Computer Vision + Paintball: A Real-Time Autonomous Sentry Gun

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Computer Vision

Target tracking is based on colored jerseys worn by the player.

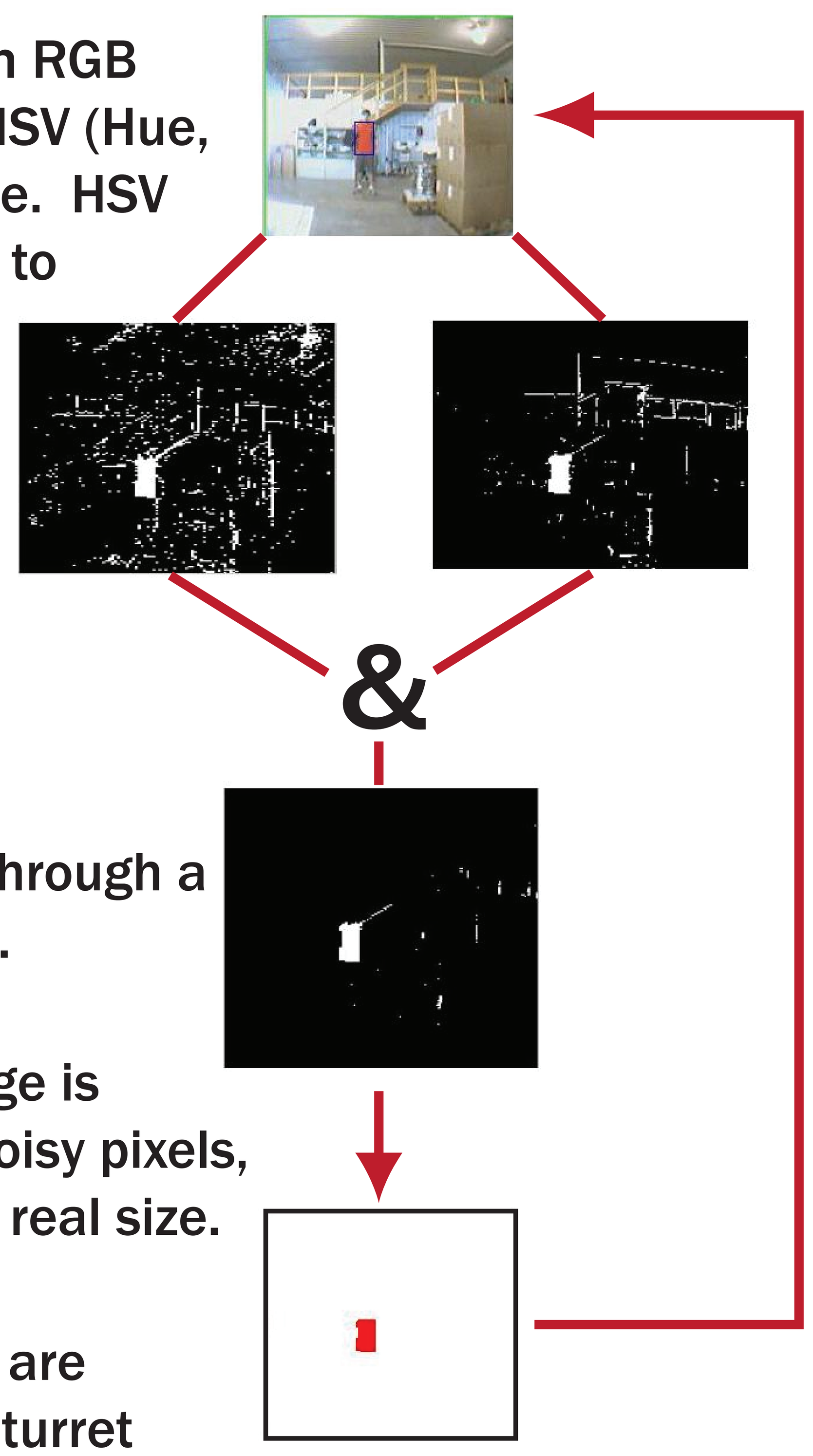
-The frame is converted from RGB (Red, Green, Blue) into the HSV (Hue, Saturation, Value) colorspace. HSV colorspace is more immune to lighting changes than RGB.

