Human – Robot Coordination Using Wireless Communication

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Abstract— ***To aid people working in hazardous situations such as defense, military and for those pursuing research, a robot based on replication technique capable of performing any task and which can be controlled via wireless link is proposed in this paper. These robots will be of immense use in such situations as they can do the roles of human beings. It has extensive monitoring and maneuvering capability attainable at a low driving voltage and has a good response to external stimuli. This paper presents the methods for making the robot's motion to be in congruence with that of the human being who operates it, obviating the need for sensors. An efficient design of cost effective robots of various sizes which can be interfaced with a single Teaching Hand Gripper (THG) designed specifically for the joints of the human for their operation has also been proposed. The THG is calibrated to overcome the discrepancies among potentiometers used for robot motion. The performance of the proposed system is tested on a robot with a single joint and the results are presented for a simple closed loop system. The robot is given fast, medium and slow responses as inputs such that a variation of 30 degrees is achieved in time intervals of 1, 2 and 3 sec. The output lag and the system efficiency are analyzed. The distance between the robot and the point of control can be up to 75km. The control signals are transmitted from the human to the robot via FM. These robots when under use in a hazardous situation can be efficiently operated from a safe environment.***

Keywords:
Hazardous, replication, robot's motion, Teaching Hand Gripper (THG).

I. INTRODUCTION

The control of conventional button operated robot can be achieved by alternatives like voice & physical motion. The usage of body movement to activate humanoid robots is in vogue and generally expensive due to sensors used in them. Programming by human demonstration is an intuitive method of robot programming, in which the programmer demonstrates how a task is performed using a THG that measures human motion, and the data gathered is used to generate the robot program. In the existing approaches a direct duplication of the demonstrated trajectory would result in unsatisfactory robot motion due to human "wiggles" and unnecessary motion in case you use sensors. In this paper the human inconsistency is treated as noise that is eliminated by the use of potentiometer and analog to digital converters with lower resolution compared to that of the sensor. The proposed work deals with humanoid robots, which depend on the calibration, fault tolerance, control system and rotational dynamics at each joint for its motion. Non - specification of starting reference point at any instant of time after resumption from a power failure is the most salient feature of this present study. The concept of safe activation of robots of different sizes with a single THG by the use of low voltage is another desirable feature of the proposed work. By using this proposal even a person who doesn't possess knowledge of computers will be at ease in programming the robot depending on the situation. An

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efficient design of robots of various sizes which can be interfaced with a single THG is also an impressive feature of the robot. The number of potentiometers required for the THG and robot is given by 2n, where n is the number of joints either in the robot or in the THG.

II. PROPOSED WORK

Physical motion stems from the angular movement arising at the various joints in our body. Hence the measure of rotational motion at the joints of the demonstrator body is essential for replication by the robot. The Architecture of the robot and the THG plays an important role in the control of the robot. The angular displacement at the joints of the demonstrator gripper is measured with the help of a rotary potentiometer which also serves as an indicator of angular displacement. The exact positioning of the potentiometer is made on the robot, such that the potential variation in both the demonstrator gripper potentiometer and the robot potentiometer are identical as shown in Fig.1. The congruent motion of the robot and THG is due to the presence of simple closed loop system at each joint of the robot as shown in Fig.2.

The position of the robot can be determined from the potentiometer reading from all the joints. A camera attached to the top of the task robot captures the images of the objects and transfers them to the destination which in turn guides the robot to perform the desired task. The images are transferred to the destination by using data acquisition tool in Mat Lab. The potentiometers and motors are mounted in such a way that the variation in the demonstrator setup has an impact on the robot setup resulting in the matching of positions.

