Natural cooperation:

How could humans and robots work together like team members? NIFTi focuses on building cognitive robots that support humans in exploring dynamic real-life environments. Key to the NIFTi approach is that the robot **bears the human in mind**. NIFTi integrates human factor models throughout the cognitive system, so the robot can understand how a human team-member can be "best" supported in a given situation, while performing under stress.

NIFTi
Natural Human-Robot Cooperation in Dynamic Environments

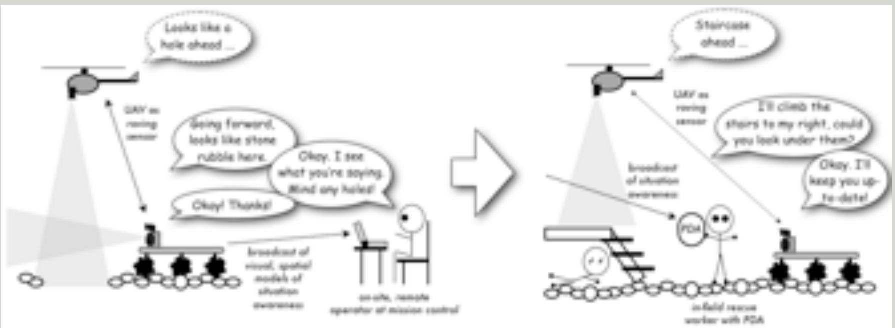
NIFTi investigates what it takes to make a robot a good team-player. What should it try to do, say, see – and how, so that it can best support its human team members under varying circumstances? In NIFTi, we take the view that human performance should drive these considerations. A robot should understand how factors like cognitive load and stress influence humans – in how they see the environment, in what they can do (or not), in what they need to know. The robot should understand this, and adapt its behavior accordingly. In short, *NIFTi puts the human factor into cognitive systems*.

In NIFTi we focus on human-robot teaming in Urban Search & Rescue (USAR). We work with end users who stand to have a real benefit from working with such robots. Our robots are to assist people in assessing disaster situations that are too dangerous or too difficult for humans to enter right away. These are the settings we want to make human-robot teaming work in. Circumstances which are difficult, stressful and tiring for the humans – that are neither human-friendly nor robot-friendly.

We believe there is only one way to really tackle this issue, and that is by going in there. In NIFTi we adopt a user-centric design methodology. Together with the end users involved in NIFTi, we formulate design requirements. We gather data in the field, and field-test our components. We then run end user trials and experiments to see how well our approaches work, in high-fidelity scenarios. And the next year, we do that again.

The development cycle guides the phases through which we go, in working with our end users and performing field studies and -tests. The NIFTi roadmap defines, how we go about gradually scaling the complexity of the S&T development. The figure below shows the basic idea of the roadmap.

In the first two years of NIFTi, humans instruct (Year 1) or supervise (Year 2) a robot team remotely. The robot team consists of a ground robot (UGV) and a microcopter (UAV). One or more humans interact with the robots in the hotzone using an Operator Control Unit (OCU).



The OCU provides a GUI for visualizing various sensor data (several maps, video- and image streams), and spoken dialogue for talking with the robots to discuss aspects of navigation and observation in the disaster area. In the second half of the project, we add in-field rescue workers, working alongside the robots. This adds a form of *in situ* situation awareness to the team, resulting in a more complex (and more realistic) team dynamics. Initially, the in-field rescue worker remains in position as an observer (Year 3). Later, the rescue worker actively takes part in the joint exploration (Year 4).

