A New Device for Holographic Photography

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Abstract

For proper reproduction of real-life scenes as digital full-colour holograms, HPO digital holographic printers require a set of scene images prepared according to certain rules. As the visual field of view characteristic of modern digital printers now approaches 100 degrees, previous "camera on a rail" technologies have been largely incapable of generating the required images. We describe here a new type of "camera on a rail" device which allows one to prepare high resolution undistorted image sets appropriate for modern high-resolution high-FOV digital printers such as those developed by Geola Group and XYZ Imaging Inc. The device described is based on latest generation digital camera technology, a specially programmed linear and angular camera trajectory and software image distortion. The sets of real life scene images prepared by our device are also compatible with images sets produced by 3D design programs; this allows combinations of real life and virtual scenes to be printed as digital colour holograms

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Introduction

Simple digital stereographic hologram printers appeared in the 1970s and typically used image data from a static movie camera and a rotating stage on which a subject was placed. Later, reflex cameras on a rail were used to generate data particularly for small embossed holograms but also for larger work. Due to the poor quality of data of these early stereographic printers image capture was not perceived as a problem.

More recently however full colour dot-matrix printers such as those patented in 1999 by Geola UAB have been able to produce fundamentally higher quality HPO (horizontal parallax only) reflection holograms. These holographic printers can produce holograms up to 1 x 1.5m.

This new generation of holographic printer places fundamental new pressure on image capture systems for the production of holograms based on real-life objects. Because of the size and increased resolution of the new holograms, up to 1000 high resolution pictures are now typically required to be captured within a few seconds from a real-life scene if an HPO hologram of this scene is to be printed. Additionally the field of view of contemporary holograms has risen to around 100 degrees. Typical modern printers therefore require image data to be collected from a camera that has an FOV of approximately 100 degrees - Picture 1.

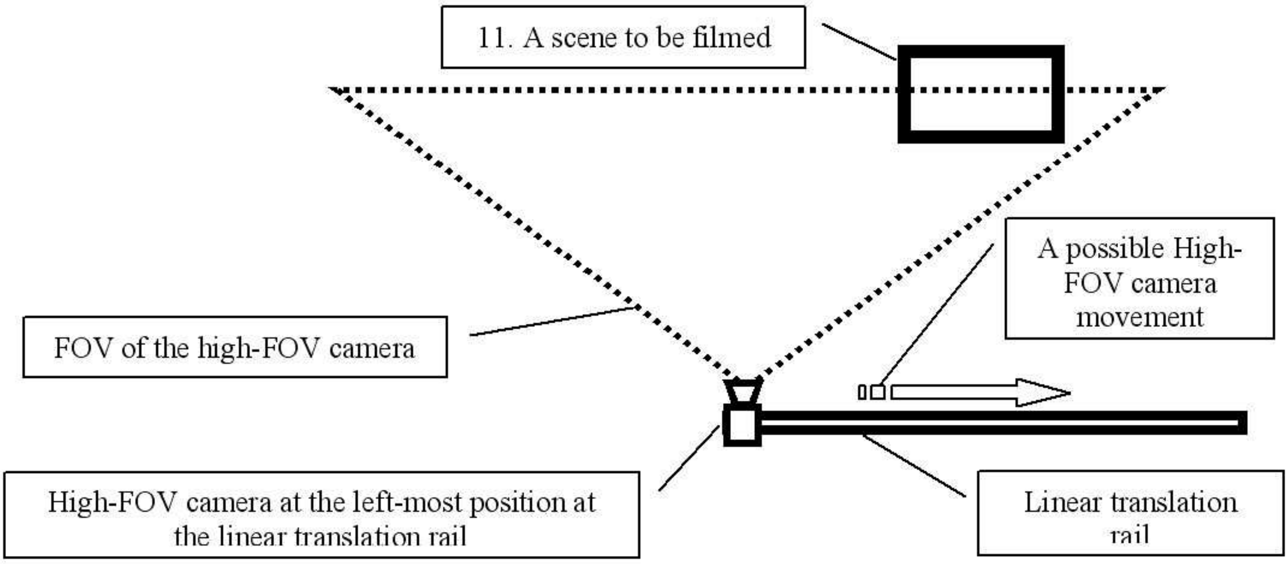


Fig. 1 A diagram of a perfectly translating high-FOV camera on a rail

The combination of high-resolution holograms and their high FOV means that the conventional solution for image capture of a real world scene of translating a forward facing camera on a rail is impractical. CCD arrays are not currently available of the size required. One known solution is to translate the CCD in the camera itself as the camera itself translates on a rail. However, not only does this require making a specialized camera and an extremely precise movement of the CCD, but the resulting image is necessarily severely distorted by the need for an extremely high FOV lens.

