CopyBot

Extending your limits

Every once in a while there comes a product which enables the users with the **power** to express **their ideas** into reality. These tools are the biggest

reason that intensify the large scale **collaborative ventures** which lead to technological advancements. All through history, the best selling products were the **tools that gave users the power to design and develop** their products, services or application.

From the early days innovations (which now look quite basic but should not be taken for granted) like lever and abacus to the modern world innovations like personal computer, Android OS and Raspberry Pi, these greatest breakthrough had one attribute in common. ***They all augmented basic human capabilities and transferred the power in the hands of the users.***

These tools were made possible only because the product designers **tapped into the great potential which the research in those sectors promised**. This brings home the point that great technology in any domain needs **simultaneous advancements in the corresponding research area** to make any significant impact on the industry. They were tools built after rigorous redesigning, constant reviewing and planning to convert **purely academic research papers to successfully selling products**.

This is exactly what we are trying to do; tapping into the great potential which the research in robotic arms offers. Day by day, we are advancing in the research areas related to the robotic arms leading to more robust, efficient and reliable robotic arms. The problem is that robotic arms, in spite of their advancements, have still not seen enough penetration in the consumer market because :-

- The products directly targeting the such consumers are still not developed (or are still being thought upon) that provide easy interfaces to control the robotic arm.
- The overhead of learning a particular programming language to even get the basic control of the robot arm is costly and time-consuming.

The notable innovators in robotic design and development industry, shared quite similar opinions about the problem of complicated interfaces that are presently used to control interesting systems, thus adding a whole new layer of complexity.

The reason that 3D gesture control is a promising avenue for our work is because we're all natural experts at this from birth. We are trained to interact with things in a 3D environment. We're not born knowing how to use a keyboard or a mouse. How can we build devices and interfaces that make it intuitive and natural for people – first to understand the state of a complicated robot – and then control it?

- Jeff Norris, Mission Operations Innovation Lead at the JPL, NASA.

As evident from Jeff Norris' comment, this problem is being realized in many top robotics organizations . Solutions are still being thought of to reduce this challenge of complexity.

This is the problem that we decided to solve by taking the initiative to design and develop interfaces which are intuitive and easy enough for the consumer to control a robotic arm. This way the users, without prior programming experience, will be able to tap into the great potential that the research in mobile manipulation offers. Thus, rather than solving a particular target problem, we are empowering the users to solve their own problems.

Keeping this design philosophy in mind, we proposed the idea of CopyBot , an intuitive and amazingly simple to use mobile manipulator made using the state-of-the-art software and hardware interface that **gives its user the power to make it do what <u>they</u> want**. This will be a B-

To-C product aiming to engage and motivate more and more consumers into leveraging the present technologies in mobile robotic arms. Its scope shall cover following topics :

- To offer gentler learning curve into the domain of robotic arms manipulation.
- To encourage collaborative engagements of more users leading to accelerated growth and development of better algorithms and design.
- To make these arms perform day-to-day small tasks that require varying degree of manipulations. For example, moving or stacking up particular objects.

These problems, market condition and popular opinion about the direction in which possible solution can be found lead us into the induction of the idea of CopyBot.

Now, we will be discussing the **detailed implementation plan** that we will be following to develop this idea from budding thoughts to a practical reality in the current market scenario.

Detailed Implementation

Keeping in mind the ideologies which NIYANTRA stressed upon, we incorporated the platform-based approach in the design of our CopyBot. Developing this system from scratch would only pose problems already solved in the industry.

- More time would be required to get even the basic functionality of the system.
- Even if the bare minimum software and hardware is built, we would only be **reinventing the wheel.**

Thus, we decided to use the platform based approach by integrating COTS products in developing our system. Thus, it would allow us to focus entirely on the problem of developing intuitive interfaces, rather than solving problems which have already been solved.

"... NIYANTRA encourages students to use a platform based approach to build their systems using industry standard COTS hardware and software, instead of building a system from scratch..."

As evident NIYANTRA, too, had same design ideologies; thus we chose the following industry standard platforms in our design:

- *NI LabVIEW RIO Architecture*
- *KUKA youBot*
- *wit.ai*

NI LabVIEW RIO Architecture

The LabVIEW RIO architecture is the ultimate building block for innovative designs. The architecture combines real-time processors, user-programmable FPGAs, and modular I/O with a cohesive software environment that can be used to program and customize each element of the system. With its ability to interface with any kind of sensor or specialty I/O, perform advanced signal processing and custom analytics, and execute advanced control algorithms, the LabVIEW RIO architecture is the ideal architecture to build upon when designing advanced control or monitoring systems, especially in Internet of Things (IoT) applications.