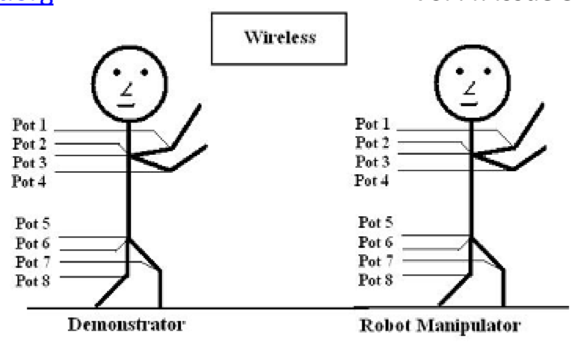

Fig.1 Arrangement of potentiometer

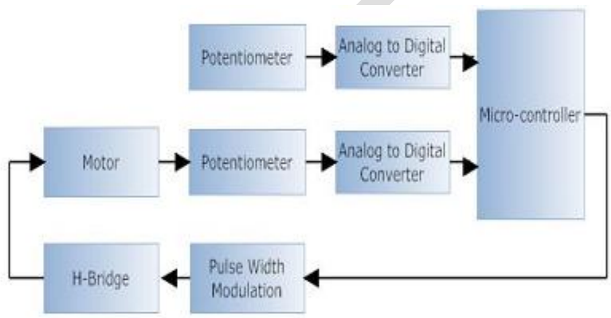

Fig.2 Simple closed loop system

III. WORKING PRINCIPLE

A. Closed Loop System for replication process

The development of control systems for robot manipulators with redundant kinematics is still a demanding task. This task becomes even more challenging if the robots to be controlled operates in partly unknown environments which vary over time and may be thousands of kilometers away from the operator, for example in space. The motor is connected with the potentiometer, thus causing the potentiometer to rotate and correct the error, resulting in least possible error. Depending on the error the input to the motor applied is decided by an H- Bridge circuit, to either rotate clockwise or anti-clockwise as shown in Fig.3. If the error is positive, positive potential is applied to the motor which

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overcomes the error with a positive correction, hence rotating the motor in clockwise direction. If the error is negative, negative potential is applied to the motor which corrects the error with a negative correction, thereby rotating the motor in counter clockwise direction. The equation to compute error is given by

$E(s) = C(s) – R(s)$

$E(s)$ – Error

$C(s)$ – Input to the system

$R(s)$ – Output from the system

To avoid steady state error and for the error to be zero, the motor speed is varied when the position of the robot is nearer to the THG position. When the difference in position of the robot and the THG is less than 15^o, the motor speed is reduced to one half of the original speed by the use of Pulse Width Modulation. When the difference in position of the robot and the THG is less than 7^o, the motor speed is reduced to a quarter of the original speed. The algorithm for operation is as shown in Fig.4.

B. Multi-Sized Robot matching with a single designed demonstrator gripper

Condition for the robot to replicate the action performed in THG at each joint is

$\theta(s) = \varphi(s)$

Where θ and φ is the angle moved by the THG and the robot respectively.

To have a clear idea about the concept, a humanoid robot is taken for reference and illustrated. The condition for a robot of any size to replicate the action performed in the gripper at each joint is

$\theta(s) = \alpha\, \varphi(s)$

Where α is a constant.

If a>1, Variation of the potentiometer in the THG is greater than that of the robot potentiometer as shown in Fig. 5

If a<1, Variation of the potentiometer in the robot is greater than that of the THG potentiometer as shown in Fig. 6

If a=1, Variation of the potentiometer in the robot is same as that of the THG potentiometer as shown in Fig. 1

While using different dimensions of robot and THG, the robot cannot replicate the action because the variation of the potentiometer at the joint is dependent on the size of the potentiometer used in the robot and THG. Any multi-sized robot replicates the actions of the THG by means of the potentiometer installed which helps in defining a factor and nullify the effect of the variation.

In a transmitter, the factor is defined by the user with the potentiometer as shown in Fig.8 and the factor is multiplied so that the data received in the receiver will be in accordance with the dimensions of the THG as shown in Fig.7. Assumption is made that all the potentiometers at the joints of the robot and the THG vary by the same factor.

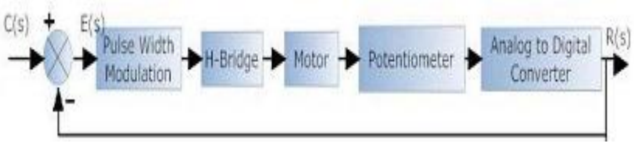

Fig.3 Simple closed loop in frequency domain

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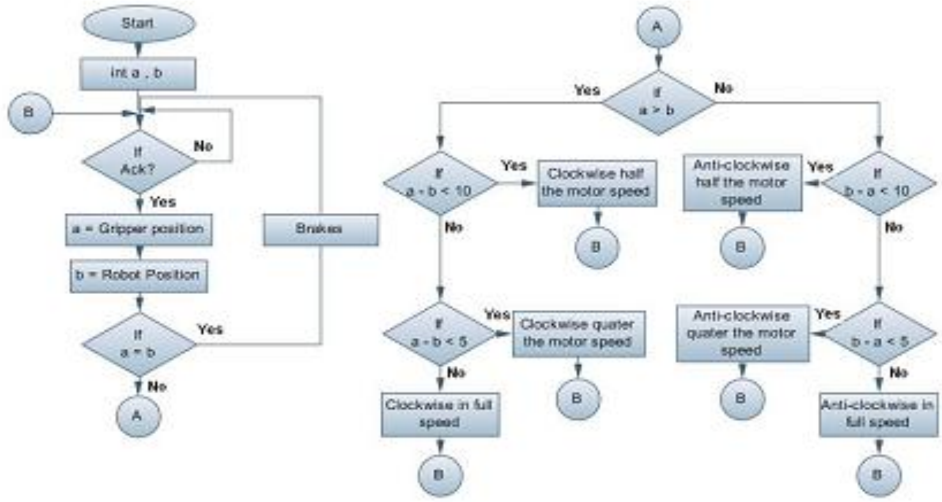

