# A real-time data processing framework for steered FUS

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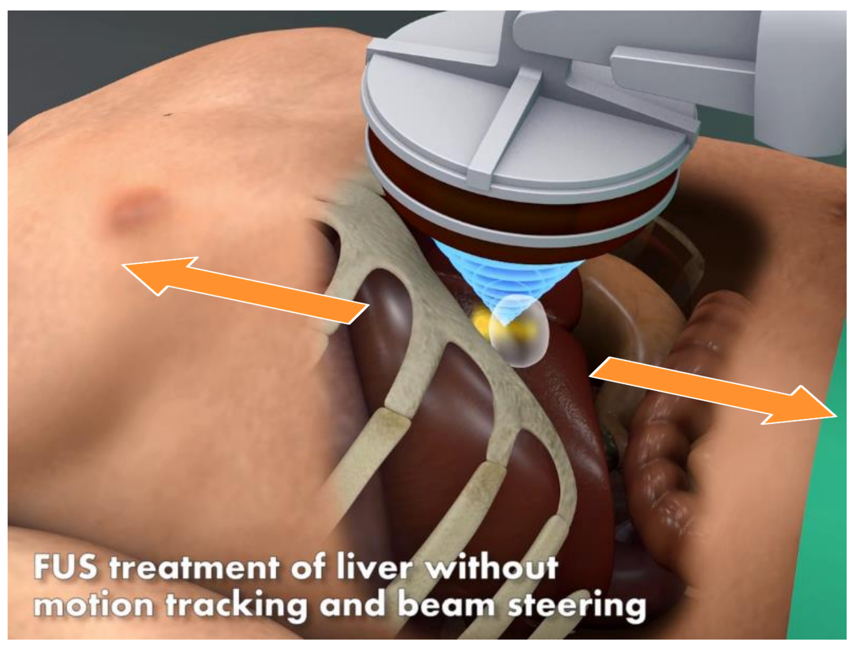
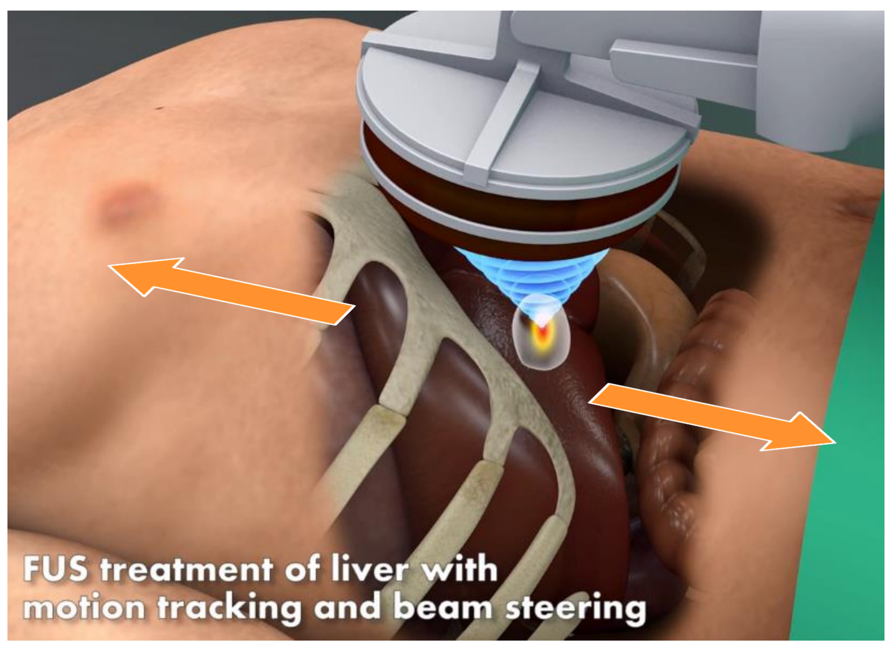
## Vision

FUS in moving organs can be realized by updating the focal spot position to follow the target motion (steered FUS).



