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Advanced Networking and Robotics for Societal Engagement and Support of Elders

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Abstract

The percentage of older population is growing quickly, especially in developed countries, where the retired elders have to be paid by the expense of people who are working, often remaining, however, the most experienced, knowledgeable, and skilful part of the society, also accumulating considerable material wealth. Elders also have specific requirements to be satisfied to ensure their prolonged decent and independent life. The paper considers the use of an advanced distributed knowledge processing and control technology capable of solving broad and complex tasks in modern societies, including continuing involvement of elders in their development.

The approach integrates distributed physical and networked virtual worlds, which can cover from smart home to smart city to smart nation, being coordinated and processed altogether by a powerful spatial engine capable of solving any knowledge processing, control, and coordination tasks in parallel and distributed manner. The key element of the approach, Distributed Scenario Language, is briefed, along with practical examples of elderly population support in it. Having been prototyped in different countries and tested on various network-related problems, the technology can be easily put on any software or hardware platform, with massive cooperative use in mobile phones and mobile robots.

Keywords: Ageing population, decent life, elderly support, knowledge processing, distributed scenario language, mobile phones, mobile robots.

1 Introduction

The world is facing a rapid growth of elderly population, which causes serious social and economic problems. To satisfy specific needs and ensure prolonged decent and independent life of elders, advanced information and networking technologies are considered at the forefront of possible solutions.

European Union (EU) has created a special Ambient Assisted Living (AAL) Joint Program and initiated a number of big research projects to tackle such problems, with considerable funds being invested [1, 2, 3]. EU made thorough analyses of the potential for developing Information and Communication Technologies (ICT) for the elderly and summarized them:

- Europeans over 65 possess wealth and revenues of over 3000 Billion € (Euro).
- The market for smart home applications (age-related assistance in shopping, dressing, moving independently) will triple between 2005 and 2020, from 13 million people up to 37 million.
- 68 million people in 2005 had several forms of age-related impairment. This will grow to 84 million in 2020.
- Early patient discharge from hospital due to the introduction of mobile health monitoring would save € 1.5 billion per year in Germany alone.
- EU research projects have developed technologies for personalized route guidance; home care and remote health monitoring and advice; intelligent alarms; natural interfaces for accessible ICT.

A related project in Japan [4, 5, 6] addresses technological aspects of the AAL and employs innovative methods and facilities for ambient information control based on attaching spatial connotation to surfaces that surround elderly people. In this way, semantic surfaces for direct ambient interactions can be created and invisible intuitive support to the elders can be provided.

Semantic surfaces could make a difference in the lifestyle of the aging population and ensure the much needed self-confidence and dignity of the elders, also continue keeping them as an integral and productive part of the society. These works are also in line with known broader concepts of seamless interfaces "between people, bits and atoms" [7].

The current work represents a further development of these and related projects in Europe and Japan towards practical implementation in distributed networked environments. The approach offered allows us to solve various non-local problems for the elderly support, especially those in need of involvement and joint use of distributed resources (manned as well as unmanned) and smart networking in dynamic situations. The paper also inherits the semantic web concept [8], offering for the latter its possible solution for a specific domain.

2 Using Spatial Grasp Technology

The developed Spatial Grasp Technology [9, 10, 11] has been successfully prototyped in different countries and studied for most diverse networked applications – from classical graph and network problems to distributed knowledge bases to intelligent network management to distributed interactive simulation of dynamic systems to road traffic management to collective robotics to security and defense [12-34]. Many of these applications (if not all) can be useful in some or other form for the alleviation of demographic problems linked with ageing population.

For the current application, the semantic surfaces, assisting the elderly, can be represented altogether within a heterogeneous semantic network describing the whole domain in an integral form, with certain nodes having double digital-physical representation. This network can be arbitrarily and seamlessly distributed throughout any territory (including smart home, smart city, "smart" country, or even worldwide) using computers or other commonly used electronic devices (like mobile phones, smart sensors, or mobile robots).

High-level operational scenarios in a special Distributed Scenario Language (DSL) can start from any point (node), runtime covering this semantic world (with it, the physical one too) in a spatial pattern-matching mode, bringing operations to data, data to operations, and control to both, organizing overall goal-driven behavior in the way required.

Complex network-related problems can be expressed in DSL in a compact and simple form (often up to a hundred times shorter and proportionally simpler than, say, in Java). And the language interpretation can be organized in a parallel and fully distributed mode, without central resources, thus increasing robustness of the whole system and capability of self-recovery from damages.