Fig.4 Micro-Controller A Algorithm

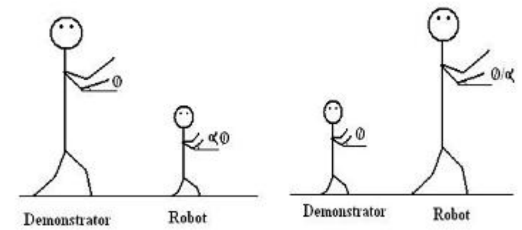

Fig.5 For α>1 **Fig.6 For α<1**

Fig.7 Multi–sized robot coordination by adjusting α

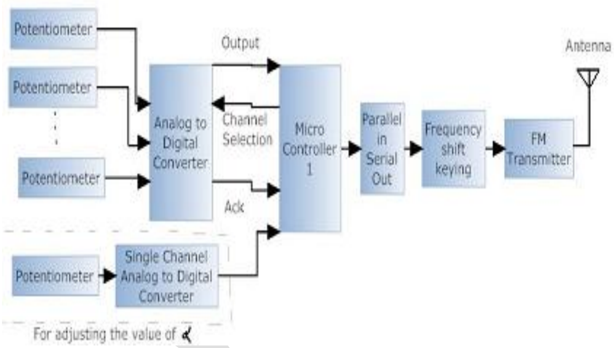

Fig.8 Wireless Transmitter

IV. USING WIRELESS COMMUNICATION

A. Demonstrator Gripper Circuit

The THG circuit using wired communication is shown in the Fig.8. The algorithm for microcontroller 1 in the transmitter is shown in Fig.9. The potentiometer rotates up to 320 degrees but no joint in our body has the capacity to rotate more than 270 degrees. So a value is assigned for acknowledgement of cycle completion such that any loss of data will be corrected by the new data received in the next cycle as shown in Fig.12. The output decimal value of 255 is assigned for acknowledgement of completion of one cycle. When the value of 255 is obtained at the receiver side, the next data transmitted will be considered as new cycle. Before the pulses are given as input to the FSK modulator, it must be converted to serial data which is achieved with the help of the shift register.

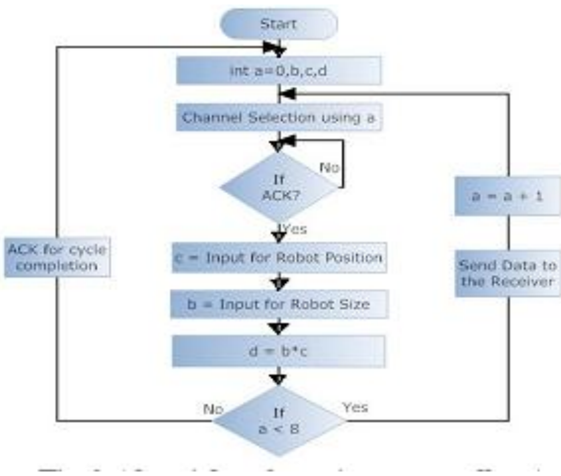

Fig.9 Algorithm for microcontroller 1

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The Frequency shift Keying (FSK Digital modulation technique) circuitry is used for converting the digital pulse to analog output to be fed into the FM transmitter. In the FM transmitter is an analog modulation technique hence requires analog input which is achieved with the help of FSK modulator. The output from the FSK will be fed as input to the FM Transmitter, where Microphone is replaced by the FSK modulated waveform

