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MINISTÈRE DE LA DÉFENSE

DGA

Integrating human / machine interaction into robot control architectures for defense applications

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Outline of the presentation

4. Demain 2015, BOA (Bulle Opérationnelle Aéroterrestre), Hommes et robots en reconnaissance.

- **Introduction**
- **Operational context for HRI** (Human / Robot interaction)
- **Overview of existing HRI mechanisms within robot control architectures** (defense applications)
- **Description on our work concerning HARPIC**
- **Perspectives and open issues** about HRI within software architectures
- **Conclusion**

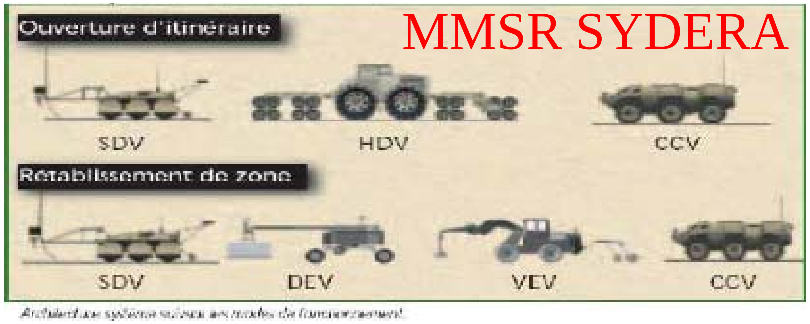
Introduction

Given recent advances in robotics technologies, the range of operational missions for robots is getting wider :