We therefore needed to find a novel and effective solution to this image capture problem. Our invention, GEOLA HOLOCAM (initially called HOLOSHOT) is a portable system that comprises a stepmotor-controlled translating digital camera mounted on a 1 to 4 meter horizontal rail whose direction is constantly modified using a rotational electromechanical stage. The camera uses a low FOV lens with zoom-in zoom-out function. A computer running a GUI controls camera operation and camera movement. Because of the high frame rates required acceleration and deceleration phases of the camera are provided for such that when taking pictures the camera does so at a constant rate. We use a novel numerical algorithm to transform the data obtained from the camera to produce high-resolution distortion free data of a format that is required by modern printers (i.e. data produced by a high FOV purely translating camera). Results from our system clearly show it to be a superior method to the prior art and is capable of producing fundamentally better holograms. The simplicity of the solution also means that HOLOCAM is portable and, for static objects, several HOLOCAM systems can even be linked together to produce better data.

Working Principles of the GEOLA HOLOCAM

Fig.2 shows a diagram of the stationary GEOLA HOLOCAM system incorporating an electromechanical stepper-motor rail (2.1), a digital camera (2.2), a stepper-motor precision rotation stage (2.3), a camera zoom objective (2.4), a controller that digitally controls a stepper-motor precision rotation stage and an stepper-motor driven rail (2.8) and a computer (2.7). The object (2.5) to be recorded is placed at a known distance from the rail.

Initially a frame (2.6) is used to mark the physical edges of the desired scene to be printed for the hologram. It is placed horizontally parallel to the camera track and vertically such that the camera track height is the same as the centre-point height of the frame. The object is generally placed within this frame and whatever part of the object projects out in front of this physical frame will then project out of the final hologram accordingly.