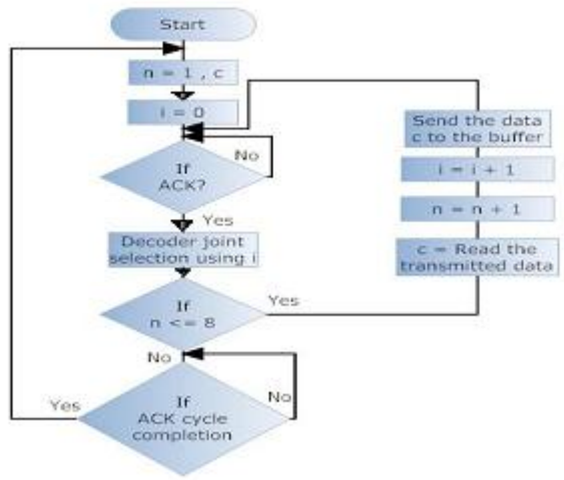

Fig.10 Algorithm for microcontroller 2

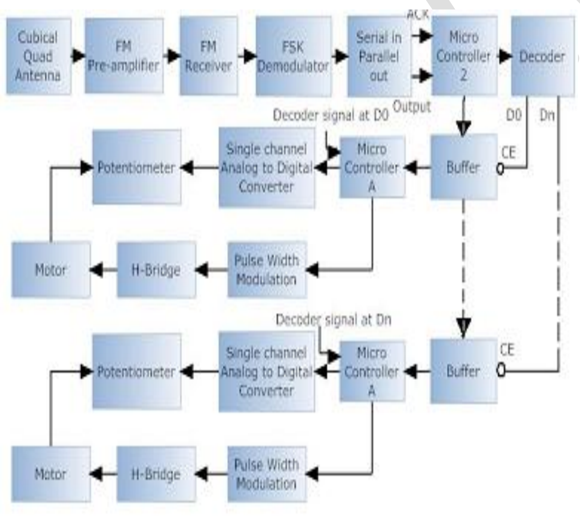

Fig.11 Wireless Receiver

B. Receiver

The block diagram for the circuit in the fish-like robot using wireless communication is shown in Fig.11. The algorithm for microcontroller 2 and microcontroller A in the receiver are shown in Fig.10 and Fig.4 respectively. At the receiver end, mounting a small size antenna would make the architecture of the robot stable. To have a better efficiency in mind Cubical Quad type antenna is chosen for FM receiver .The FM preamplifier act as an amplifier that amplifies the signal before data processing. The FSK Demodulator is used for converting analog output from the FM Receiver to digital data. The microcontroller is connected to the decoder to select only one buffer at a time. All the buffers are given parallel connection to the output port of the microcontroller 1, so that it will enable the data to reach only a particular joint. The chip enable pin of the buffer helps to correlate the data from the demonstrator setup to the corresponding joint of the robot.

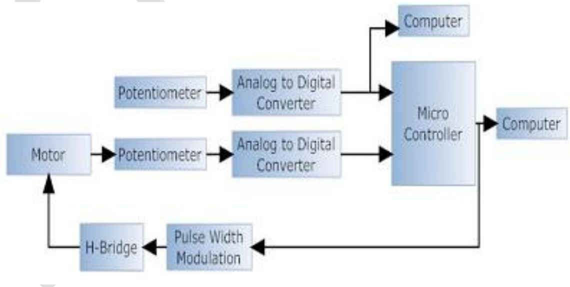

Fig.12 Closed loop system

The FM transmitter of 2W is constructed and tested at various distance from the operating point. The serial in parallel out helps to make data processing easier by sending parallel data to the microcontroller. The FM transmitter that can send the signal up to 2km can be received from a distance of 75km by using the Pre – amplifier designed with Dual Gate MOSFET. Dual Gate MOSFET pre – amplifier circuit has much higher gain approaching that of the vacuum and having high signal to noise ratio. Dual Gate MOSFET Pre – amplifier circuit designed gives an excellent gain of about 18dB.

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V. PERFORMANCE ANALYSIS

A closed loop control system as in Fig.12 is used for performance analysis. For our present study, parameters such as time, frequency, angular displacement, angular displacement lag, efficiency, velocity, displacement and propelling speed are considered. Practical testing introduces a variation of 1.4 degrees which will cause the input of the micro controller to change by one decimal or one hexadecimal. So the variation in the position is determined by the values got as input from the computer and the decimal is converted in terms of degrees.