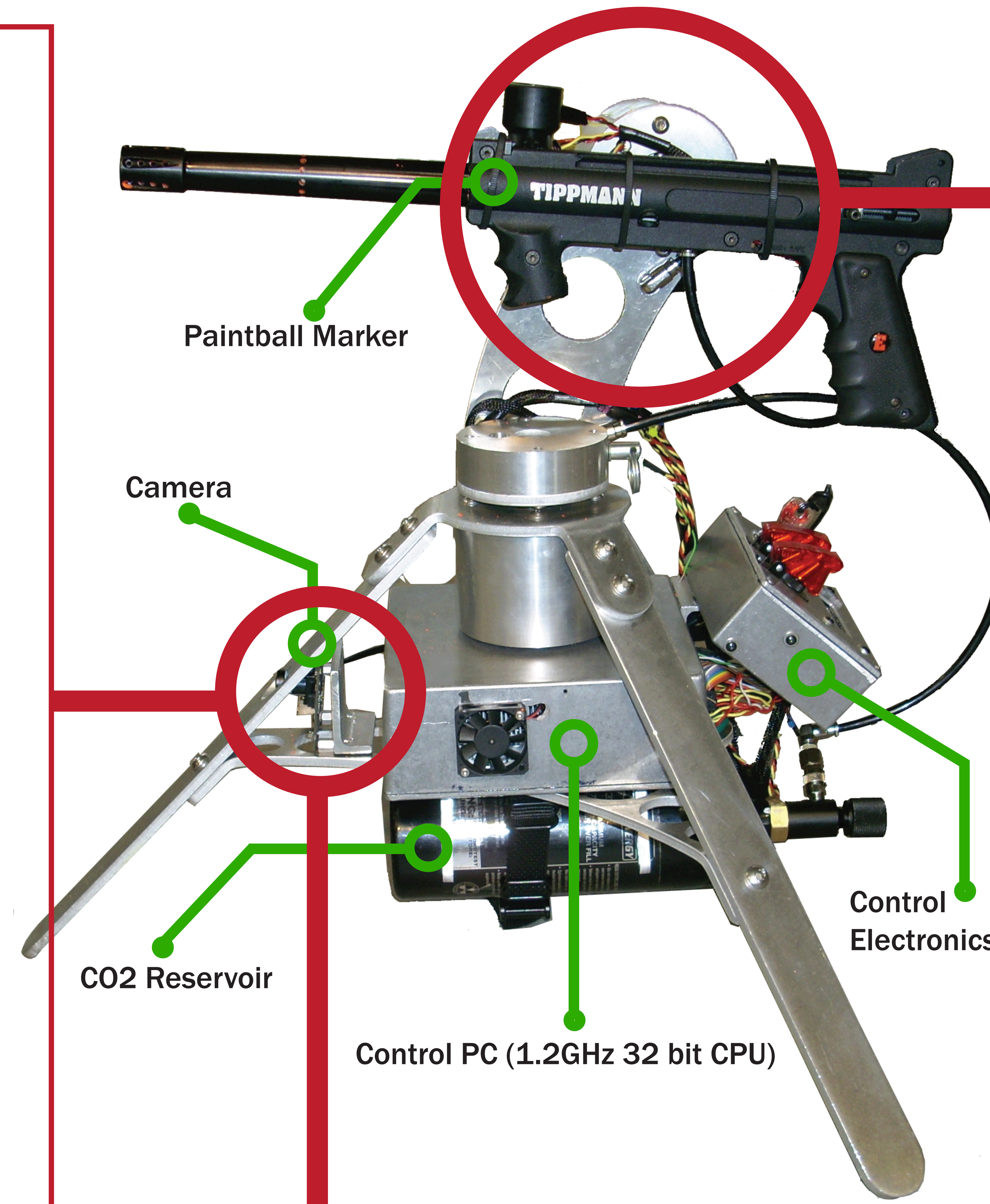
-H and S frames go through thresholding, and are converted into binary images (pixels are either white or black).

-The images are combined through a pixel by pixel AND operation.

-After combination, the image is 'eroded' to clean up small noisy pixels, and then 'dissolved' back to real size.

-The resulting regions in red are considered targets, and the turret begins to track them.





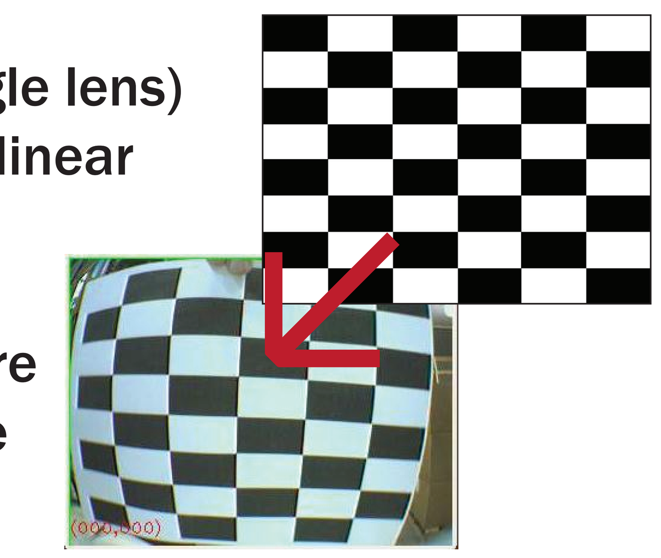
Calibration

Relating pixel coordinates to motor coordinates

-Given a pixel P(x,y), we want to find motor coordinates M(x2,y2) which will aim at pixel P.