NI myRIO 1900

We had to design and develop innovative system by integrating various different off-the-shelf products. Thus, the LabVIEW RIO architecture was a natural choice because it had some significant advantages over its competitors. By providing a graphical programming interface in the

LabVIEW System Design Software(in RIO architecture) it provided advantages like:

1. ***Gentler learning curve*** into building solutions in various domains. 2. ***Easy debugging*** by providing various features in LabVIEW like
    - Highlight Execution- Visualizes dataflow at grass root level in applications.
    - Probe tool- to see what value is flowing through the wire in real time.
    - Breakpoint - to the find the area where the bug possibly occurred.
3. ***Faster development*** - Drag-and-drop is considerably faster than typing the code.
4. ***Good community support*** - Lots of example and sample to get started quickly.

This was the software part; on the hardware end the RIO architecture provided:

1. ***Powerful dual-core ARM Cortex-A9 processer*** for computation intensive tasks.
2. ***FPGA -*** which is quite a buzz around these days for the right reasons. It would provide the feature of offloading critical processor intensive tasks and provide high throughput.
3. **NI LabVIEW FPGA Compile Cloud Service -** which reduces the time required in compiling the FPGA code by transferring the processing to dedicated hosted servers by National Instruments. This is free of cost for first 3 months to new users.

4. ***Onboard devices*** like Wifi and audio-in/out jacks (in myRIO) would eliminate the need for externally interfacing them.

Thus, we'll be using LabVIEW software as well as myRIO to harness the maximum functionality out of the RIO architecture.

KUKA youBot

The KUKA youBot is an open platform that is operated with open source software. It is on its way to become a reference platform for hardware and software development in mobile manipulation. The youBot enables researchers, developers and robotics students to write their own software, learn from others' accomplishments and configure the hardware as required or desired.

KUKA youBot

So, rather than reinventing the wheel we thought of using the KUKA youBot which provided the open platform to design my system. YouBot is just the bare minimum hardware consisting of

- a five degree-of-freedom robot arm
- an omnidirectional mobile platform
- two finger gripper as the end-effecter

The youBot provide low-level access to the its hardware to move the joint motors according to the developer's intent(within its mechanical hard limits). This will be used as the industry compliant open platform to display the potential of intuitive interfaces in robotic arms. It also includes :

- a maintenance-free 24V/5A lead-acid battery.
- communication over Ethernet and etherCAT protocol.

Wit.ai

Wit.ai allows you to understand the meaning of a user input. You may need it as a stand-alone layer to parse text or speech into structure data.

This platform will be used as a service(it's completely free of cost) to send voice signals and receive clear instructions according to the data its trained for. This voice signal will be recorded by the microphone and sent to the server using data sockets in LabVIEW, leveraging the Wifi connectivity of myRIO. **Also, an important point to note is that because voice signal capture will be a processor intensive task, FPGA capability of myRIO will be used in the capture of voice signals without having any significant impact on the onboard processor.**

Main Sensors

LEAP Motion sensor

We believe that simple, natural input is key to unlocking the immense power of technology. With Leap Motion, you can interact with digital content using your hands just as you would in the real world. Our unique combination of software and hardware tracks the movement of hands and fingers with very low latency, converting it into 3D input

<u>LEAP Motion Sensor</u>

To design these intuitive interfaces we'll be using the LEAP Motion sensor to capture and record hand gesture data to move the robot arm. With an accuracy up to 0.7mm, this small package will be the most important key in our system control.

Microsoft LifeCam

The webcam will be mounted on youBot end-effecter to provide live video feed of the surrounding environment of the robotic arm. Its aim will be to:

1. Help user to make better use of the robot arm even from a remote location by getting constant video feedback from the camera.
2. Pursue more ambitious aim of incorporating object recognition and tracking(machine learning)[using camshift, meanshift, Viola-Jones, KTL algorithms, etc] as an open-ended option so that the arm becomes intelligent enough to carry out basic manipulations after such tasks have been taught to it.

Zebronics Microphone(ZEB-1200SM)

This microphone will be used to record voice instruction from the user near the CopyBot to handle emergency tasks such as STOP. This microphone will be plugged into the Audio-in jack of myRIO. Voice signals recorded by the microphone(after noise removal) will be sent over to the cloud service, ***wit.ai*** . This will draw useful insights from the voice signal and send back clear instructions to myRIO to control the robotic arm.