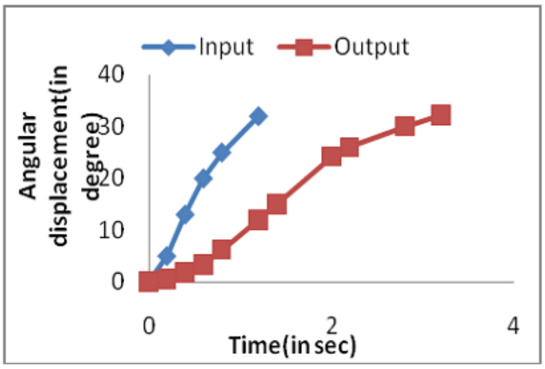

Fig.13 Time vs. Displacement in 1 sec

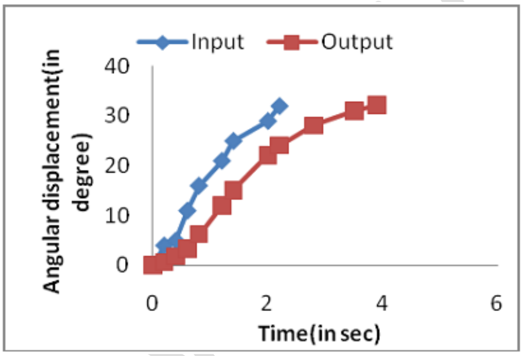

Fig.14 Time vs. Displacement in 2 sec

In Fig.13 to 15, the robot is tested by slow, medium and fast responses as inputs such that a variation of 30 degrees is achieved in time intervals of 1, 2 and 3seconds. The robot's performance is analyzed under three different scenarios in which input applied can be categorized as Slow, Medium, and Fast.

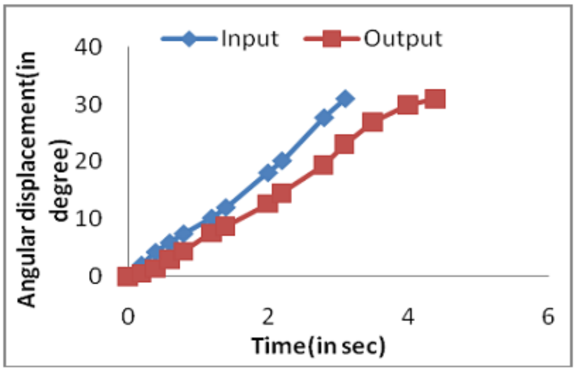

Fig.15 Time vs. Displacement in 3 sec

VI. NEW QUESTIONS FOR INNOVATION IN HUMAN–ROBOT COORDINATION

A. Intent at a Distance

Many technological advances can be viewed as means for perception at a distance or action at distance. In these cases, technology extends our perception through sensors and scopes, or extends our activities in terms of the sequences, precision, or forces we exert indirectly on the world (e.g., one act triggers a sequence of activities, or one activity is translated into the component physical actions needed to accomplish intent as in modern aircraft controls).

New capabilities for robotic systems are a major step forward within this tradition of coupling people to scenes at a distance. Fig.16 starts from this tradition to provide a framework for human–robot coordination. The framework juxtaposes at the far left the human as problem holder, i.e., those people and groups responsible for achieving goals, and on the far right the world in which the person/group needs to project perception and action at a distance.

Robotic systems provide a new form of perception action coupling at a distance, especially when these systems are

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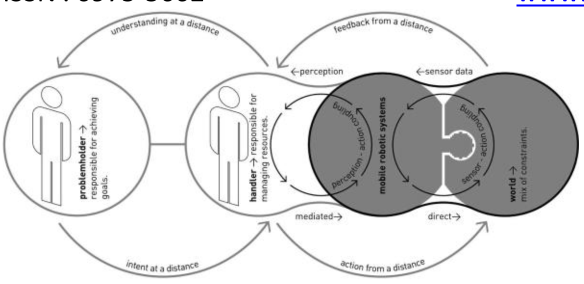

Fig:16 Roles in human–robot coordination. Robots allow a problem holder to project intent at a distance through a robot handler/robotic system couple. The sensor-action coupling of the robotic system to the world is unstable due to the inherent brittleness of automata and can drift as situations change (indicated in the figure by the loose fit between the robotic system and the world). The robot handler can anticipate context shifts and adapt to realign this coupling.

endowed with sufficient capability to move on their own beyond teleoperation only.
As the robotic system's perception-action coupling becomes more sophisticated, this power does not remove the human from the scene but ironically couples them in a way that is paradoxically intimate, though physically removed (or mediated). This relationship is fruitfully conceptualized as intent at a distance as robotic systems provide human stakeholders higher order means to achieve their goals (Fig. 16). The target for human–robot coordination is projecting human intent into the world (not simply inferring or communicating intent across agents). Ultimately, robotic capabilities represent new powers for human problem and stake holders to project intent at a distance.

