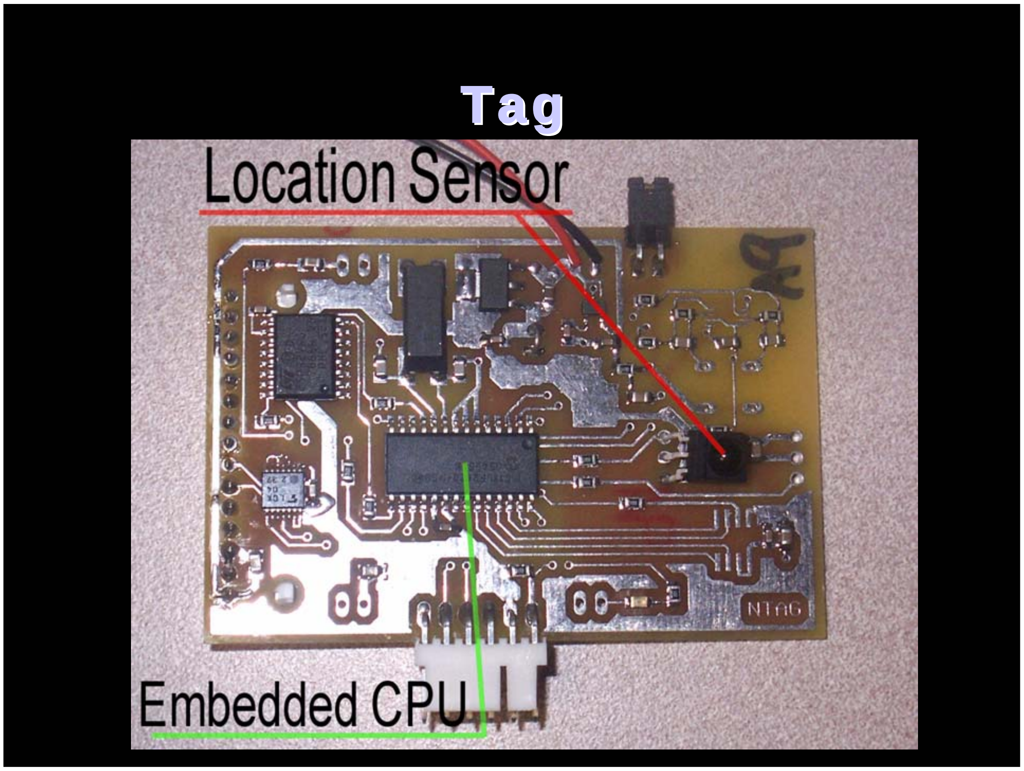
For high speed tracking, the majority of optical motion capture systems use high speed cameras. These camera-based systems require special sensors and high bandwidth, are expensive and use a sanitized environment to maintain a high-contrast between the marker and its background. In this paper, we reverse the traditional approach. Instead of high speed cameras, we use high speed projectors to optically encode the space. Instead of retro-reflective or active light emitting diode (LED) markers, we use photosensitive tags to decode the optical signals.



Unlike previous methods that employ high speed cameras or scanning lasers, we capture the scene appearance using the simplest possible optical devices – a light-emitting diode (LED) with a passive binary mask used as the transmitter and a photosensor used as the receiver. We strategically place a set of optical transmitters to spatio-temporally encode the volume of interest. Photosensors attached to scene points demultiplex the coded optical signals from multiple transmitters, allowing us to compute not only receiver location and orientation but also their incident illumination and the reflectance of the surfaces to which the photosensors are attached.
We use our untethered tag system, called Prakash, to demonstrate the new methods.

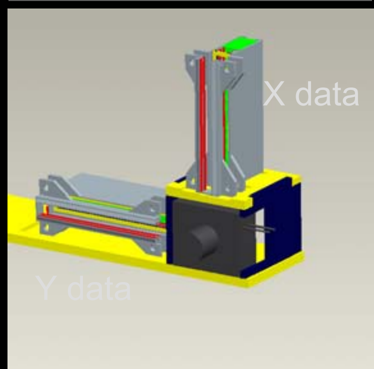


Multi-LED projectors are light transmitters for space-labeling. Each beamer is simply a LED with a passive binary film (mask) set in front. The light intensity sequencing provides a temporal modulation, and the mask provides a spatial modulation. We use a rigid array of such beamers, called projectors. The binary masks of individual beamers are carefully chosen to exploit the epipolar geometry of the complete beamer arrangement. Each beamer projects invisible (near infrared) binary patterns thousands of times per second.