- reconnaissance and scout missions
- surveillance, target acquisition and illumination
- demining, breaching, security missions (EOD, IED neutralization…)
- supply delivery, mule applications, obstacle clearing, retrieval of injured people, telemanipulation
- communication relays, diversion...

French Defense robotics projects

SYRANO



Mini-RoC

(+ PEAs Minidrones, SUAV, Evolution, Action, OISAU...)

DGA

Why introduce HRI into military operations ?

- **Basic teleoperation may induce a heavy workload on the operator (e.g. TMR robots at WTC disaster)**

  -> need for autonomy

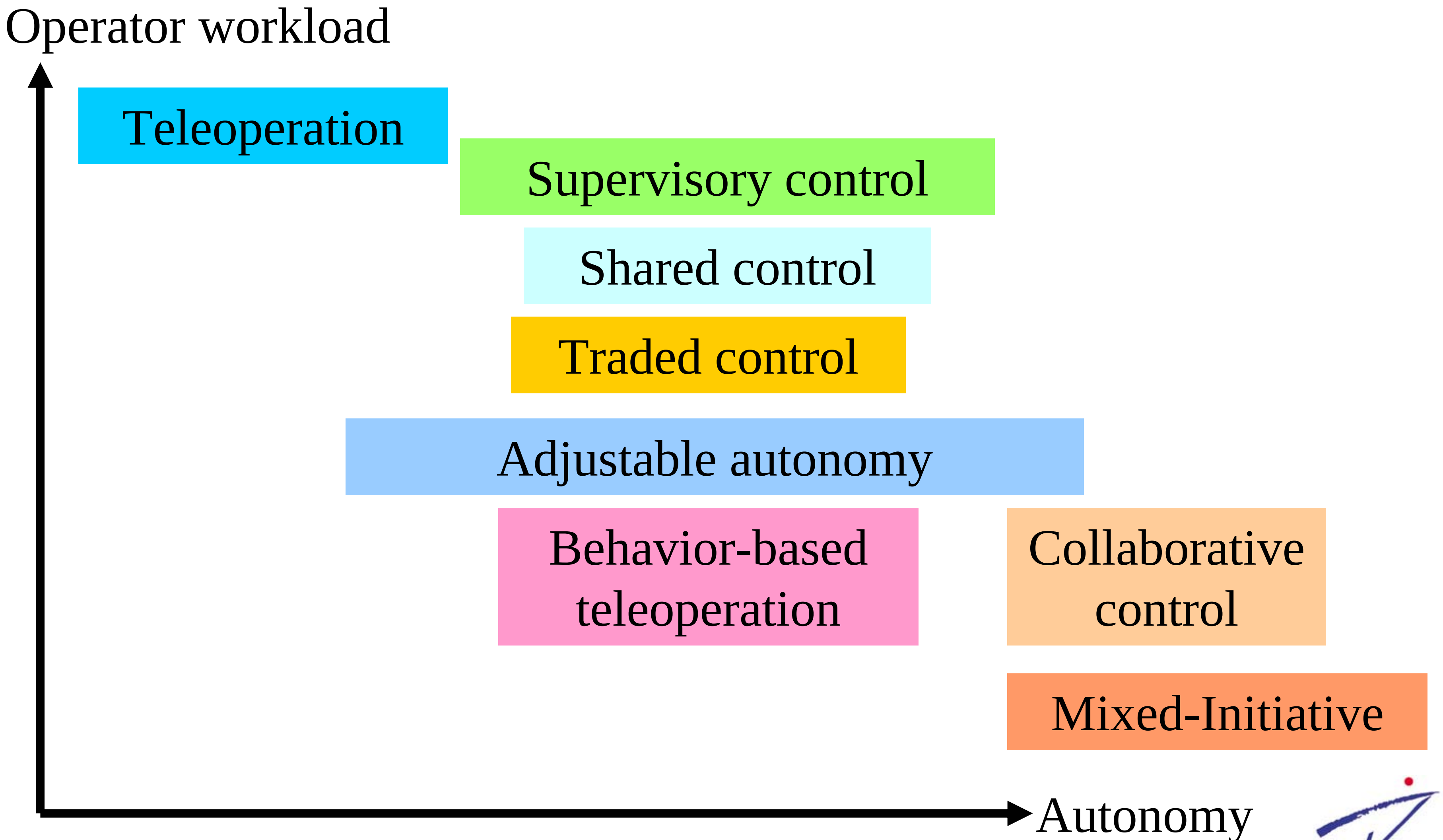
- **However, technology is not mature enough to enable full autonomy during complex missions + autonomy is not desirable in some operational situations**