The use of SGT can be purely user-centric, when the injected system scenario serves exclusive interests of a single person (possibly, subsequently involving other people and distributed resources for this). It is also possible to create any active distributed system and organize collective behavior of many individuals in it (humans or robots) pursuing together a common goal, with global control of this distributed activity.

SGT also directly works within the same formalism with distributed physical world, or any combination of the semantic (virtual, digital) and physical worlds, with (parallel) operations in the former capable of guiding the ones in the latter in a look-ahead distributed simulation manner.

3 The Distributed Scenario Language (DSL)

DSL is quite different from traditional programming languages. Rather than describing data processing in a computer memory, as usual, it allows us to directly move through, observe, and make any actions in fully distributed environments (whether physical or virtual), seeing and treating them as an organized whole rather than collection of parts. DSL operates with:

- *Virtual World* (VW), which is finite and discrete, consisting of nodes and semantic links between them.
- *Physical World* (PW), an infinite and continuous, where each point can be identified with physical coordinates (with a certain precision).
- *Virtual-Physical World* (VPW), being finite and discrete similar to VW, but associating some or all virtual nodes with PW coordinates.

DSL also has the following features:

- A scenario expressed in it develops as a transition between sets of progress points (or *props*) in the form of parallel waves.
- Starting from a prop, an action may result in one or more new props.
- Each prop has a resulting value (which can be multiple) and resulting state, being one of the four: *thru* (full success allowing us to proceed further from this point), *done* (success with termination of the activity in this point), *fail* (regular failure with local termination), and *abort* (emergency failure, terminating the whole distributed process, associated with other points too).
- Different actions may evolve independently or interdependently from the same prop, contributing to (and forming altogether) the resultant set of props.
- Actions may also spatially succeed each other, with new ones applied in parallel from props reached by the preceding actions.
- Elementary operations can directly use local or remote values of props obtained from other actions (the whole scenarios including), resulting in value(s) of prop(s) produced by these operations.
- These resultant values can be used as operands by other operations in an expression or by the next operations in a sequence (the latter can be multiple, if processes split). These values can also be directly assigned to local or remote variables (for the latter case, an access to these variables may invoke scenarios of any complexity).
- Any prop can associate with a node in VW or a position in PW, or both (when dealing with VPW); it can also refer to both worlds separately and independently.
- Any number of props can be simultaneously associated with the same points of the worlds (physical, virtual, or combined).
- Staying with the world points, it is possible to directly access and update local data in them.
- Moving in physical, virtual or combined worlds, with their possible modification or even creation from scratch, are as routine operations as, say, arithmetic, logical, or control flow of traditional programming languages.
- DSL can also be used as a universal programming language (similar to C, Java or FORTRAN), thus serving as a single language for expressing knowledge processing, intelligent communication protocols, and overall control in distributed systems.

DSL has recursive syntax, represented on top level as follows (programs called *grasps*, reflecting their main semantics as gasping and integrating distributed resources into goal-driven systems).

grasp → *phenomenon* | *rule* ({ *grasp* , })
phenomenon → *constant* | *variable* | *special*
constant → *information* | *matter* | *combined*
variable → *heritable* | *frontal* | *environmental* | *nodal*
rule → *movement* | *creation* | *elimination* | *echoing* | *fusion* | *verification* | *assignment* | *advancing* | *branching* | *transference* | *timing* | *granting*

The basic construct, *rule*, can represent any definition, action or decision, for example:

- elementary arithmetic, string or logic operation;

- hop in a physical, virtual, or combined space;
- hierarchical fusion and return of (remote) data;
- distributed control, both sequential and parallel;
- a variety of special contexts for navigation in space, influencing operations and decisions;
- type or sense of a value, or its chosen usage, guiding automatic interpretation.

There are different types of variables in DSL:

- *Heritable variables* – these are starting in a prop and serving all subsequent props, which can share them in both read & write operations.
- *Frontal variables* – are an individual and exclusive prop's property (not shared with other props), being transferred between the consecutive props, and replicated if from a single prop a number of props emerge.
- *Environmental variables* – are accessing different elements of physical and virtual words when navigating them, also a variety of parameters of the internal world of DSL interpreter.
- *Nodal variables* – allow us to attach an individual temporary property to VW and VPW nodes, accessed and shared by props associated with these nodes.

These variables, especially when used together, allow us to create efficient spatial algorithms not associated with particular processing resources, working in between components of distributed systems rather than in them. These algorithms can also freely move in distributed processing environment (partially or as a whole), always preserving integrity and overall control.

DSL also permits the use of traditional operational symbols and delimiters, to simplify and shorten programs, if this proves useful.

