# A Retrospect on Robotic Telepresence

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***Abstract*— Determination of response times of the communicating distributed processes is presented as a fundamental problem in time-critical applications. A lot of research has been done on the analysis of communication protocols. Todays distributed real time systems grow more and more complex. Telecommunication has introduced RTC (real time communication) as a method of information exchange with a negligible latency. A fundamental requirement of all real time systems is that all the tasks should have a deadline to estimate their worst execution times (WET) reliably. Real time communications may include telephony, amateur radio, instant messaging (IM), voice over internet protocol (VoIP), live videoconference communications, live teleconference communications and robotic telepresence. In this paper, we are going to discuss the applications of robotic telepresence whereby an agent acts as a surrogate for a remote user.**

**Keywords-** *real time communication; robotic telepresence; teleaction; teleoperator*

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## I. INTRODUCTION

*"After 100 years of advances in communications, where we discovered how to transmit text, voice, images, why not try to transmit presence?"* —Trevor Blackwell, founder and CEO of Anybots.

Robots have been established in the industry for quite a long time. They are programmed in advance and are well known to perform repeatable tasks in a structured environment. With the advancement in the Information and Communication Systems (ICT), the popularity of robotics such as robot football competition and international EUROBOT contests has been increasing day by day.In the beginning, robotics was confined to the development of toys such as LEGO Mindstorm or for simple repeating tasks, for example home cleaners. Now a daysthe science of robotics has been moved a step forward as a result of the advancement in the techniques and technologies.

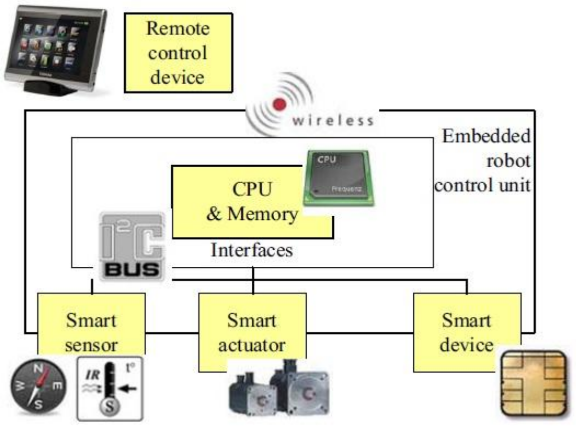


Figure 1: Embedded Robot Architecture

Development of the sensors, actuators and advancement in the mechanical platforms accompanied with the increase in the processing speed, memory resources and communication interfaces have continuously improved the robotic intelligence [1].Robots are programmed in such a way so as to interact with the environment reliably and in a very efficient manner, which have brought them close up to the humans. Algorithms to program robots should be quite efficient and must have a high level of fault tolerance.

One of the finest methods employed in robotic programming is based on Bayesian interference and learning. Any model of real life phenomenon is incomplete and always have some hidden variables which are often ignored and are not taken into account in this model but have an influence over the phenomenon. As a result of the fact, the phenomenon and the model behave in a different manner and this problem is faced by every robotic system. Rational reasoning with insufficient information has always been a difficulty for the artificial systems. The purpose of the Bayesian interference and learning providesa solution to this problem through the concept of Bayesian theory [2]. The joint probability of two events A and B can be expressed as

$$P(AB) = P(A|B)P(B)(1)$$
$$= P(B|A)P(A) \qquad (2)$$

Bayesian probability theory states that one of theevents is the hypothesis, H, and the other is data, D. if the data, D, is given, we can judge the truth of the hypothesis via this relation

$$P(H|D) = \frac{P(D|H)P(H)}{P(D)} \qquad (3)$$

The *likelihood* function $P(D|H)$ gives us the probability ofobserved data arising from the hypothesis [3].