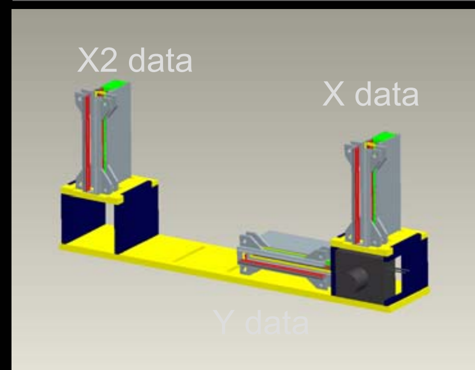


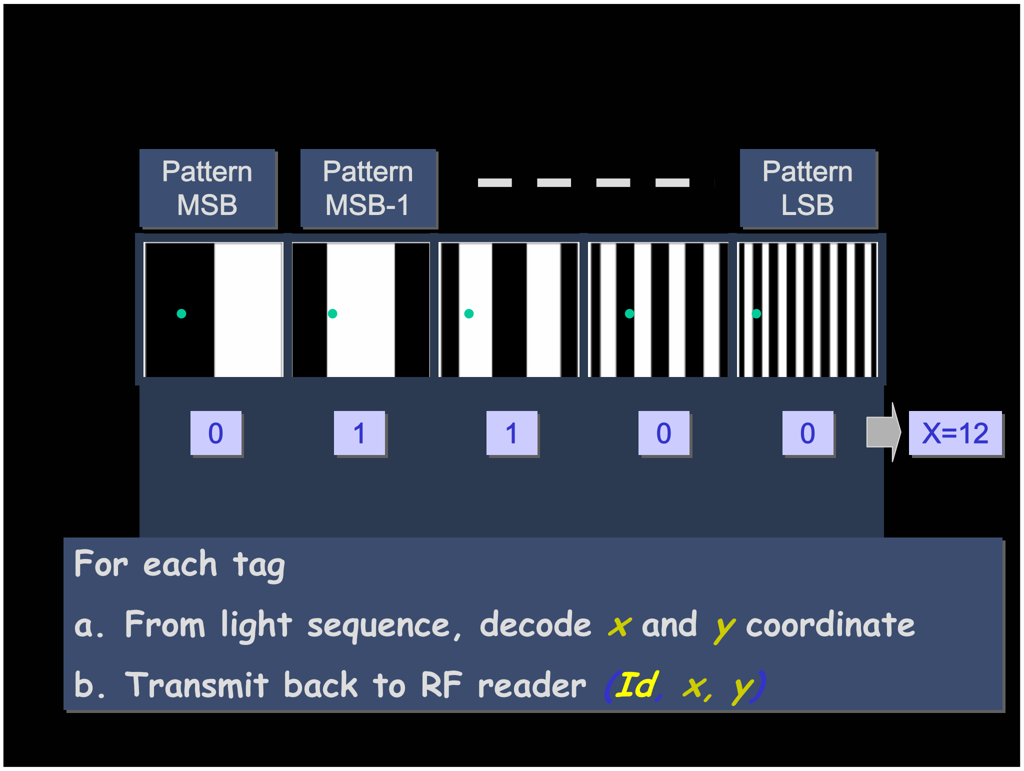
Photosensing
tags determine their location by decoding the transmitted
space-dependent labels.

