Evaluation of Temporal and Spatial Characteristics of 2D HYPR Processing Using Simulations

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Summarized By Kacie Jacklin

Purpose of Study

- Evaluate the temporal and spatial characteristics of images produces using the HYPR algorithm.
- Matlab was used to evaluate the properties of HYPR.
  - Bit-reversed ordering was used in obtaining the projections.

HYPR Algorithm

- Spatial information comes from a nearly fully sampled, high spatial resolution, high-quality reference image.
- Temporal information comes from a more sparsely samples temporal weighting image.
- Multiplication of temporal weighting images by spatial-reference composite images yields
    - high signal-to-noise ratio (SNR),
    - low artifact images,
    - good spatial and temporal resolution.

HYPR continued…

$$HYPR(x,y,z) = \frac{1}{N_p} C(x,y,z) \sum \frac{P(r,\theta,\varphi)}{P_c(r,\theta,\varphi)}$$

To prevent the ratio from going to infinity as P_c approaches zero, all values of P_c between zero and a certain threshold, 5% of the maximum value of all the points along all profile P_c, are set to equal this threshold.

The equation to quantify the accuracy of the signal in a HYPR image:

$$D = \sqrt{\frac{\sum \left(HYPR(x,y,z) - INPUT(x,y,z) \right)^2}{\sum INPUT(x,y,z)^2}}$$

To calculate the temporal accuracy, The cross-correlation between the temporal waveforms of the HYPR image and the waveforms of the input image. Cross-correlation is the covariance or the signal similarity between two intensities.

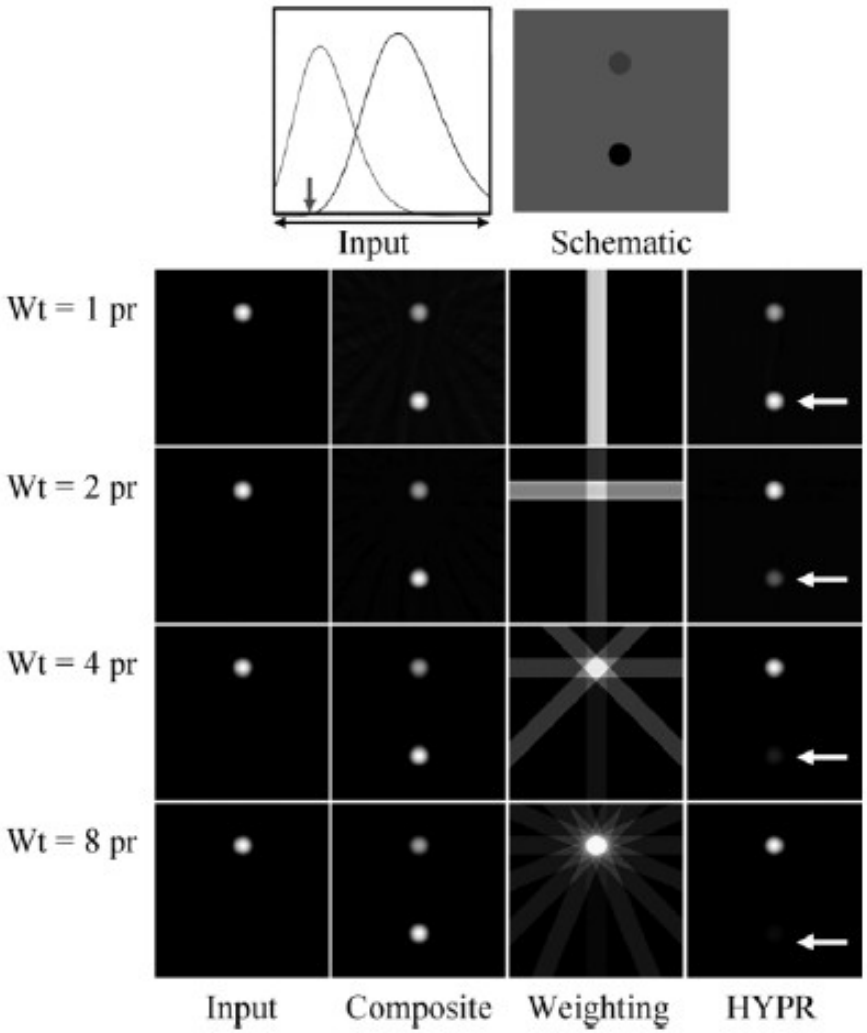
SNR

- SNR - Signal to Noise Ratio
- Signal - measured as the mean intensity of all pixels within the object.
- Noise - measured as the standard deviation of intensities of all pixels within a large region of interest outside the object.
- SNR equals the ratio of then two quantities.
- The SNR of a HYPR image is dominated by the SNR of the composite image.