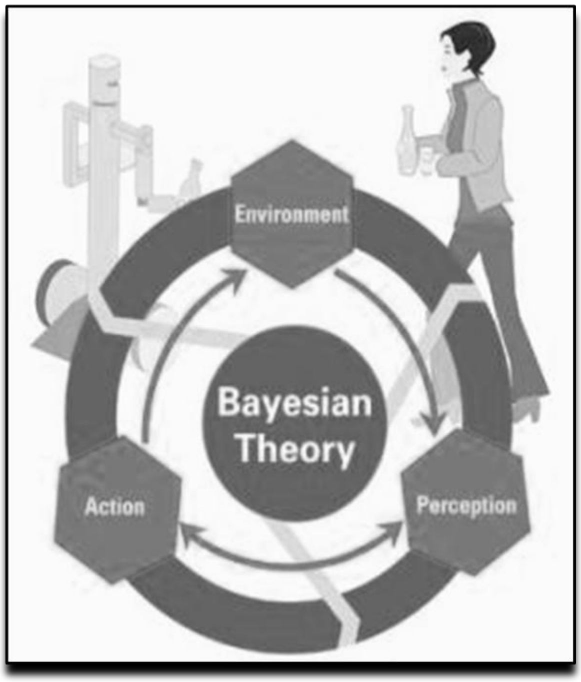


Figure 2: Bayes Theorem

## II. TELEPRESENCE

Telepresence and teleaction systems provides human operator a feeling of being in a remote environment and can also perform complex tasks without actually being there through the teleoperator. The state of feeling of presence at a remote place without actually being there is known as "virtually there". The design of a telepresence system is having two conflicting objectives, transparency and stability. The former is suitable to project a very high degree of emersion of the human operator into the remote environment and the latter desires to prevent any kind of damages to the system and perfectly execute the desired tasks in a highly efficient manner. Both transparency and stability are affected if there is any kind of deficiency in the sensors or actuators. The transparency and stability is also affected severely by the time delay in the communication channel. The additional knowledge about the remote environment can help us to increase the stability and transparency of the system.

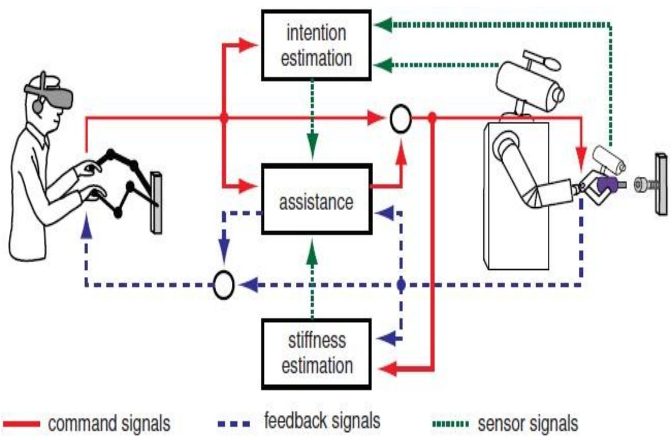


Figure 3: Concept of intelligent assistive teleoperator

Since most of the ideas miss a high degree of transparency and stability, a recent idea shows that if the bandwidth is increased in the delayed teleoperation systems and then coupling the master to a local model of the remote environment on the operator site can help to achieve high degree of transparency and stability.If we combine the knowledge of the environment and the intended actions of the human operator, it can help us to further increase the degree of the stability and transparency. This *Human Machine Collaborative Telepresence System*leads to the augmentation of interchanged position and force signals which is based on the integration of the human operator and the remote environment. This model helps to predict the position and force signals over a short horizon of time. The measured position and force updates are continuously transmitted from the remote environment to the teleoperator site.

A position-force exchange is considered in a bilateral telepresence system. The master device controls the desired target dynamics with damping parameters and virtual mass. The damping parameter has a low value in free space and switches it during contact to a high value. $T_d$ is the time delay in each direction, i.e. $2T_d$is the round trip time delay. On the remote site, the arriving master position is modified by *position assistance* (PA) while on the local site the delayed interaction force is altered by *force assistance* (FA). The overall control system architecture includes human (H), master device (M) and slave device (S), environment (E), and a communication channel (CC).