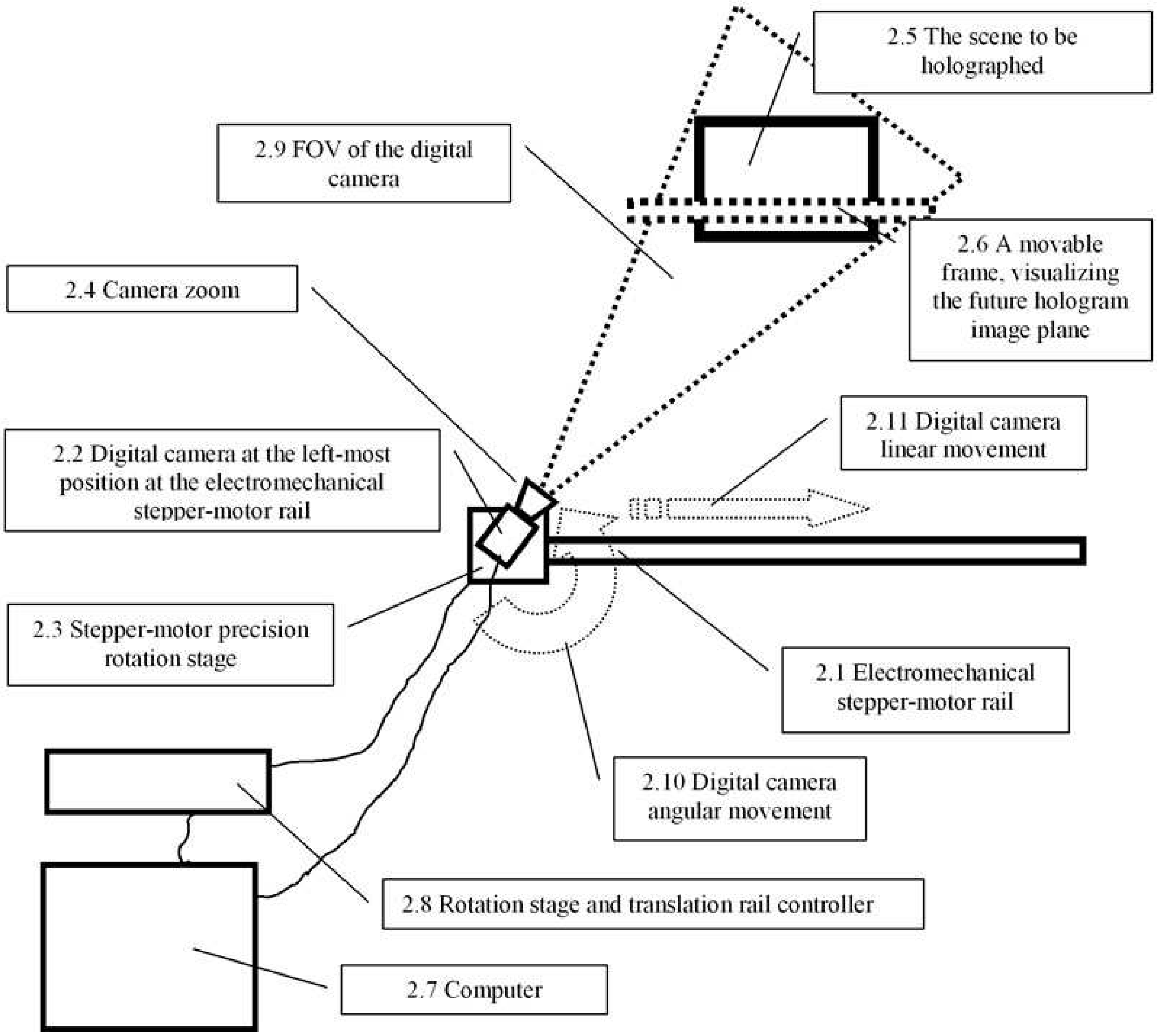


Fig. 2 A diagram of the GEOLA HOLOCAM system.

Given the distance of the frame from the camera track (h), the hologram width (D) (= the frame width) and the horizontal FOV (θ)required by the hologram printer of an ideal purely translating camera, the camera tracking length may be calculated. The half of the required camera track length is then given by

$$T = 2h\tan(\frac{\theta}{2}) - D \qquad (1)$$

Since the camera must move symmetrically from left to right (or visa-versa) about the hologram or frame centre-point, given the track length, the start and end camera positions are defined. The rotating camera should move at a constant velocity from one end of the rail to the other. Whilst the camera is moving, the rotational stage is activated continuously so that the camera always targets the centre point of the frame. The camera takes pictures at regular intervals. When the camera has finished taking pictures the image data are processed using a special algorithm.

The operation of the camera can be realized in two different ways. One method (Still) is to synchronize the camera's shutter to each particular camera position on the rail. Another method (Movie) is to use a continuously filming camera and to start filming when the linear velocity of the camera is constant. Both methods have their advantages and disadvantages. By synchronizing the camera shutter to each particular point on the rail more precise pictures are taken, but this is slower compared to continuous shooting. On the other hand, the Movie method allows us to use in our HOLOCAM systems cheap digital movie cameras; but at the moment those cameras have a captured frame resolution that is only acceptable for capturing scenes of sizes up to 90x60cm.

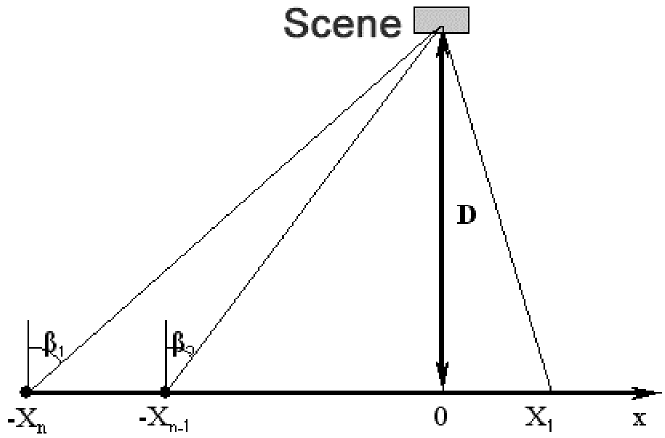


Fig. 3 HOLOCAM camera movement

Control of the step motors is different for Still and for Movie methods. When the Still method is used, the camera is moved to the exact place required, then stopped and a picture is taken, using external camera triggering. Camera angular movement at every position can be calculated by the formula (2):

$$\alpha = \beta_2 - \beta_1 = \left(\arctan\left(\frac{X_{n-1}}{D}\right) - \arctan\left(\frac{X_n}{D}\right)\right); \qquad (2)$$

Where X_{n-1}, X_n – are the coordinates of camera linear movement, D – distance from linear rail (T-plane) to photographing object, α – rotation angle for next image.