B. Robot Handler and Problem Holder Roles

But (Robin)Murphy's law, the basic asymmetry in coordinative competencies between people and automata, and other findings from human-automation teamwork remind us of the limits of automata in coordinated activity (brittleness, literal-minded, etc.). Given the inherent potential for surprise in complex settings and limits of automata, there are two human roles in the ensemble which must be planned for in HRC. The robot handler role is responsible for managing the robotic capabilities in situ as a valued resource and points to the knowledge, practice, and interfaces needed to manage the robots in a physical environment. This differs from problem holder which refers to the human roles responsible for achieving mission goals and the associated knowledge and experience. The problem holder role arises from the fundamental constraint that people create, modify and operate automata in human systems for human pur- poses (see the fourth family of Laws that Govern Cognitive Work in [20]). For example, Casper and Murphy [7] found that the demands of search and rescue operations and the limits of robotic systems today led to an organization where these two roles are represented by different teams. The search and rescue personnel function as problem holders trying to characterize the search situation and achieve rescue goals, while the robot developers act as handlers who better understand robot capabilities and limits, and direct its capabilities [21]. Together they try to use the capabilities and workaround limits to achieve operational goals. In complex settings difficulties cascade and demands escalate which will challenge robotic systems ability to compensate and demand coordination between people and robots [22]. Inevitably, robot capabilities will exhibit brittleness as situations develop beyond their boundary conditions [23]. Together, these represent challenges to the adaptive power or resilience of the human–robot ensemble (as illustrated by the only partial fit between the robotic systems and the mix of constraints in theworld in question in Fig. 16). Coordinating these roles with the limits of robotic systems creates critical guiding questions for assessing coordination: How will human team members recognize the approach to brittle boundaries and intervene effectively (e.g., bumpless transfer of control)? Inevitably, autonomous resources will be lost or fail. How will the team dynamically reconfigure or gracefully degrade as assets are lost? One function that tests coordination across these human and robotic roles is judgments of traversability or climability in context as such emergent judgments cross all of the parts of Fig. 16. The next sections briefly consider issues in HRC moving from perception-action coupling through the robot systems to adaptation to responsibility.

C. Affordances and Remote Perception

In remote explorations of an environment, a robotic system provides an action/perception stand-in at a distance (Fig. 16).

This decouples the natural dynamic relationship between properties of the scene being explored and the human perceptual system of the remote handler [24], [22]. The decoupling undermines the remote observer's perception of affordances in the scene [26] which is illustrated by recent cases of HRC where remote observers experience various difficulties in understanding the environment being traversed by a robotic system [8], [27]. While a great deal of work has addressed creating an illusion of presence for remote observers, this work has not addressed the fundamental ambiguities that arise in remote perception or how to enable the perception of affordances when access to a scene is mediated. In addition there is the issue of how to integrate partial views from a set of robotic resources into a coherent model of the environment for remote human observers. Casper and Murphy [7] found examples of the difficulty in using remote vision effectively while studying the use of robots for search and rescue at the site of the World Trade Center (WTC) immediately after September 11, 2001. Rescue workers attempting to use robots to search areas of debris inaccessible to humans had to try to deal with the unexpected perception issues that arose in coordinating the robot's sensing of the world it was in and the remote observer's perception of that world. For this set of issues, the robot can be thought of as a remote, semi-autonomous sensor platform, and the problem is then determining what can we as remote observers understand about the environment being traversed by the robot. To better understand these issues, consider a specific problem in remote perception—scale ambiguity. This ambiguity arose when robots were used to search through rubble at the WTC—remote human operators were often unable to perceive whether the robot could pass through openings or over obstacles [8]. Note the contrast to our own perceptual performance. In a directly perceived natural environment, we are able to recognize immediately the scale of the environment relative to our ability to move through that scene (one kind of affordance we directly pick up). In a natural environment we have a very strong sense of our own body size and movement relative to the obstacles or passages we encounter. This is an example of how people perceive the affordances of the environment based on perception of high level dynamic relationships such as point of view, relative scale, and rate of approach to obstacles [25], [28]. However, when we try to interpret visual information from remote robotic platforms our visual system must overcome the ambiguities that result from the disruption of the correlation between perceptual cues that exists in natural perception. For example, when an observer moves, the vestibular system provides feedback about acceleration that can in principle be used to interpret rate of motion and thus provide a natural scaling of the distances in the environment.

This information also is lost during remote perception. The robotic platform in the field may be moving to create the video images, but the remote observer's vestibular system is indicating the body is stationary. This is actually a cue conflict situation, and so the vestibular system is not merely providing no information about motion, it is contradicting what the remote observer sees.

Cues to depth are limited or in conflict in raw video feeds from robotic platforms. For example, a single camera view to a remote observer creates cue conflicts in binocular stereopsis— one of the most powerful cues to depth and surface shape for human observers.