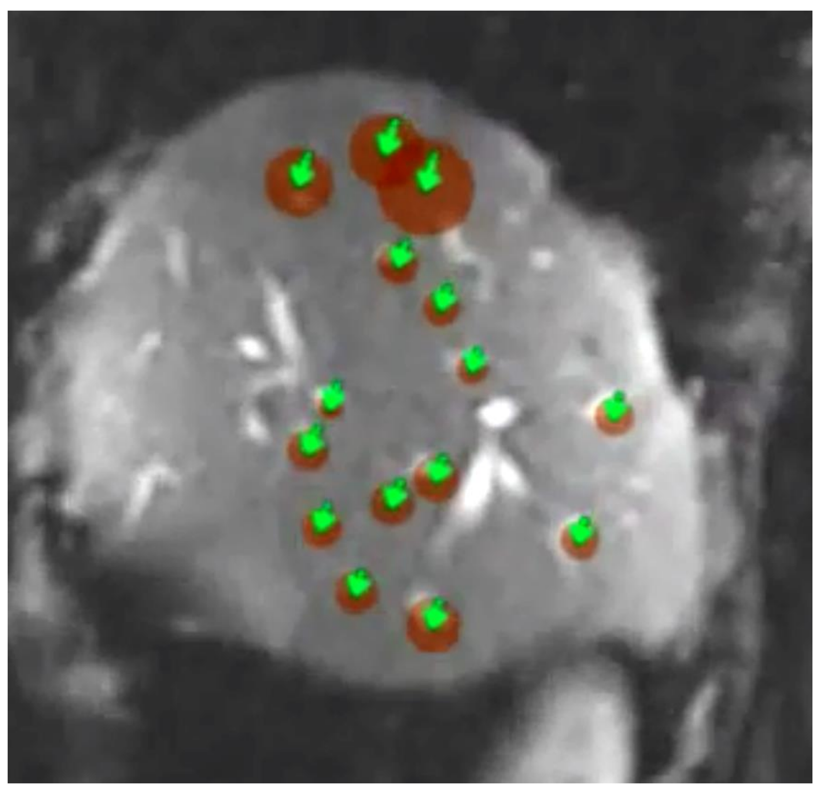

Without steering the energy is distributed to a larger volume.



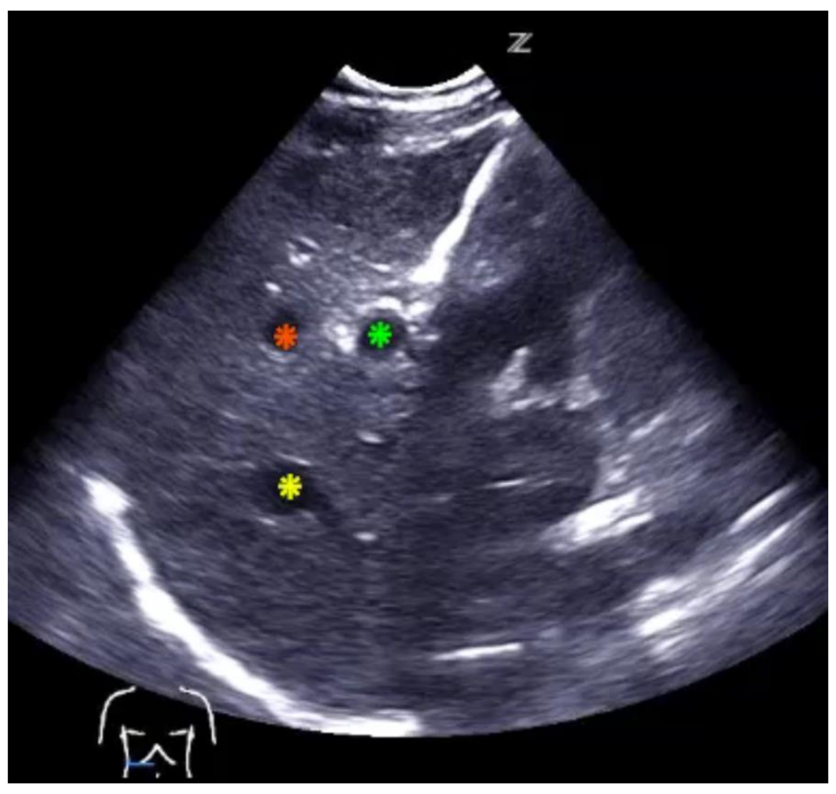

Steering leads to a sharp heating pattern.