-Must compensate for barrel (wide angle lens) distortion, geometric offsets, and non-linear systems.

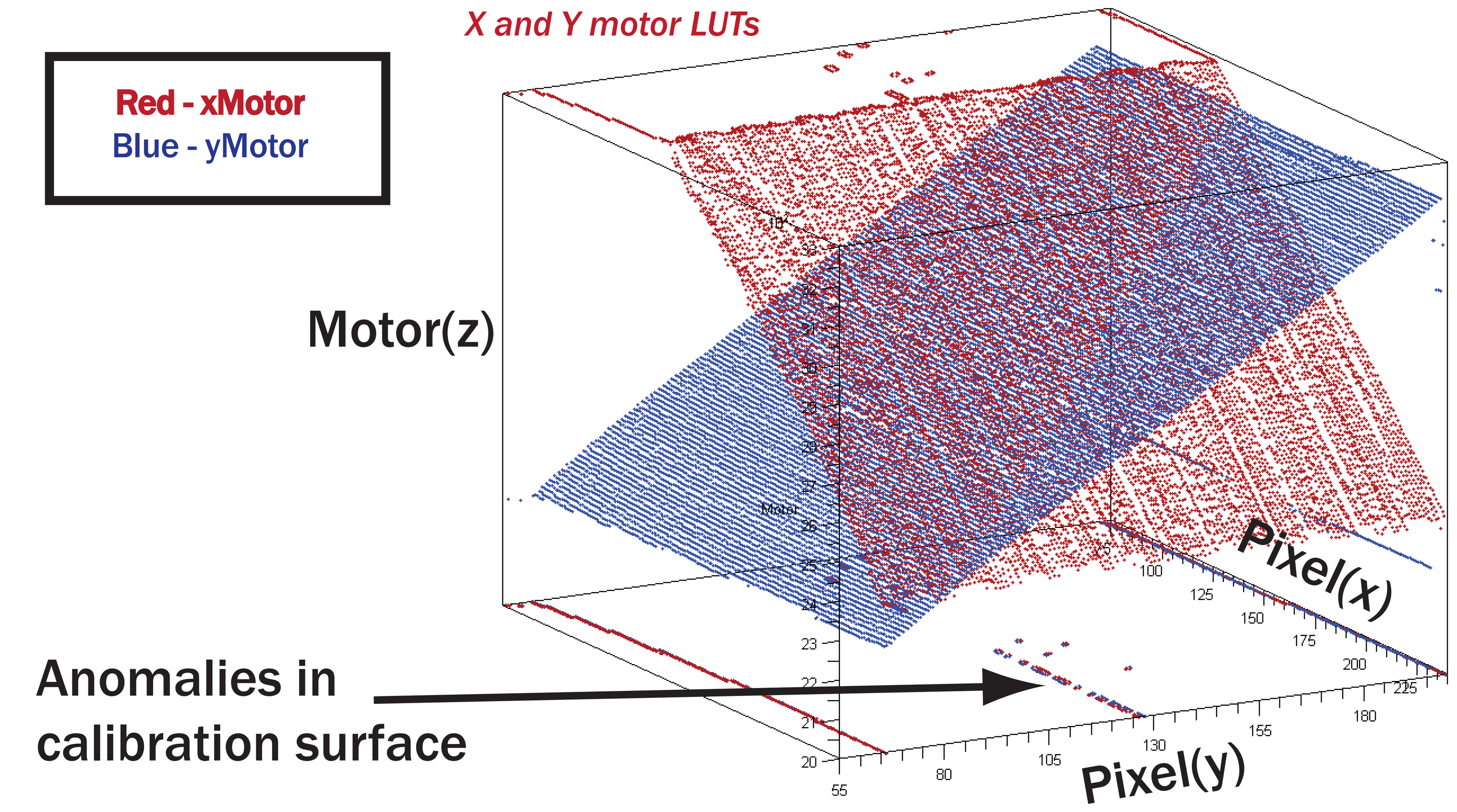
-To overcome complex, hard to measure parameters, an autocalibration routine fills look up tables (LUTs) with motor coordinates for all 76,800 pixels.



Wide Angle Distortion

-Feedback is achieved through a laser affixed to the barrel. The auto calibration routine moves through motor coordinates and records pixel location of laser.

X and Y motor LUTs



Note that every point in the above graph was recorded entirely by the auto calibration routine.