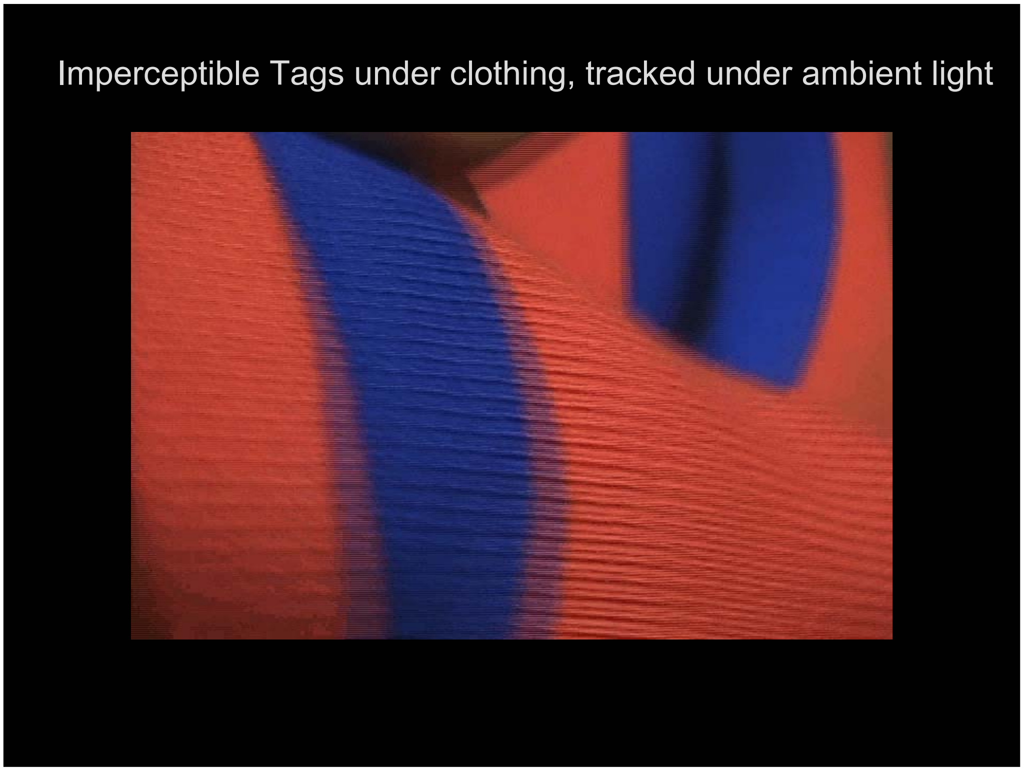
2D Location



3D Location



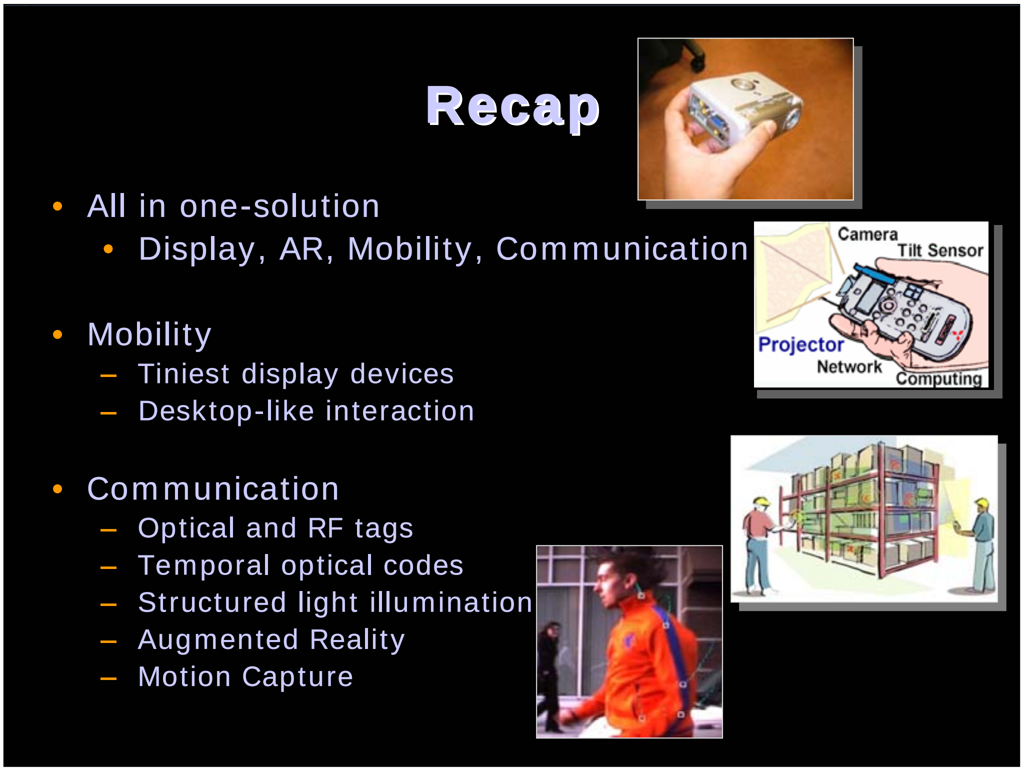

Pattern MSB
Pattern MSB-1
Pattern LSB
0
1
1
0
0
X=12
For each tag
a. From light sequence, decode x and y coordinate
b. Transmit back to RF reader (Id, x, y)



Let us look at the benefits of using multi-LED projectors for communication and photosensing markers.

Expensive high-speed cameras pose several scalability issues. Bandwidth limits resolution as well as frame-rate. Higher frame-rate (i.e., shorter exposure time) requires either brighter controlled scene lighting for passive markers or the use of power hungry active LED markers. To robustly segment the markers from the background, these systems also use methods for increasing marker contrast. This usually involves requiring the actor to wear dark clothing under controlled lighting. The use of photosensing allows capture in natural settings. Since the photosensors are barely discernible, they can be embedded in a wide range of natural clothing so long as the photosensing element is exposed. The power of emitters is comparable to the IR emission from TV remote controls. Instead of high-power emission, we exploit high-frequency modulation to robustly communicate with the photosensors. Similar to photosensors in TVs, our sensors will work in many lighting conditions. So, in studio settings, the actor may wear the final costume, and he/she can be shot under theatrical lighting.

Motion capture to date has been limited to exclusive and special purpose environments. Our low cost, easily portable, and visually imperceptible tracking system makes motion capture practical in a much wider application area. Interwoven tags on can help analyze patient rehabilitation progress after injuries. Tracking may be supportable in home video games and other casual virtual and augmented reality interfaces. The dream of filmmakers and game developers is 'on-set motion capture'. One of the recent examples is the motion and appearance capture in the movie 'Pirates of the Caribbean'. Our system can support this operation with unlimited number of imperceptible and interactive tags.



Mobile projectors are allowing new opportunities thanks to the emerging small form factor.

We can use projectors in a flexible way in everyday settings. The basic unit is a projector with sensors,

computation, and networking capability. Singly or in a cluster, it

can create a display that adapts to the surfaces or objects being projected

on. As a hand-held, it allows projection of augmentation

data onto a recognized object, plus mouse-style interaction with the

projected data.

Projectors can also behave as “Smart Light,” which can provide not only images but also optical information.

The ideas provide geometric underpinnings for a new generation of projectors – autonomous devices, adaptive to their surroundings and able to optically communicate with smart devices.