Composite & Weighting Images

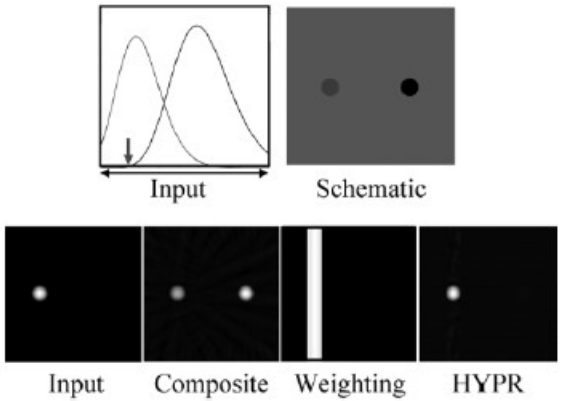
- Filtered backprojection to a large number of profiles yields a composite image that is free of artifacts and has a relatively high SNR.
- Weighting images provide temporal information into the time series of HYPR images. Interference between signals occur when the objects overlap in projections.
- When an image has sparse signal intensity, the weighting images using as few as 8 to 16 projections provide relatively accurate results.
- A sliding window approach results in more accurate intensities in the composite image.

Figure 3

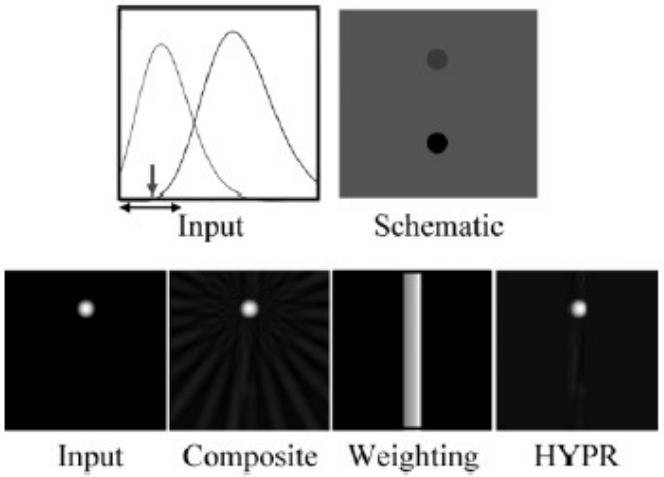


- The composite image is taken over the whole timeframe.
- The objects overlap in the projection.
- With one projection, the HYPR image shows both images.
- This is an early timeframe and should only show the top image.
- As the number of projections is increased, a more accurate depiction is achieved in the HYPR image.