  -> need to keep humans in the loop

- **Humans and robots have orthogonal strengths**

-> the best solution seems to be a good collaboration between humans and robots

Existing control modes



Existing demonstrators (defense applications)

- **Most of them include various control modes**
- **Mostly based on well-known architectures**
- **Examples :**
  - **Sweden small UGV : sliding autonomy - SSS ;**
  - **TMR (INEEL-ARL) : safeguarded teleoperation / sliding autonomy – subsumption architecture** (at the lower level)
  - **PRIMUS-D (UBM-Dornier) : teleoperation + behaviors – 4D/RCS**
  - **Demo III (ARL-NIST) : sliding autonomy - 4D/RCS**
  - **MARS (CMU) : cooperative control – message-based architecture**
  - **TMR (Georgia Tech) : multi-robot schema-based control - AuRA (+ Mission Lab)**
- **But difficult to compare - more feedback needed**

Description of our work on HARPIC (CEP Arcueil)

Goals :

- **Investigate different ways to control a mobile robot, using various levels of autonomy**
- **Integrate these various modes into an operator control unit suited for PDA**
- **Demonstrate the potentialities of the control strategies**
- **Get feedback from operational forces**
- **Express requirements for future systems**

The selected control modes

We have selected the following control modes for our application:

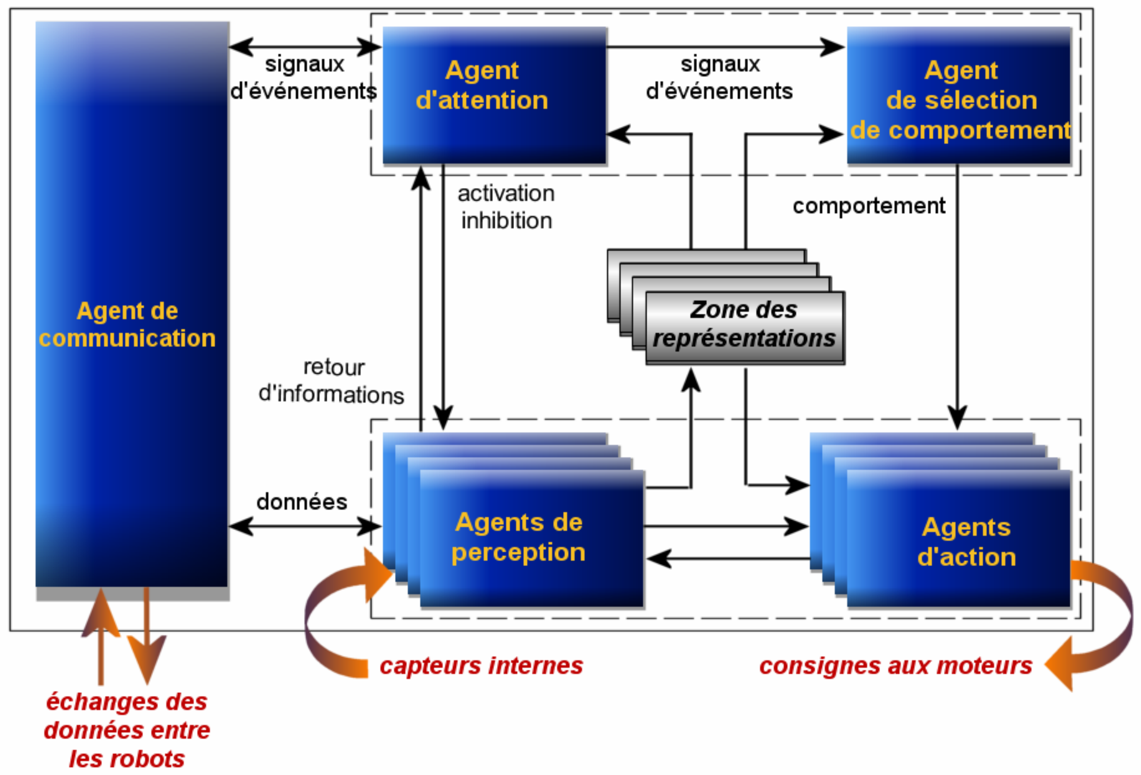
- manual control (total control) - teleoperation
- assisted control (anti-collision and obstacle avoidance ensured by the robot) - shared control (safeguarded teleoperation)
- waypoints or goal-directed navigation - supervisory teleoperation
- behavior-based autonomy (wall following, corridor following...) - behavior-based teleoperation
- sequences of behaviors - full autonomy
- different modes within the same system allowing dynamic swapping - adjustable autonomy

Constraints

- Software adapted to multi-robot applications
- Allow simple access to robot perceptions
- Small size interface (fit to the PDA screen): 320x240 pixels
- Using 2 laptops with wireless lan (1 on the robot and 1 for the operator)
- The agents of the multiagent control architecture can be executed on either laptop
- The interface must be compatible with our simulator and work on a robot equipped with a color camera, sonar range sensors and a laser range finder

Underlying control architecture: HARPIC

- Harpic is a multi-agent hybrid architecture which allows communication and task allocation between operators and robots.
- The interface itself is an agent of the architecture.