## Motion Observation

A key feature of such a system is the ability to predict the target motion for the treatment time. Real-time 2D **imaging** enables capturing some of the organ motion, which is quantified by consecutive **tracking of anatomical features** in the image stream **(observation)**.



Motion tracking on MR EPI images.



Motion tracking on diagnostic ultrasound images.

## FUS control

All occurring **delays need to be compensated for** by introducing a **spatio-temporal prediction** of the potentially unobserved target region and surrounding structures.

The final step in the processing pipeline is the update of the FUS control parameter values derived from the prediction **(control)**.

## Acknowledgements

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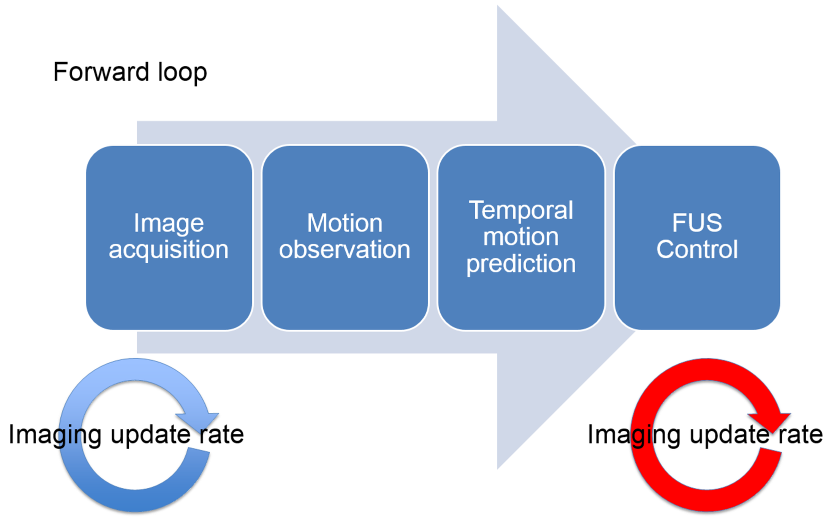
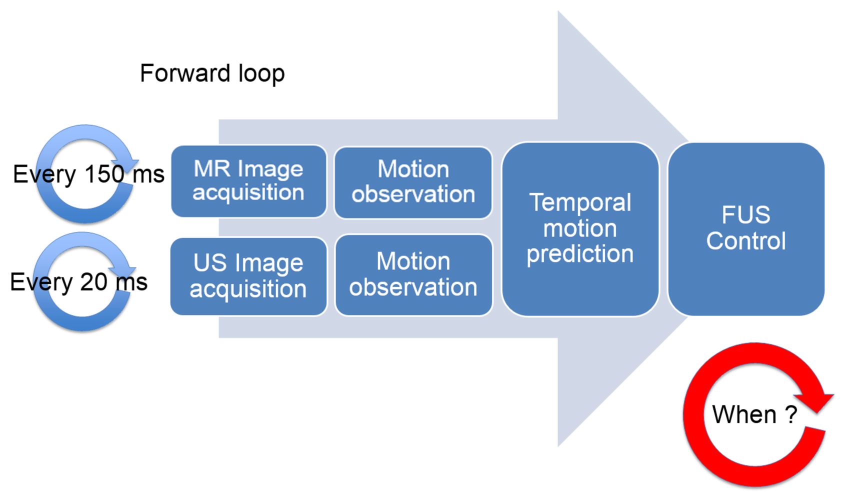
## Processing loop considerations

A common **problem is the tight coupling** between observation and control loop.




Forward loop approach leads to control updates with imaging update rates.