When looking at a video monitor of the remote scene with our two eyes, binocular stereopsis is indicating that all the objects in the remote environment are at the same depth. Of course other cues (e.g., motion parallax, shading, perspective, and texture deformation) are available in the video stream to counteract the flatness indicated by binocular stereopsis, but this cue conflict is another instance of the disruption of the correlations between visual cues found in natural vision. Another important ambiguity which occurs for the robot handler involves the perceived rate of motion.

The relationship between optic flow and rate of motion in the environment depends on our eye height, or camera height for the robotic platform [25], [28], [29]. Thus, some intermediate optic flow rate in the image could result from a slow moving small robot or a relatively fast moving large robot. When viewing video from a remote robotic system our visual system is processing the optic flow without motion feedback information and based on an eye height that may or may not match the camera's height.

These discrepancies will introduce ambiguities and misperceptions of perceived velocity by the human operators viewing the remote video from robots. The limited angular view associated with many remote vision platforms creates a sense of trying to understand the environment through what remote observers often call a "soda straw. "This is an example of the keyhole effect in viewing large virtual data spaces [30]. Typical consequences of the keyhole effect include missing new events, increased difficulty in navigating novel environments, gaps or incoherent models of the explored space.

Keyhole problems arise from the fact that typical virtual environments sever the foveal field of view and focal attention from the orienting perceptual functions that help people fluently know where to look next, despite the potential for new interesting events to intrude on ongoing activities.

Related to this, the mechanisms that allow people to coordinate direction of gaze and direction of movement as they move in a changing scene are removed in remote perception. But the link between the robot's direction of gaze and the mechanisms that support visual exploration of a scene are quite impoverished in today's robotic systems/human–robot coordination mechanisms. For example, human gaze control is tuned to anticipate future movements and conditions of interest.

Contrast how you would direct gaze as you turn to climb a stairs with scattered debris on it and with various items or activities of interest at the top of the stairs versus how robotic platforms position their cameras during the same maneuver. Generally, the robot camera either points at each step one at a time or remains pointed at the ceiling as the robot climbs, whereas people direct and shift gaze in tight coordination with the affordances present in the situation given their purposes and context (e.g., when to look at the activities heading for the top of the stairs and when to look at potential obstacles along the stairs).

Our main point in describing these perceptual ambiguities is to make clear that seeing though a remote camera is not the equivalent performance as having a human observer at a scene.

Perception is an active process in which the observer causes the visual image to change by performing actions in the environment [26].

When human handlers interact and coordinate with remote robotic platforms, the perception-action cycle becomes mediated, and the robot handler must respond based on the action capabilities and limitations of the robot rather than his own. When we fail to appreciate the impoverished nature of the stimulus set in remote perception, we are surprised by findings such as in [27].

Darken and colleagues asked remote observers to track their spatial location and identify objects based on video footage from a remote reconnaissance mission, and found that neither task could be performed adequately. Such results lead to the conclusion that the raw video needs to be enhanced to recover what was lost by decoupling the human perceptual processor from the environment being explored.

D. Functional Presence

The ambiguities in remote perception are part of a broader challenge of creating shared perspective across agents-in-the scene and remote agents so that they can productively interact and work together.

How do we synchronize models of the world across these agents, detect discrepancies and repair them? Understanding the processes involved in creating shared worldviews is particularly important in the case of semi-autonomous robotic agents that are operating with direction and intervention from problem holders and handlers. Shared perspective typically has been framed in terms of the goal of "presence." Identifying specific ambiguities in remote vision situations shifts the research goal to achieve what we term functional presence. Functional presence occurs when a remote observer has sufficient information available to his senses to effectively function as if he were directly perceiving and acting in the remote environment.

The emphasis is thus, not on creating the "you are there" impression, but instead on providing sufficient perceptual information so that the remote observer can pick up affordances from the environment as if they were there, i.e., to enable the natural competencies of perception in exploring and behaving in the scene. Thus, the breakdowns noted in [8] and [27] are natural and expected consequences of the impoverished perceptual environment created by video feeds from remote environments.

To accomplish functional presence research is needed to identify and implement perceptual cues that can augment the remote video stream and allow the human perceiver to compensate for the absence of the complex combination of naturally occurring information (e.g., vestibular feedback) that would exist if he were actually investigating the environment. These cues will be ones that re-establish in the impoverished video stream information about point of view, relative scale and rates of approach, i.e., properties of the environment that defined with reference to the observer/actor.

E. Avoiding Coordination Surprises: Seeing Into Future

Activities and Contingencies

To achieve new levels of coordination, past research has shown that increases in the level of autonomy and authority of automata require an increase in the levels and kinds of feedback between agents about their current, but especially future, activities as system state varies. Field studies, incidents and simulation results all reinforce this as a basic finding or 'law that governs cognitive work.' When this relationship is ignored coordination surprises occur between agents [11].