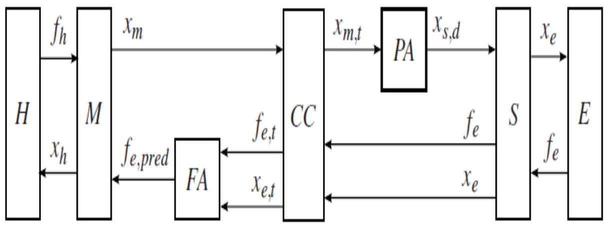


Figure 4: Control Architechture

Both the assistance functions, i.e. *force assistance* (FA) and *position assistance* (PA) increase the stability and the transparency of the overall telepresence system which is beyond the degree of unassisted systems. The *force assistance* (FA) concept is valid unless the target stiffness does not exceed the value of the initial estimated stiffness. Thus the main challenge is to overcome the problem of facing a stiffness of unknown value [4].

## III. ROBOTIC TELEPRESENCE AND TELEMEDICINE

Telemedicine was first described by Grundy et el in 1977 for real time face-to-face clinical consultation. They used a 2-way audiovisual link between a large university medical center and a small hospital and regularly consulted patients in the critical care unit. In their six month experience they realized that telemedicine can be made acceptable to users and providers and can influence the quality of care in a critical care unit. Telemedicine has played a vital role in robotic telepresence whereby a wireless mobile telemedicine system consist of a desktop or a laptop control station and a robot.


Figure 5: The physician assessing the patient via RP-7

The integration of high resolution digital cameras, microphones, amplification circuitry and custom software makes the 2-way audio-video communication possible. This robot known as RP-7 has a pan-tilt-zoom head and an omnidirectional mobility base which are combined with high speed broad-band internet which enables a physician to project himself/herself to another location and to see, hear, talk, interact as if he/she is actually there. It is known as a "virtually there" communication which takes place between the physician specialist and the physician or nurse attending the patient actually. In a sixteen week study this wireless mobile telemedicine system which was designed for intensive care units reduced severity-adjusted hospital mortality for patients in a 10-bed surgical ICU by 30% as a result of decrease in the ICU length of stay and automatically decreasing costs. A recent study showed thatthe implementation of eICU technology resulted in a decrease in the in-hospital mortality rate from 12.9% (before the implementation of eICU) to 9.4% (after the implementation of eICU). Emergency department providers have found telemedicine applications to be very successful in the care of trauma and stroke patients. A scores of patients receive brain-saving thrombolytic therapy in a timely manner with the application of wireless mobile telemedicine system in centers which lack in-house neurology consultative services. This technology may result in the overcoming of the shortage of staff in hospitals depending on the medical specialty. With the advancement in the real time communication system technology, it has become easier to provide medical expertise in areas where there is a shortage in staffing and medical specialties [5].

## IV. TELEPRESENCE ROBOT SENSORY SYSTEM.

To improve robot's operation in the outer space, scientists have proposed techniques using the combinations of different sensory systems which include thermal and video cameras, infra-red sensors, time of flight sensors, range-finders, accelerometers and gyroscopes. Two tasks are mainly assigned to a telepresence robot, navigation and object identification. The 3D information is gathered in particular by using laser range-finders, computer stereo-vision and sensors used for the time of flight [8]. Some algorithms employed to fetch the 3D information of the surrounding environment are:

### *A. Digital Fringe Projection*

the identified object. Then the height information of the object is calculated which involves *phase-shifting* followed by *phase unwrapping* and the *phase-height transformation* algorithm. Finally, phase-height information is transformed to x,y,z coordinates of the separate image pixels, which gives the actual 3D image of the identified object [9].