4 Exemplary Solutions in DSL

We will consider here some elementary solutions in DSL for the support of elderly population, which show compactness and simplicity of the higher-level code. All these can work in fully distributed environments, with casual channels and casual computing devices appeared available in different places and time (like individually kept by elderly persons, embedded in wheelchairs, mobile robots, smart sensors, or accessed via the internet).

4.1 Assisted Search for Forgotten or Lost Things

The part of a semantic network, oriented on guiding the search for regularly used items (like door keys, glasses, or wallet, for example), setting up an optimized movement between places in the house where such things may happen to be, is shown in Fig. 1. Different DSL solutions based on this network (from purely manual to fully robotic) may be as follows.

Assisted manual solution: advised manual movement and manual items recognition. The elderly person, informing the system about her current location by a physical contact with the semantic surfaces, is then advised to go to the nearest location where the item of interest can be found. This is followed by a further stepwise guidance to move to other such places via the optimum path between them (fixed in advance by the semantic network of Fig. 1), unless the item is found, about which the person informs the system. The DSL solution may be as follows:

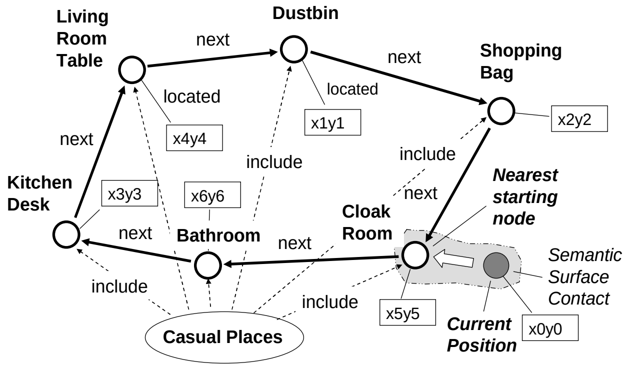

Figure 1. Networked search for a lost item.

```
heritable (Initial) = WHERE;
 minimum destination (
  hop (direct, Casual Places);
  hop (include, all);
  distance (hop (located), Initial));
 repeat (
  output ('go to', NAME, 'try finding');
  if (input == 'ok', done);
  hop (first come, + next))
```

Assisted automated wheelchair movement with manual items recognition. This case differs from the previous one in that the movement between Casual Places of Fig. 1 is performed automatically by a robotized wheelchair using given physical coordinates of the places, with visual search and recognition of the item by the elderly person herself. The latter terminating the automated movement if she finds the item. The DSL solution:

```
heritable (Initial) = WHERE;
 minimum destination (
  hop (direct, Casual Places);
  hop (include, all);
  distance (hop (located), Initial));
 repeat (WHERE = hop (located);
  output ('try finding');
  if (input == 'ok', done);
  hop (first come, + next))
```

Fully robotic solution: automatic movement and image recognition. This may all be accomplished by an intelligent robot, if employed in the house. It receives the name of the item to be found (supposedly having video camera and automatic items recognition software, as well as matching templates for different items), and starts from the nearest Casual Place to its current physical position. In DSL this may be as:

```
heritable (Initial = WHERE;
           Item = door keys);
 minimum destination (
  hop (direct, Casual Places);
  hop (include, all);
  distance (hop (located), Initial));
 repeat (WHERE = hop (located);
  if (discover (Item), done);
  hop (first come, + next))
```

In a similar way, more complex cases of navigation and movement throughout distributed territory by "dismounted" (albeit computer-assisted) individuals or with the help of robotic wheelchairs (and in the ultimate case—by single or multiple robots) can be organized in DSL with distributed maps coded as semantic networks, as, for example, in [33].

4.2 Finding Shortest Paths

The shortest path found to a certain destination may be a good guide to move through a building, region, or city, say, between nodes a and e as in the following DSL scenario (corresponding to Fig. 2). It is being found by navigating the network of weighed links in parallel and fully distributed mode, without any central resources, where the digital networked map can be arbitrarily distributed between any electronic devices having processing capabilities.

```
frontal (Remoteness, Path);
sequence (
 (hop (direct, a); Distance = 0;
  repeat (hop (all links);
    Remoteness += LINK;
    or (Distance == nil,
        Distance > Remoteness);
    Distance = Remoteness;
    Predecessor = BACK)),
 (hop (direct, e);
  repeat (Path = NAME & Path;
   hop(Predecessor));
  output (Path)))
```

The result gradually accumulated and returned to node a will be (a, b, d, e).