Tracking Methods

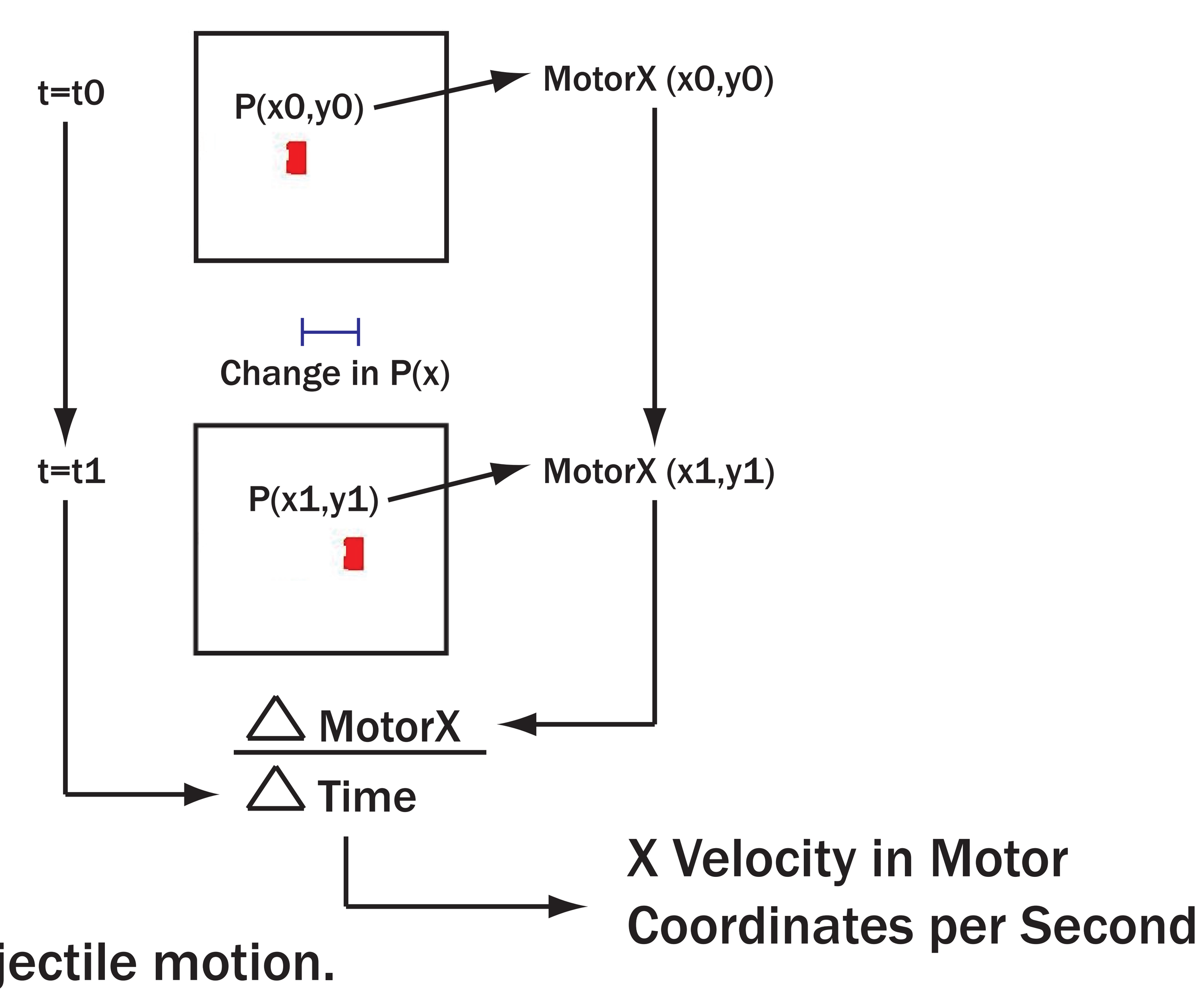
Target position with velocity vector.
The vector is drawn in red, in real time.

-Must compensate for inherent delays in the systems.
-Lag present in: frame capture, algorithm calculations, motor communication, and physical acceleration.

-An array of length n stores target position and elapsed time between frames, giving n-1 velocity readings. Various statistical methods are applied to average the velocity.

-The system can now predict the position of the target t seconds ahead. In practice, with a 1.2GHz 32 bit CPU, prediction is set at 0.15 seconds.

-This method could be expanded to track known paths, such as projectile motion.



Conclusions

Efficient real-time tracking of red and blue targets has been achieved. Targets can be tracked at distances within 20-80 feet. Performance has been verified indoors and outdoors with various lighting conditions. In practice, at 35 feet, a running target will have a 75% chance of being hit atleast once. If multiple targets are present, the turret can track one while ignoring the other, or switch targets based on predetermined logic.

Future Work

- -Range sensing & compensation based on projectile motion
- -Increased field of view and range of motion
- -Improved portability and durability
- -Target hit confirmation
- -Image segmentation to improve response time

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