### *B. The Iterative Closest Point (ICP) Algorithm*

ICP calculates iterative-transformation in between two points. The nearest point is selected by the following mathematical equation [10].

$$\hat{p}_i = \arg\min_{p_j \in P} \left\| p_j - q_i \right\| \qquad (1)$$

Next, the transformation is estimated by the following equation

$$E(\mathbf{R},\mathbf{t}) = \sum_{q_i \in Q} \left\| \hat{p}_i - (\mathbf{R}q_i + \mathbf{t}) \right\| . \qquad (2)$$

## V. TIME DELAYS IN THE COMMUNICATION CHANNEL

On one hand, bilateral-teleoperation-system can do away with the need of sending a human to the outer-space but on the other hand, there are a lots of resistances offered while we try to implement this technology. Time delays are introduced into the reference signal when the supervisor tries to establish a communication channel with the slave robot operating in the hazardous environment of the outer-space [11]. According to the researchers, there would be 30 minute round-trip time-delay [12] in the execution of high-level instructions when communicating with the slave robot operating on Mars.

**Standard ICP Algorithm**

**Input:**
$p \in P$ : a set of model points
$q \in Q$ : a set of query points
$\mathbf{Rt}_0$ : initial transformation
**Output**:
$\mathbf{Rt}_{iter}$ : estimate transformation

1: $\hat{Q} = \text{Reproject}(Q, \mathbf{Rt}_0)$
2: **for** $iter = 1$ to max_iter **do**
3: $[\hat{P}] = \text{SearchNN}(\hat{Q})$
4: $[\mathbf{Rt}_{iter}] = \text{EstimateTransformation}(\hat{P}, \hat{Q}, \mathbf{Rt}_{iter-1})$
5: $\hat{Q} = \text{Reproject}(Q, \mathbf{Rt}_{iter})$
6: **end for**
7: **return** $\mathbf{Rt}_{iter}$

## VI. TELEPRESENCE AND SPACE EXPLORATION

Experiencing remote locations such as distant continents or other planets without physically being there has always been a fascinating thought for human race. People often experienced space exploration missions through the data that is transmitted back from a satellite sent to outer space. Telephone, teleconferencing and television have now become an inseparable element of our life. Telepresence can go beyond these technologies as it would help humans to do physical work remotely without being actually at any other distant place. Telepresence can become a surrogate for manned missions to outer space. Telepresence can become an alternative for manned missions to Mars as it is too dangerous to send a human being to Mars although it has been confirmed that it is same like that of our planet Earth. It has an atmosphere, the presence of water which is essential for life has been confirmed. There are many things that are calling for a manned mission to Mars but sending a manned mission to Mars is not affordable as the safe return of the humans is not guaranteed. The early stage of the concept of telepresence is being used for the exploration of Mars with rover vehicles. It is also used for certain terrestrial applications. Soldiers use this technology to remotely disable explosive devices with unmanned vehicles. Air force is using unmanned air vehicles to trace and attack terrorists [6]. Powerhouse museum in Sydney is hosting the initiative to improve Australia's engineering and science education. Secondary school students are being given a chance to explore space sitting in some classroom or a laboratory on the surface earth. They are being trained to develop space robotics and are promoted to explore planet Mars. Students living in any part of the world can participate through Cisco TelePresence fitted classrooms, or interactive videoconferencing (IVC), and are able to interact with robotics engineers and astrobiologists. These students will be working with them to organize the robotic missions to Mars and would be driving virtual Mars rovers. Beyond that they can also drive these rovers in a museum's Mars yard. This project gives student an amazing experience of working with the people at the cutting edge of the scientific research and would engage them as adults in this world changing experience [7].

## VII. CONCLUSION

In this paper, we discussed robotic telepresence as an important aspect of real time communications. This paper initially gives an introduction to robotics followed by which it describes the concept of telepresence and how it has been implemented in the real life so far. We have thrown light on how*human machine collaborative real time systems*execute tasks far better than pre-programmed and unassisted robotic systems. We have witnesses the success of telepresence in the field of medicine. We explained how advanced surgeries are carried out by a human operator from a remote place. There is a lot of scope of telepresence in space exploration missions as it would reduce its cost and exploit outer space without sending humans to such unsecure and unreliable space missions. The concept of telepresence is also being used to give students a virtual experience of exploring outer space. Till now we are in the early stage of this wonderful technology. There is a lot of scope for research and experimentation in certain areas of real time communications technology especially *telepresence*.

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