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## Locating RFID tags for surgical navigation using dynamic neural fields

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# Purpose

In medical treatment navigation is increasingly often a crucial part of operations. In combination with image data, it provides the surgeon with real time visualization when performing minimal invasive procedures. However, there are some limitations to current optical tracking systems [1]. Primarily, the required free line of sight between the camera system and the patient restricts the surgeon's movements. Additionally, optical markers are large and sensible in handling as well as limited in their numbers for parallel use.

To overcome these limitations different types of navigation systems have been considered. Recently, RFID-based navigation entered that list. Such systems allow the localization of hundreds of markers, which exist in various sizes and forms. More importantly, it might be possible to localize targets hidden behind obstacles. However, all RFID-based systems presented so far are lacking in accuracy [2]. The main reason is the occurrence of strong multi-path reflections in crowded environments. Focusing on an evaluation of the direct line of sight signal these can be considered as noise affecting the estimated distances between markers and reader antennas.

In our work we intend to reduce the effect of such multi-path reflection noise algorithmically. This leads to a more stable localization result and will help to enhance the overall accuracy.

# Methods

### RFID system and experiments

The PRPS navigation system developed by amedo STS GmbH especially for medical purposes was used [3]. This system compares an emitted signal with the signal reflections from the marker and returns a value corresponding to the occurring phase difference. Since the signal frequency is 868 MHz a distance between 0 and 17 cm can be detected. Distances which differ by a multitude of 17 cm will results in exactly the same measurement. Therefore we obtain more than one distance measurement for each connected antenna. In our experiments this was restricted to 5 alternatives for a target area of 100 cm × 100 cm.

To produce a mapping between the measurement values and phase differences, measurements were performed in steps of 1 cm over a distance of 70 cm. With this, measurements were recorded in different positions for one minute each and recomputed to distance estimations.

For simulations the phase difference was drawn from a Gaussian distribution instead. All positions with a distance to the antenna corresponding to this phase difference were computed with a resolution of 1 cm – resulting in circles with changing radii.

### Localization

In the described scenario every combination of several distances per antenna must be considered to find the desired marker position. Once noise is taken into account, the best fitting intersection point might quickly jump from one set of distance combinations to another. Hence small variations in the phase measurements might easily cause large shifts of the calculated marker position. As a consequence we adopted only the representation of trilateration but applied dynamical neural fields to stabilize the best fitting intersection.

### Dynamic neural fields

Dynamic neural fields are inspired by neural connectivity within the human brain and are largely applied to problems in the field of robotics [4]. They are usually described in form of a field equation. Relevant components in this are the activation of neurons, their connection and an activation depending firing function. Of further importance are the local input and a time constant describing the relaxation to a base level of activation [5].

Such neural fields can produce complex dynamics when the connection parameters are chosen appropriately for a given input. The features we are aiming at are detection of strong recurring input and selection between competing regions of activity for a decision between intersections.

For the implementation we used the open-source Cedar framework. To reduce the influence of strong radius shifts a high time constant was chosen. By defining the neural field with global inhibition and strong local excitation, a reliable creation of stable peaks may be achieved.

# Results

### Noise in PRPS data

All measurements showed fluctuations in the signal for fixed marker positions. After conversion the signal had a standard deviation between 0.3 and 1.4 cm under optimal conditions. In an application scenario this went up to 4.2 cm in the worst case with an average deviation of 2.4 cm due to changes in the environment. The quality of the mean distance and thus the occurrence of systematic errors are so far not taken into account. However, these values can be seen as a lower limit of the required noise reduction to make RFID localization work on centimeter scale.

### Simulation results

Figure 1 shows a visualization of the generated input for one antenna (left) and the combination of five inputs (right) at a given time step. Circles with possible marker positions are highlighted. For the combination the color encodes the strength of superposition with the most fitting intersection marked in red.

Based on this temporally changing input a dynamic interaction within the neural field took place and after an initialization period of a few seconds it showed the activation depicted in

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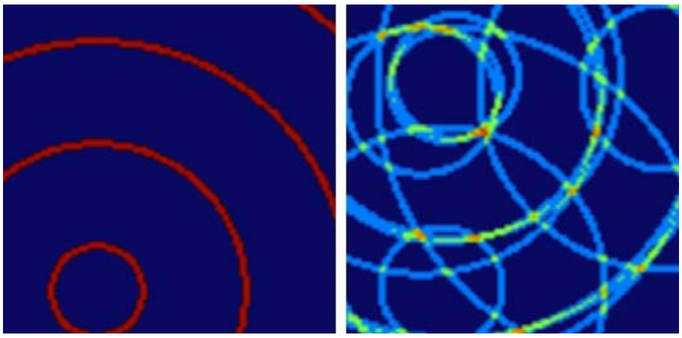

Figure 1: Simulated input - positions with correct distances for one antenna (left) and the combination for five antennas (right).

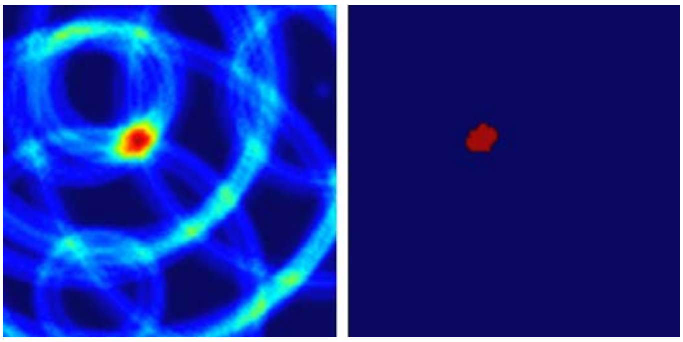

Figure 2: Localization result - activation of the neural field (left) and stable peak for the selected marker position (right).

figure 2 (left). Thanks to the local excitation activation around the correct marker position added up and after reaching a threshold a stable peak was formed which is shown in figure 2 (right). Depending on the excitation width the peak was self-stabilizing or not.

For average radius shifts of ±3 cm the correct marker position was selected in most cases. For higher variances this happened less often. However, even after increasing the radius shifts up to ±4 cm reasonable positions were still detected, although they did not match the marker position.

# Conclusion

The presented work can be seen as a proof of concept for the novel idea of incorporating neural fields in the process of RFID-based localization. It is tackling the task of noise reduction which is a precondition for high accuracy. In addition, the field’s stabilizing properties lay the foundation for a robust tracking of moving tags

The comparison between the signal variation in data recorded with the PRPS system and simulated data shows that the simulation results were achieved under realistic conditions. Therefore the developed software system will likely be able to handle the PRPS data well, which will be tested in our next step once a direct input interface is finished.

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