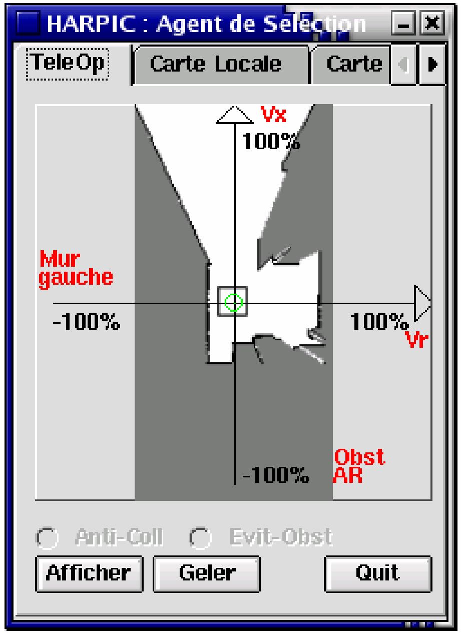


HARPIC implementation

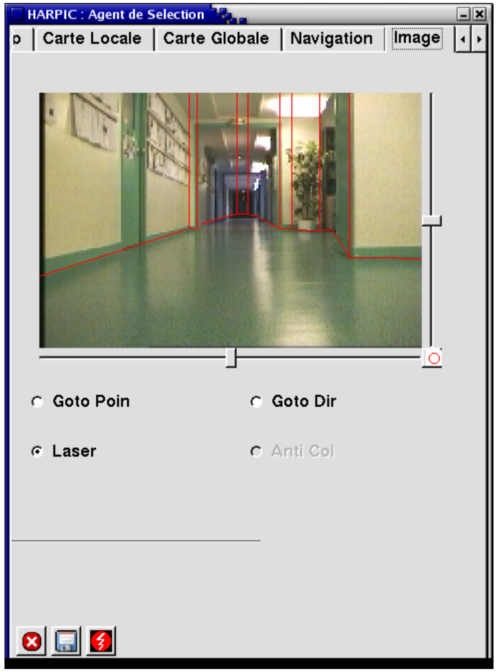
- Multi-agent formalism + object-oriented language (C++) -> modularity, encapsulation, scalability
- POSIX threads -> parallel execution
- Common structure for all agents (communication)
  - A special Adminstrator agent to record information about the others -> modularity
  - Two specific agents to bind architecture to hardware (interface software/physical robot + image acquisition) -> modularity
  - Perception and action agents
  - Attention agent
  - Behavior selection agent

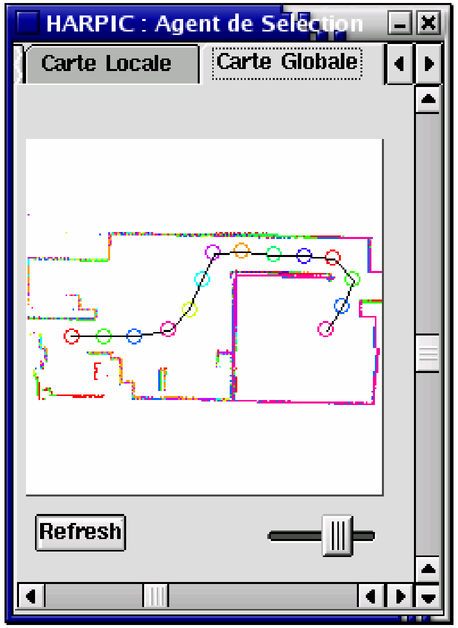
Mode: assisted remote control

- speed commands



- speed and direction commands



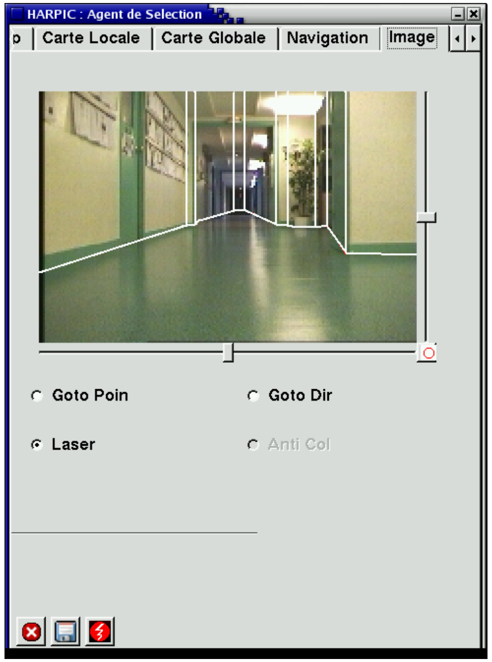


- SLAM

- Safeguarded Teleoperation (collision avoidance)

- Reflexive teleoperation (using contextual information)