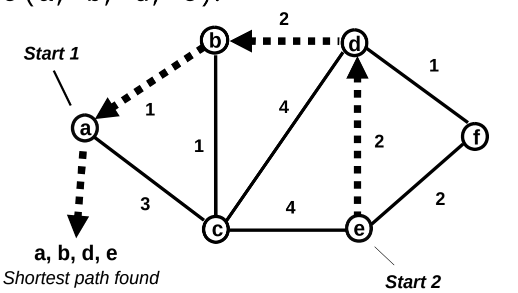

Figure 2. Finding shortest path between nodes a and e.

Many important problems of optimization and control can be expressed as finding shortest paths in distributed spaces. The solution shown (already tested on different distributed network applications) may also be useful for tasks related to the elderly and handicapped, like, for example, finding ways to shops, hospitals, friends, even their own homes (in case of being lost in a forgotten place). This may be possible in full, however, if advanced integration between distributed physical and virtual worlds exists in the society, which may be achieved with the technology discussed.

4.3 Tracking Physical Movement of Individuals by Mobile Intelligence

As in recent known cases in Japan, the elderly people and traces of them can be lost in the society. The DSL scenario in this section shows how whereabouts of the elderly can be regularly checked and traced by a mobile spatial intelligence propagating in a virtual world while following the movements in physical world, as in Fig. 3.

Current positions of certain individuals can be fixed by their physical contacts with semantic surfaces or by networked video cameras (to which key pictures of the persons can be delivered by mobile intelligence accompanying them, for automatic recognition). The tracking intelligence can analyze and accumulate behavior of the moving person, demand checking her current physical condition (e.g. heartbeat, blood pressure, body temperature, etc.). It can also alarm the nearest medical facilities in case of irregular situations. Many moving persons can be simultaneously and individually checked and nursed by the DSL scenario shown below.

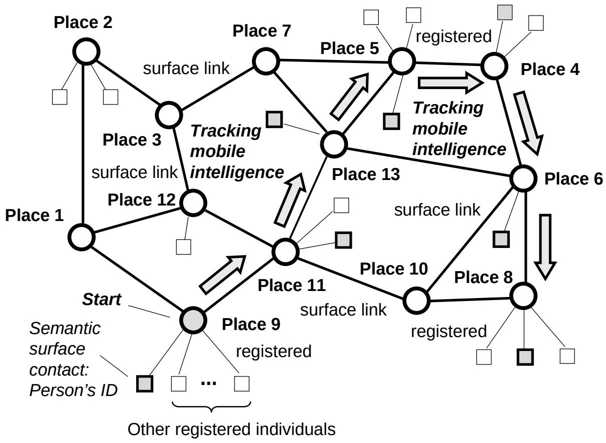

Figure 3. Networked tracking of individuals.

```
frontal (ID = individual; History);
 repeat (loop (
   belong (ID, hop (registered, all));
   update (History, check condition);
   if (problems (History),
     alarm (nearest medical staff));
   delay (delay));
  hop (surface link, all);
  belong (ID, hop (registered, all)))
```

4.4 Collective Evacuation from a Disaster Zone

In case of major disasters (earthquakes, hurricanes, flooding, landslides, forest fires, etc.) the elderly and handicapped may appear to be the least protected and most vulnerable ones, thus needing particular help, possibly, even to survive. A related DSL scenario may be activated by any person caught in such an event, or by a special emergency organization setting up coordinated massive evacuation from the disaster zone, regularly issuing instructions to individuals (say, via mobile phones, hopefully still working) on where and how to move.

A chained collective movement in this respect through a safe narrow passage in the disaster zone is shown by the program below and in Fig. 4, where individuals move in a coordinated (with each other and with the waypoints supplied externally) way. Only the first individual in this emergency chain is a pure leader (directly following the waypoints), and the last one is a pure follower, while the others combine both functionalities (thus moving right after the previous person, and being directly followed by the same next person).

```
cycle (if (exist (unmarked individuals),
   (N += 1; assign (next individual,
            create (node (N))));
 (NAME == 1; Waypoints= (w1, w2, w3, …);
  loop (output (‘move to’,
    withdraw (Waypoints, 1));
   wait (input == ‘ok’))),
 (NAME != 1; sling (
   Leader coordinates =
    (hop (direct, NAME - 1); WHERE);
   output (‘move by’, direction
    (WHERE, Leader coordinates))))
```

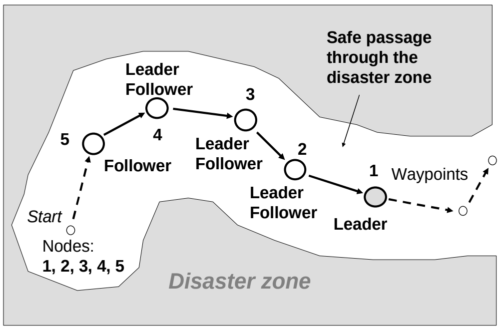

Figure 4. Chained evacuation from a disaster zone.