Figure 2 & 4

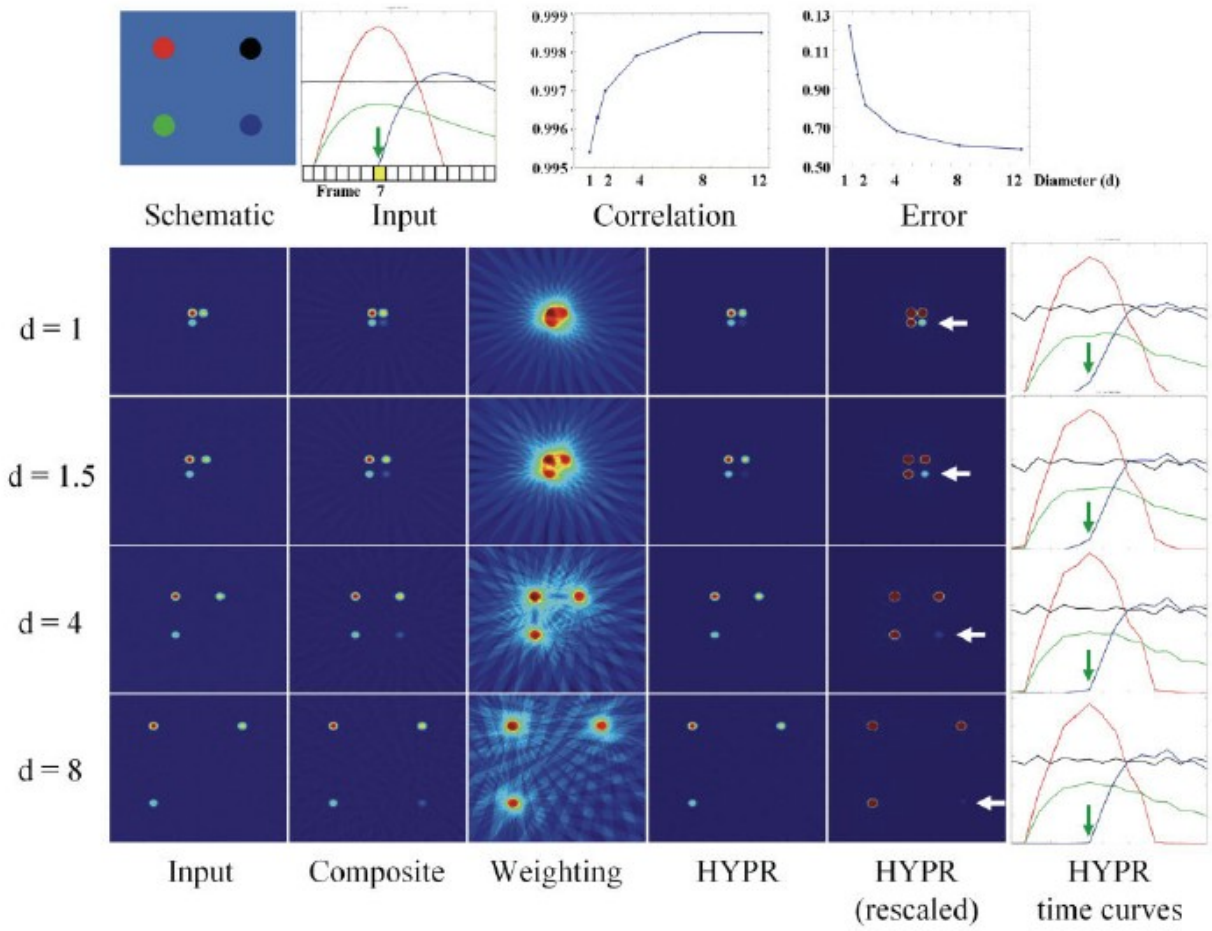


•When the objects don't overlap in the projection, the reconstruction is more accurate.



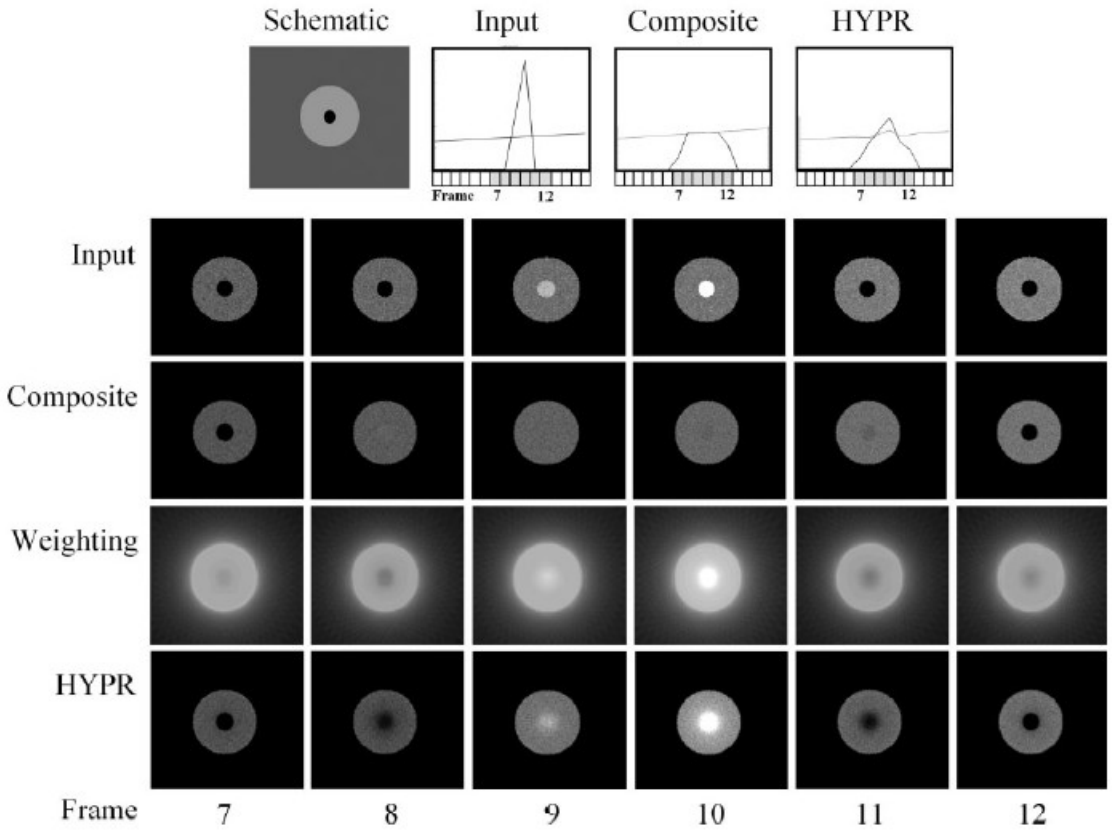
•A sliding window approach for the composite image is used in this case.
•25 projections were used to create the composite image.
•We obtain better temporal accuracy.