When the Movie method is used, the camera should move continuously. As the camera's internal clock is running at a constant frame rate, the linear velocity must be strictly constant, to have pictures taken at the correct points. Rotation speed then may be calculated using the formula (3):

$$\omega(x) = v \cdot \frac{D}{D^2 + x^2}; \qquad (3)$$

Where ω – is the angular speed, x – linear position of camera, v – linear speed, D – distance from linear rail (T-plane) to photographed object.

Both camera movement control methods have been physically implemented in different models of the GEOLA HOLOCAM device family.

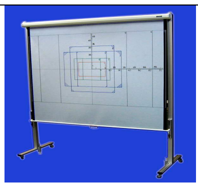
HOLOCAM Systems Family

Currently Geola manufactures two models of HoloCam systems – the Studio and the Compact systems. Both systems are based on the same camera movement principles. The difference between the systems is in their designations – the Studio system is used for the capture of large life-scenes and is performed in a professional photographic-like studio. Compact systems are designed for the capture of smaller life-scenes on-the-road and for the capture of small museum artifacts for their future printing using a digital holographic printer.

The Studio HOLOCAM System.

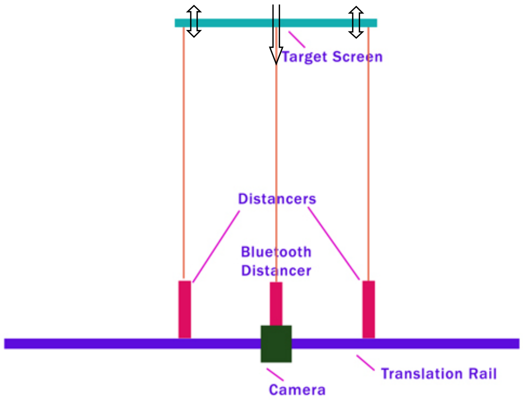
In the Studio HOLOCAM system (the first one is currently installed in OpTIC Technium, Wales, UK) we have used a CMOS camera (MIKROTRON MC311 High Speed CMOS Camera with Camera Link frame grabber) having a pixel resolution of 1280 x 1024 and a maximum frame rate of 500 frames/second. We have used a basic stepmotor and rail system supplied by Isel with a physical rail length of 4.34 meters and a linear movement of 4.1 meters. We have used a rotational stage having a resolution of 200 steps/degree. We have built our own electronic controllers for both mechanical advance systems and for the camera control and data download.

We have implemented a GUI in Microsoft Visual C++ running under Microsoft Windows XP that controls all functions of the HOLOCAM system including data processing. The camera control method "Still" is used for all camera operation. Below are the photographs of the system components and camera's assembly.

			
Movable universal target screen with holder	Holoshot motors and camera controller	• Rapid moving precision translation	• Precision rotation stage

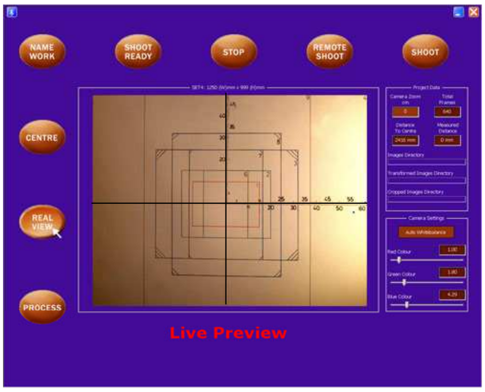
Picture 1. Some components of the Studio HoloCam (HoloShot) system

Picture 2a. Studio HoloCam (HoloShot) assembly



Picture 2b. Scene setup in Studio HoloCam (HoloShot)

For a cquick and proper scene setup, we have used in this model a target screen with 10 potential hologram sizes drafted in conjunction with a laser distance-measuring device incorporating a bluetooth interface. The photographer positions the target screen in such a way that the desired hologram format fills the whole HoloCam program interface window (Picture 3a). When the target screen is placed at the right place, the distance is checked with a laser distance meter and the measured figure is entered into the HoloCam software; this is used then for image transformation processing. The screen is then rolled up and the photographer can set up the desired scene lighting (Picture 3b).