4.5 Using Service Robots

This example shows how home cleaning robots (on a demand of an elderly person) can process the area needed. Let us consider DSL scenarios for a single cleaning robot, and also for their swarm operating in parallel.

Sequential cleaning. The sequential coverage of a territory (assumed here to be rectangular, for simplicity) by a single robot can be organized in a variety of ways, including the one with minimum waypoints to pass, in a zigzag fashion, as shown in Fig. 5. For this latter option, the DSL program may be as simple as follows (the movement between adjacent waypoints is supposed to be accompanied by the cleaning process).

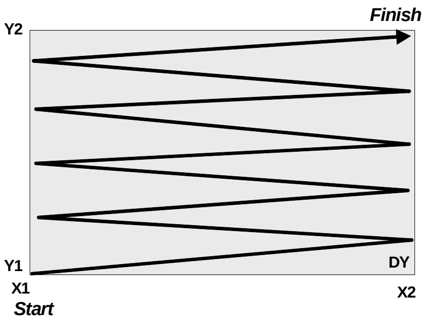

Figure 5. Sequential cleaning by a single robot.

```
X1 =…; X2 =…; Y = Y1 =…; Y2 =…; DY =…;
loop (move_clean (X1, Y); (Y += DY) < Y2;
      move_clean (X2, Y); (Y += DY) < Y2)
```

Parallel cleaning. Parallel cleaning of a territory (assumed here to be of arbitrary shape) by a cooperative robotic swarm can also be organized in different ways, for example, *randomly*, as in Fig. 6. For this, each cleaning device finds its next possible position independently by a random choice, checking if the new destination is not occupied by other robot to avoid collision, and also has not been visited (cleaned) before (using visual sensors).

Such parallel random navigation may have advantages before any predetermined search as can eventually cover the whole area with at least a single robot operable. Such a search, where physical processes start from a number of initial points (named `c1` to `c5`), which can be chosen randomly too, and keep a threshold distance from each other, may be expressed by this program:

```
move (c1, c2, c3, c4, c5);
Range = range;
Polygon = (x1y1, x2y2, x3y3, x4y4,
   x5y5, x6y6); D = shift;
loop (New = WHERE +
       twice (random (-D, D));
     inside (New, Polygon);
     and (empty (hop (New, Range)),
          non cleaned (New),
          move_check_clean (New)))
```

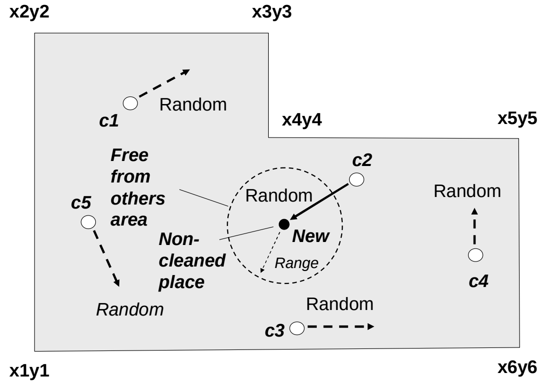

Figure 6. Parallel random cleaning by a robotic swarm.

Many such scenarios, due to high level and simplicity of DSL, may be created by the users (elders) themselves, or may just be activated by names, being prepared in advance and regularly updated by special social services, as a library of recommended reactions on different events (accessible from laptops or mobile phones).

5 Conclusions

The described approach, effectively integrating physical and virtual worlds, with individuals comfortably living in both under the guidance of a powerful spatial engine, can allow us to effectively formulate and solve complex non-local problems in human societies, demographic ones including.

High level but fully formal societal scenarios in DSL may contain a good deal of flexibility for their implementation: a) by younger people, who may be following them creatively, as general recommendations; b) by elders, with possibly weakened decision-making, to follow them closely, and if needed, directly; and c) by mobile robots and their swarms—just executing them strictly as formal programs.

The scenarios may provide any combination of and shifts between these options, with unified goal-driven control allowing for gradual transition to fully unmanned systems effectively solving urgent problems, including special support of elderly and handicapped people and their further active engagement for the benefit of the whole society.

The approach offered can be easily implemented on any platform, say, as a special intelligent module in laptops, mobile phones (the number of which is approaching 3bn worldwide), smart sensors or mobile robots, and this work can be effectively carried out by both professionals and university students (as for the previous versions of the technology [10, 11]).

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