Figure 5



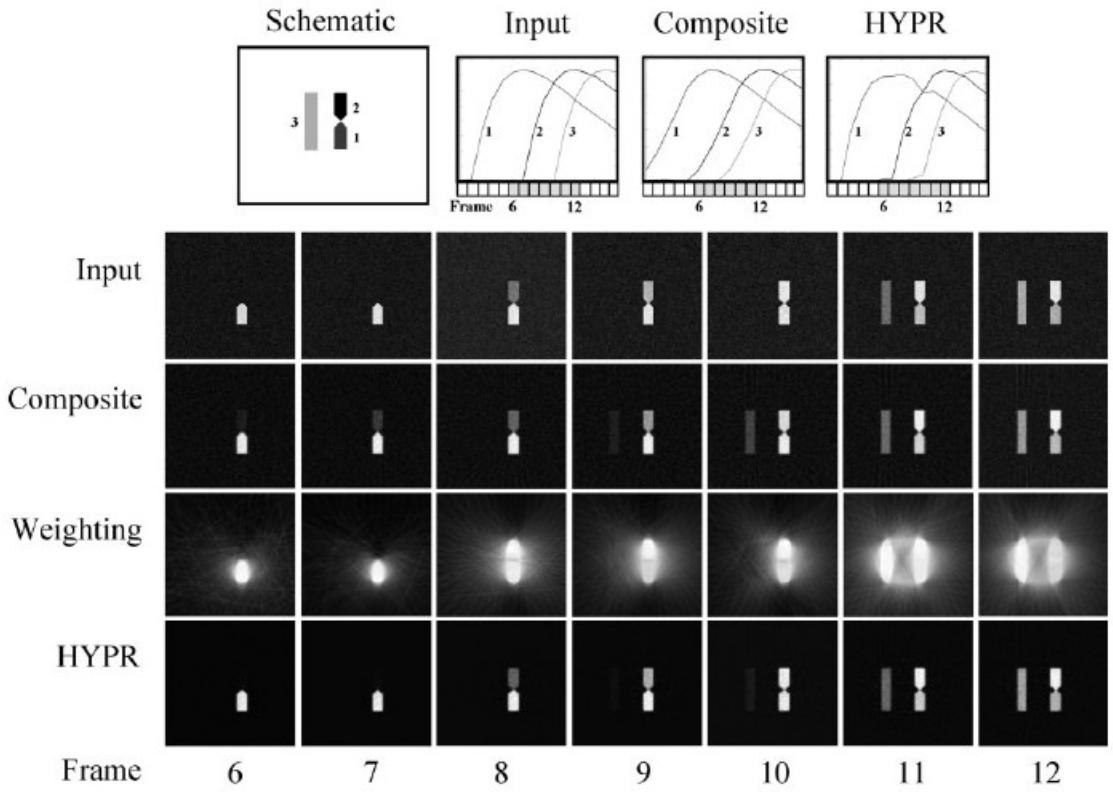
- 4 objects with varying intensities.
- This causes the HYPR image to be less accurate.
- The arrow depicts timeframe 7.
- At this time, the blue object has zero intensity. The HYPR image shows otherwise.

Figure 6



- A circular object within an annular object.
- The circular object's intensity increases and decreases rapidly.
- The annular object's intensity increases at a slow steady rate.
- The objects overlap in every projection.
- This degrades the HYPR image.
- The composite image is a lot worse than the HYPR image.

Figure 7



- This figure depicts vascular stenosis.
- 3 signal varying objects that are very close together.
- Sliding window is used for the composite image with a width of 5 timeframes.
- Noise was also added to the image.
- The temporal waveforms for the HYPR image are distorted, as well as the waveforms of the composite.

Conclusion

- Scenarios when HYPR can produce a less accurate image:
  - Objects are close to each other,
  - Signal intensities change dramatically,
  - Low temporal correlation,
  - A low number of projections is taken.
- Even when there are scenarios that are ill-suited for HYPR, it still performs relatively well.
- HYPR images demonstrate better temporal variations than the sliding window composite image.
- Composite window width can play a part in the quality of the HYPR image produced.