Year 1: The events

In Year 1 we instantiated the development cycle and roadmap as follows. Our main goal was *to get to know the structure of the domain*, and gain first experience with human-robot teaming in realistic USAR scenarios. We started at our kick-off with a visit to the EikDo training site for earthquake disasters (Jan 2010), to see what kinds of terrain we might be operating in. During Spring, we then met several times with end users to discuss robot platform requirements (Feb 2010, BLUE) and use case requirements (Apr 2010, FDDO). Consortium-internally we met to discuss development methodology and infrastructure (Mar 2010, Fraunhofer). We consolidated the resulting requirements and initial designs at a consortium-wide meeting (May 2010, VVFF). We also settled the use cases for instantiating the roadmap to concrete scenarios, opting for a tunnel accident (Years 1-2), a chemical accident in a railway yard (Year 3), and a collapsed building (Year 4). We have drawn parallels between the structural complexity of each use case and the NIST USAR Arena standards. We combined the May meeting with a visit to the VVFF training site in Montelibretti (SFO). Over the summer, component- and system development began with an integration meeting (June 2010, DFKI) and several follow-up individual partner visits (at ETHZ, ROMA). This first phase culminated in a week-long field exercise at the SFO training site (Sep 2010, VVFF). Together with the FDDO and VVFF end users we built up a high-fidelity use case, in which we gathered data on mapping, vision, selectional attention, and multi-modal interaction. We used this data to drive further development, leading up to further integration meetings (Dec 2010, Jan 2011), and the Year 1 field trials to let end users experiment with our systems (Jan 2011, FDDO).

Year1: Tunnel Accident Use Case

In Year 1 we explored the *Tunnel Accident* use case. In a tunnel, a lorry lost its load of barrels, pipes, and pallets. This caused an accident involving several cars. The mission for the human-robot team is to assess the situation in terms of the layout of the hotzone, victims locations, and potential threats. The team consisted in Year 1 of a single human, and a UGV. In this setup, the human is located outside of the hotzone, and communicates with the UGV remotely through the OCU. The OCU provides a GUI showing a 2D map (possibly including 3D landmarks), and several video streams. The videostreams are from an omnicam, and a monocular camera on a pan-tilt unit. The human can use spoken dialogue, waypoint selection, or full tele-operation in the OCU to instruct the UGV where to navigate.

Year 1: Progress

Overall, we made the following progress on achieving our project objectives. The objectives focus on bringing ``the human factor'' into a robot's situation awareness and collaborative behavior, balancing that with its own operation.

Objective 1: Functional models of dynamic environments. *NIFTi develops new methods for building functional maps, which connect the spatiotemporal organization of the environment, and the conditions for executing an action. This makes it possible to trace, ground, and adapt the execution of a plan. NIFTi combines spatial and perceptual models, with domain inference.*

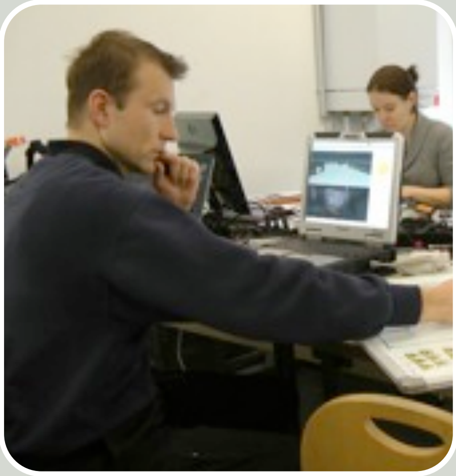
We developed a first approach to functional mapping. It is based on news method for creating 2D/3D maps, and topological structure in an outdoor environment, on which we can ground observations of landmarks (e.g. cars), and inferences over domain knowledge to identify regions where the UGV should be to look for victims (WP1). As an example, the robot can infer that it needs to be near the windows of a car to look into it for victims. This is based on field data on what and where a human rescuer attends to during exploration (WP5), and state-of-the-art methods for navigation (WP1), and for visual object tracking using an omni-directional camera (WP2).

Objective 2: Situated cognitive user models: *NIFTi develops new approaches for learning and employing situated cognitive user models. These models connect models of task load and attention with conditions on executing actions in different situations. Using these models a robot can anticipate where and how to act, and adjust focus on what to do next or look for.*

We developed a first model of human cognitive task load for working in a human-robot team for USAR (WP4). We performed several field experiments to gather data on task load (WP4), and on selectional attention during exploration (WP5). We now have several baselines on cognitive task load, for (remote) teaming with a tele-operated UGV (telepresence) and a semi-autonomous UGV (NIFTi OCU) (WP7).

Objective 3: User-adaptive human-robot communication. NIFTi develops novel methods for adapting multi-modal human-robot communication to a user. A robot uses its cognitive user models to adjust its strategies for communicating with a user in a given context, to align with perceived changes in communication, cognitive task load and attention.