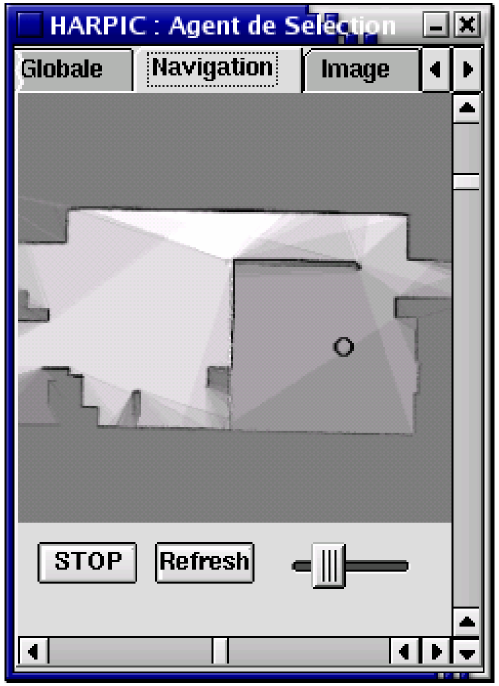
Mode: goal-oriented navigation



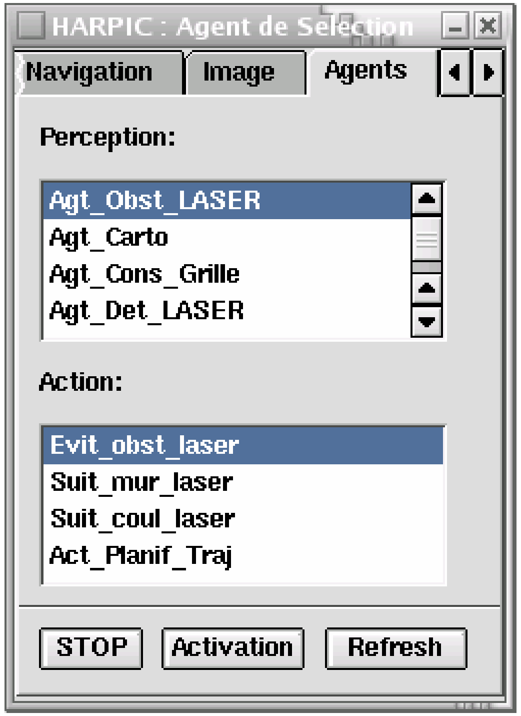
- goal point in the image

- Automatic planning and trajectory following
- Localization and mapping still running
- The goal point can be changed anytime

- goal point in the map



Mode: autonomous behaviors



- The operator selects, activates or stops behaviors:
  - obstacle avoidance
  - wall following
  - corridor following
  - ...

- The operator selects, activates or stops behavior sequences

Mode : multirobot

➔ The operator can connect to and control different robots.

Experimentations

- **JNRR'03 :**
  - •Navigation in a machine-tool hall about 60 x 60 m large
  - • Trajectories with loops and abrupt heading changes.
- **CEP, Eurosatory, Le Bourget, RND, colloque AAT…**

Perspectives concerning HARPIC

- **Improvement of existing modules, implementation of new behaviors** (both for navigation and mission purposes) **and multi-robot cooperation**
- **Development of semi-autonomous transition mechanisms between modes:**
  - Using a priori-evaluation (fixed rules for transition)
  - Using on-line evaluation of the quality of perception or behaviors, learning
- **Introduction of HRI at other levels of the architecture :** assistance to perception, attention and action…

General open issues about HRI

- How can we modify existing control architectures to introduce efficient HRI ? What kind of HRI is supported by existing architectures ? Are some architectures more adapted to HRI than others ?
- Is it possible to build general standard architectures allowing any kind of HRI ? Do we need to distinguish different classes of architectures dedicated to different HRI modalities ?
- What kind of software technologies could support HRI development ?

HRI within robot control architectures

- **Any function, any level may be concerned by HRI:**
  since many architectures are oriented towards full autonomy, they may not allow the whole panel for HRI ?
- **Various modes (8 modes above, ANS, ALFUS…)**
- **Constraints and limitations for HRI design:**
  - **Security**
  - **Communication bandwidth and real-time**
  - **Ergonomics and human capabilities**
  - **Hardware**
  - **Dependence from missions, platforms, payloads and interface devices**

New software technologies for HRI

- Ubiquitous, ambient and pervasive computing for soldiers
- Multi-agent systems:
  - Autonomy, interaction, organization, emmergence…
  - Combine several emerging technologies :