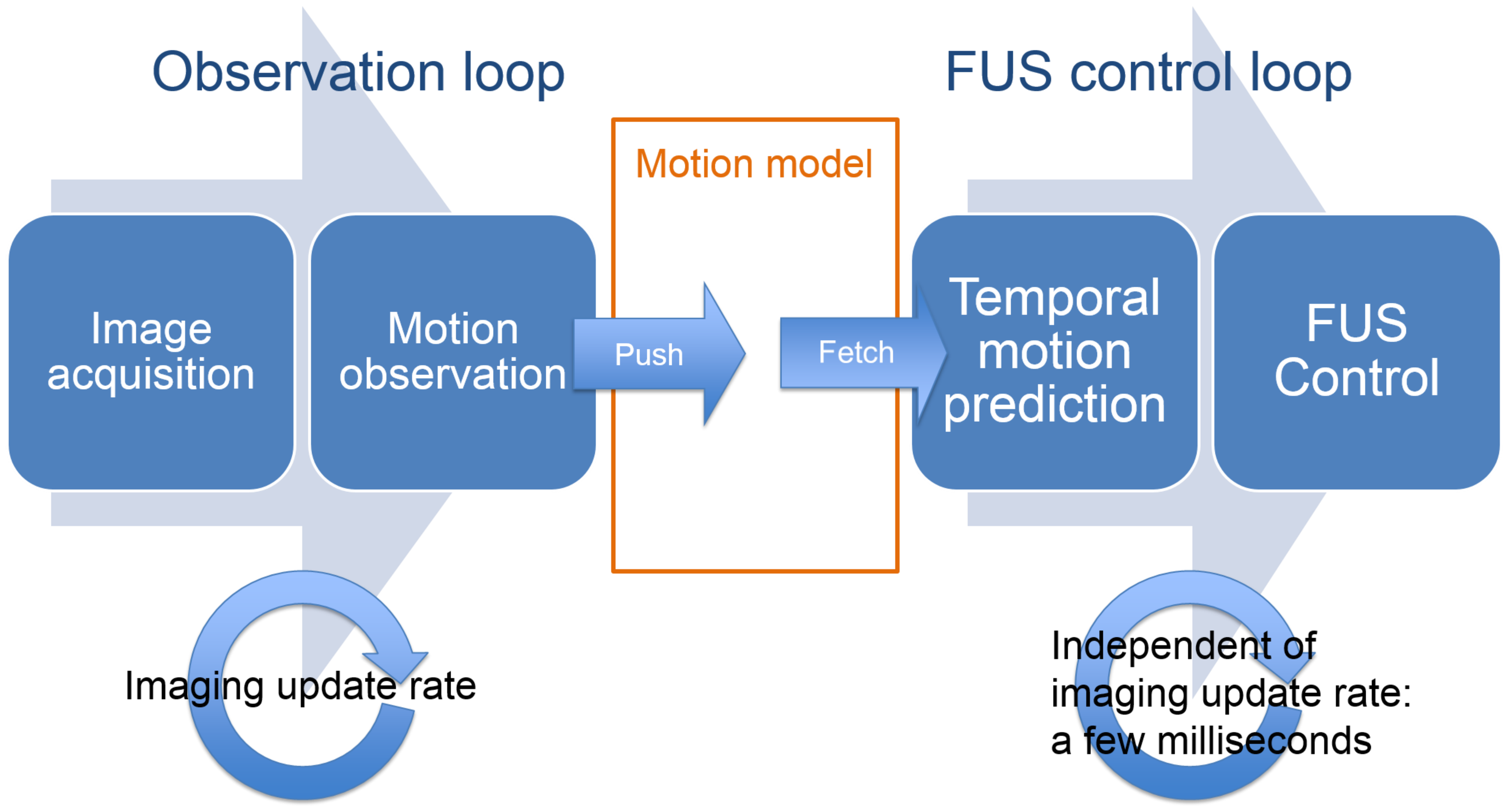



Combination of different sources is difficult in the forward loop.

While the observation rate is restricted by the update frequency of the imaging device, it is **desirable to update the FUS focal spot position as often as possible** to achieve the best possible approximation of the target trajectory given the hardware constraints.

## Decoupling observation and control

We propose an approach for decoupling observation and control loop by **inserting an asynchronous motion model** between the two loops. The motion model is **continuously updated using tracking information** while an independently running control loop **queries the model for target position predictions** and controls the FUS device.




## Results

A **treatment system was developed that implements the real-time processing as described.** The system continuously measures the delays caused by all components (imaging, processing, FUS hardware upload) of both loops to calculate the time between the observed target motion and the actual arrival of FUS energy at the target (time of action). A spatio-temporal prediction is then calculated using the motion model for the time of action to compensate the delays. **The system is currently being evaluated pre-clinically.**

**Furthermore real-time numerical FUS simulations** are currently used to **evaluate** the **impact of the update rates for observation/ imaging and FUS control.**