We developed a multi-modal OCU for a human to remotely instruct a robot where to explore in a disaster area (WP3). We performed field experiments to gather data on adaptivity preferences in information display (WP3), and on the use of the NIFTi OCU (WP7). We developed a new approach to situated reference processing in situated task-driven dialogue, and we began modeling how team dynamics can affect optimal communication strategies (WP3).



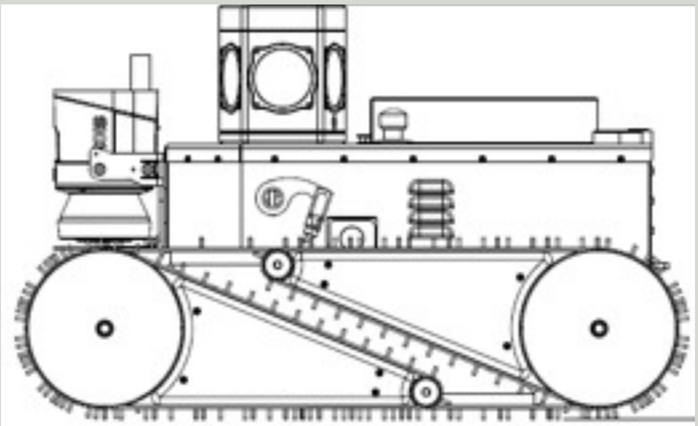
Objective 4: Morphology-adaptive flexible planning & execution. NIFTi develops methods for acquiring new strategies for planning and plan execution which explicitly take attention models and morphological constraints into account. Attention drives where to explore. NIFTi develops a new robot platform that provides active and passive forms to adapt locomotion to terrain features, and uses a UAV in the human-robot team as roving sensor.

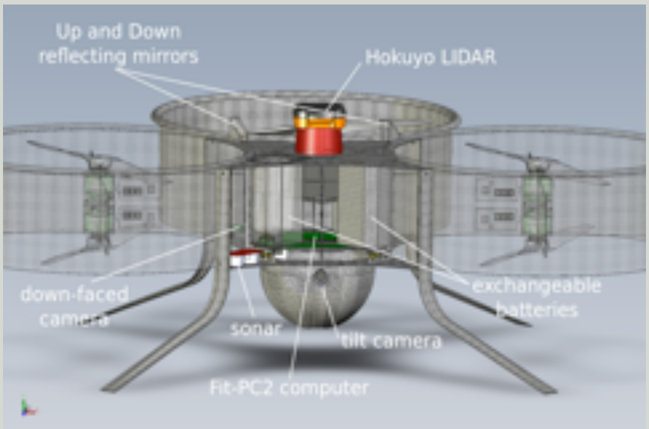
Together with end users we developed task primitives and learning skills for use in flexible planning & execution (WP5). We designed a UGV platform, based on end user requirements, and a new UAV microcopter platform (WP6). These platforms are delivered in early 2011 for use in NIFTi.

Outllook

For Year 1, NIFTi achieved its project milestones. We gained valuable insights into the domain through several end user meetings, domain studies, and field tests. We translated these insights into models, components and systems that were run in field trials with end users. In Year 2, we use the same use case as in Year 1, to gradually improve and extend our models for human-robot teaming in the USAR domain.

In Year 2 our focus extends from understanding the structure of the domain, to include operating in the domain. From the S&T perspective this means an increased stress on acting and interacting in a teamwork context. To gather experience for ourselves, we are scheduling a high-fidelity joint exercise in 2011 for human-robot teams that join end users, developers, and robots in working together on exploration-type missions.





Coordinator:
G.J.M. Kruijff (gj@dfki.de)
DFKI GmbH, Saarbrücken
Germany

Consortium:
DFKI GmbH, TNO Human Factors, Fraunhofer IAIS, Bluebotics, ETH Zürich, Czech Technical University, “La Sapienza” University, Fire Department of Dortmund, Corpo Nazionale dei Vigili del Fuoco.

Internet:

http://www.nifti.eu

Funding:

EU FP7 ICT Cognitive Systems & Robotics #247870 (IP, 2010.1 - 2013.12)