The research challenge is to define the levels and forms of feedback needed to achieve coordination across partially autonomous human and computer agents [31]. Critical to the new forms of feedback are representations of automation activity that capture events, are sensitive to future developments, and integrate data into higher order patterns—not simply current process state or automation configuration.

For example, as robotic systems have the capability to follow plans and to shift to a new plan as the situation changes (e.g., current UAVs), how will human supervisors monitor robot plan selection, plan following, recognize disrupting events, and modify plans [32].

F. Directing and Delegating

Past research also has shown that increases in the level of autonomy and authority of automata require mechanisms to manage or redirect automated systems as resources—directability. Giving human agents the ability to observe the automation's reasoning processes and activities against the evolving state of the world is only one side of the coin in shaping machine agents into team players. Human supervisors also need the ability to substantively redirect the machine agent's activities. From the point of view of coordination, human–robot design is concerned with the kinds of coordination strategies available and how to shift dynamically from one strategy to another as context changes. How will handlers give and robots take direction [33].

A sample of the possible generic strategies include:

- **plan based direction,**
- **constraint based direction,**
- **direction through commanders intent.**

In plan based direction, mission and contingency plans are developed in advance; distant human direction modifies these plans or directs the robot to switch to a different plan [34]. In the absence of specific direction from distant handlers, the robot selects a plan or contingency to follow given its on-board criteria.

This is the form of coordination used with some of the Air Force's UAVs and used by NASA with space exploration missions. In constraint based direction, remote robot functions autonomously, while distant human monitors direct the robot by introducing constraints on its freedom of action (autonomy). This form of coordination is being developed and explored for the national air transportation system for aircraft-ATC coordination under enroute free flight rules. Commanders intent is the form of coordination used in military command and control for adapting plans to surprises, both disruptions and opportunities [35].

In this form of coordination commanders communicate the intent behind the plan to subordinates who will be on the scene (the robotic platform in the future). When disruptions to the plan occur, the actors in the scene use the intent information to adapt activities to achieve the goals of the plan.

The measure of different strategies for giving/taking direction is the team's resilience in adapting to surprises.

G. Responsibility in Human–Automation Teams—Remote Responsibility

How does responsibility for the consequences of actions influence the design of human–robot coordination? Billings has developed a set of first principles for responsibility in human automation systems which build from a basic premise ([10]):.

Some human practitioners bear ultimate responsibility for operational goals (see also [20] particularly the fourth family of laws on responsibility in cognitive work). As a result those with responsibility within the system must have some means to effectively command within that scope of responsibility (as problem holders): These supervisory human operators must be in command [10] The question, then, is what does it mean to be 'in command' of robotic agents and what does it mean for robotic agents to be part of a "command?" Billings answer is that to be in effective command within a scope of responsibility, the supervisory agent [10]

- **must be involved;**
- **must be informed;**
- **must be able to monitor the automation or other subordinate agents;**
- **must be able to track the intent of the other agents in the system.**

The automated systems "and other subordinate agents" activities therefore must be comprehensible and predictable.

IV. WRITING THE FUTURE STORY OF HUMAN–ROBOT COORDINATION

The interplay across the R&D roles represented by the three characters creates new questions to be pursued and new possibilities for wielding the power of robotic systems while taking seriously the limits of automata.[20] The advancing capabilities create new opportunities (and new demands) to envision alternative forms of coordination between people and machine agents as they carry out activities in the world. Studying new forms and functions in coordinated activity, given robotic capabilities, then can seed development of specific systems in specific work contexts.

The developments underway in human–robot coordination also become a setting for considering how to aid envisioning as a process of discovery. In this case our three characters are writing out stories of future operations, as they are also actors in the unfolding story. Neither as writers, actors, stakeholders, or audience does any one participant have a clear viewof the events to come or the ending. The remainder of the story will emerge as real people and organizations balance or misbalance the intermingled roles, synchronize or missynchronize the three perspectives to achieve new forms of coordinated activity to serve human purposes [13].

VII. CONCLUSION

A humanoid robot which can be operated by physical movement of the demonstrator using wireless communication is designed and tested. From the experimental results, it is shown that efficiency of the robot can be varied by changing the input response given by the THG. At low input response, the efficiency was found to be the highest with negligible lag. Thus by varying the input the efficiency can be varied. The steady state error of the robot while settling in a position was found to be nil. This concept can be extended to an autonomous robot by programming it accordingly.

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