Picture 3a. Studio HoloCam GUI screen shot. Target screen is placed for shooting a hologram of 1x1.5m

Picture 2b. Scene lighting setup in Studio HoloCam

When the scene is setup, the camera moves to the filming start point on the linear rail and rotates until it points at the center of the scene to be shot. Then the distance control key is activated and the filming starts. In 15 seconds the camera moves from its start position to the end position (4.13m maximum), while rotating and pointing at the center of the scene. During this movement the camera makes 640 shots of the scene to be printed on the hologram. Then each frame shot is processed by software and is ready for submission to a digital holographic printer.

The Compact HoloCam System.

In the compact system (Picture 4), a shorter precision translation rail is used – only 1 meter in length with a 92cm linear movement. The same rotational stage having a resolution of 200 steps/degree was used for the camera's rotation. A standard pocket photocamera (a Canon PowerShot S2 IS) is used as an image capture device. An external activation trigger was implanted into the camera, thus allowing us to activate the camera from our controller. The device uses the "Movie" method of camera movement for life-scene shooting. The "Still" camera movement control method is however also implemented in the device controller, so it is also possible to shoot small static scenes with full photocamera resolution. Of course the scene's capture then takes at least half of hour, but this feature is useful, for example, for filming museum artifacts for holographic archiving.

Picture 4. HoloCam compact

The size of the scene that this device can shoot is only 64x48cm. However it is the perfect solution when scenes must be shot outside the studio.

The HoloCam and Hologram Production.

As mentioned above, before the invention of the Geola HoloCam system, modern commercial large-format holographic printers were only able to print scenes created in sophisticated three-dimensional design programs such as 3D Studio Max™. Because of this, three-dimensional printing was used problematically in the usual advertising and mass media production chain. Moreover, all the experience and expertise of two-dimensional media creators were not involved in the new process of the creation of three-dimensional prints. With HoloCam, putting a three-dimensional scene onto a three-dimensional print becomes a convenient and simple process, similar to usual photographic operations.

Below we present one example of results obtained with a GEOLA HOLOCAM in middle of 2005, when the firsts life-scenes were captured and printed as colour holograms.

left centre right

Picture. 5. Beer advertising hologram with model. The scene was captured using the first Studio HoloCam device and printed on a digital holographic printer in Vilnius, Lithuania.

The scene was shot in a professional photographic studio, using professional photographic expertise for the scene's setup, make-up, lighting and model behavior preparation. The live capture of this scene took one hour, of which the scene's capture itself took 15 seconds and the rest of the time was used for the scene's set-up in a professional photographic manner, using the photostudio lights.

The 640 shots taken were processed with Geola's HoloCam program. Figure 5 shows three frames from the whole captured image sequence

Picture. 6 Raw camera data taken with a hybrid rotating/translating camera

Then the images were automatically transformed into the images that would have been captured if instead of the rotating-translating camera a purely translating camera with much higher FOV would have been used.

First image processed   Center image processed   Last image processed

Picture. 7 Cut Transformed images data

Note that since the format of these life-images is fully compatible with the format of virtual images obtained from three-dimensional design programs, it is possible very easily to combine real and virtual scenes in one full-colour digital hologram.

Conclusions

- A new device enabling the capture of life-scenes for digital holographic printing has been invented.
- The HoloCam (previously HoloShot) device separates the life-scene imaging acquisition process from the hologram production process thus allowing the preparation of images for holograms in a convenient photographic way and in photographic studios.
- The scenes shot by Geola's HoloCam devices are fully compatible with those created in 3d design programs; this opens up a lot of new possibilities for positioning digital holograms as a new advertising medium.
- Geola's HoloCam device, in conjunction with modern digital holographic printers should help open a new commercial era in imaging holography.