    Distributed computing (grid-computing), AI, constrained programming, data mining, planning, scheduling, web semantics…
  - Decentralized, open, pro-active (and bottom-up) conception

    -> extensibility, portability, robustness, fault tolerance…

  -> interesting, especially for network-centric warfare
- Multi-threading and object-oriented languages
- Integration platforms: specification, validation, simulation…

HRI scalability and standardization

- Scalability (extension capabilities) – cf. NCW :
  - **Specialization, communication and hierarchy :** globally OK for software systems
  - **Adaptation, negociation, re-organization :** more challenging (cf. communication services, “Autonomic Computing”…?)
  - **What kind of information, representations should be used ?**
  - **Future network centric systems ≡ Web services ???**
- Standardization :
  - **Beyond using standard technologies:** modular conception, scalability of components…
  - **Is it possible to build generic logical views** (components + communications / relationships) **for architectures including any kind of HRI ?**

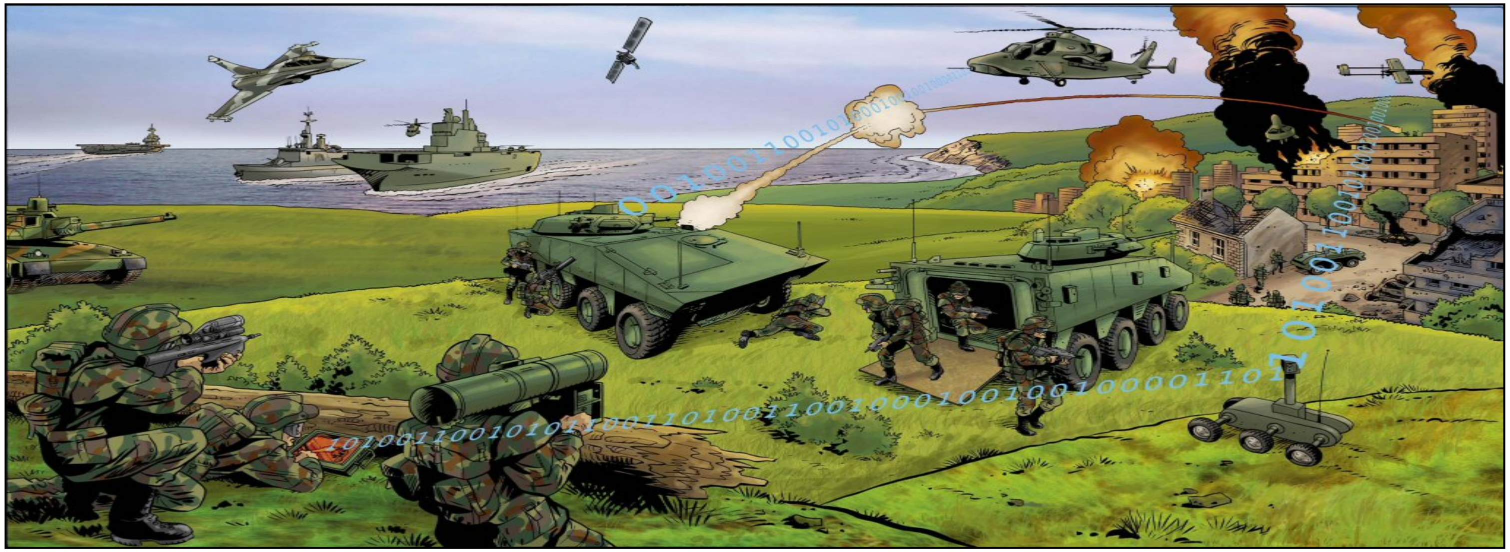
Conclusion

- **Various and challenging contexts in the field of defense robotics (variety of platforms, missions, environments)**

- **Open and challenging issues for HRI:**
  - **How to develop efficient and scalable HRI ?**
  - **How to introduce HRI into existing systems ?**
  - **How to support HRI development for future systems (software technologies, standardization…) ?**

-> Even though today's research and new technologies are promising, there is still a major effort to be done in order to meet tomorrow needs in defense applications

Thank you for your attention !



Any questions ?