User Flow

- User will install an executable (made using LabVIEW) on his PC and plug in the Leap Motion sensor to control the CopyBot using the most intuitive controller on planet - Human hands.
    1. Left hand will control the movement of mobile omnidirectional platform.

    2. Right hand will control the movement of the robotic arm in the 3D space.

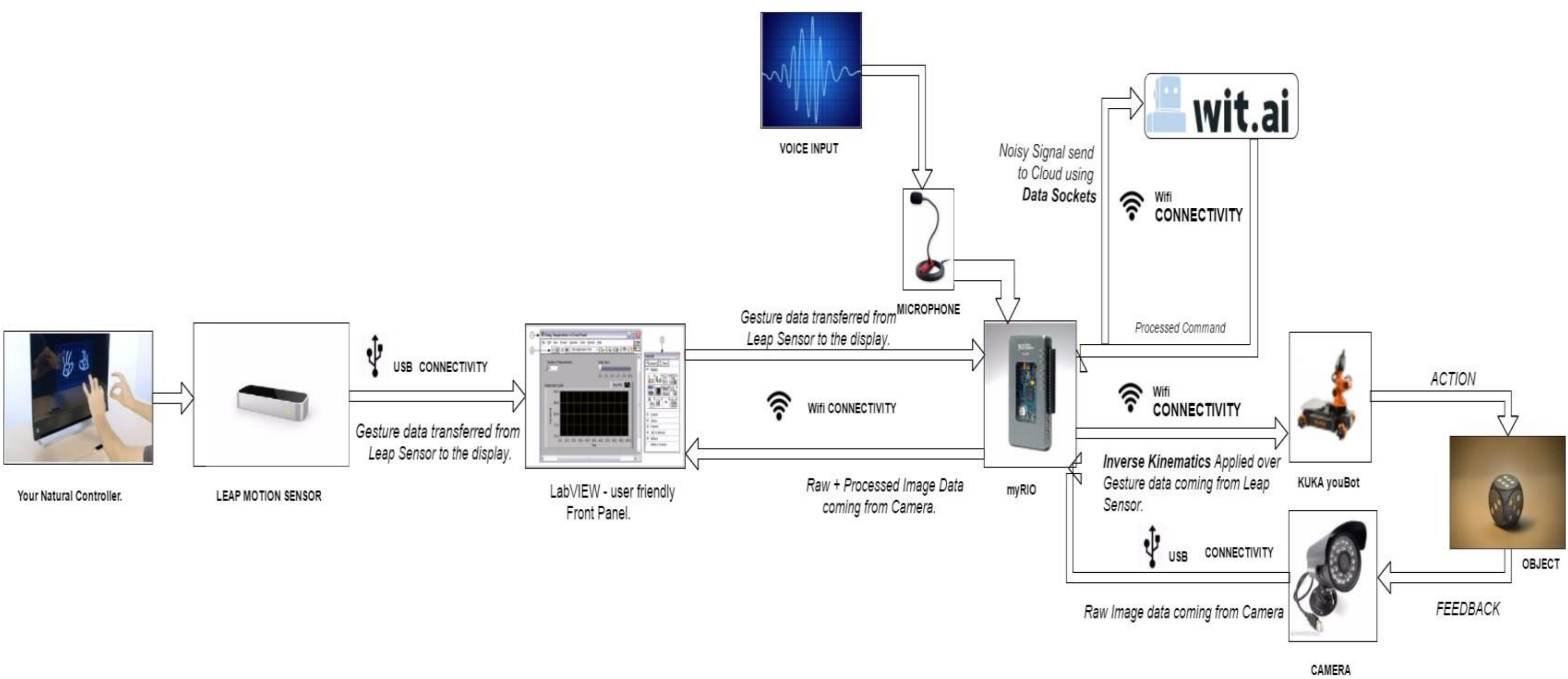
3. Tip of right index finger and thumb will control the endeffecter(two-finger gripper).

- While controlling the CopyBot using this interface, user will also have live video feedback through the camera onboard to see the surrounding of the arm to better control the robot arm.
- After the LEAP motion sensor records the gesture data, the Cartesian coordinates of the hands in all the three dimensions will be extracted and sent over Wifi to myRIO.
- When myRIO receives the gesture coordinate data, inverse kinematics calculations will be done on the coordinates to find out all the 5 joint angles of youBot.
- These 5 joint angles will be fed to the low-level drivers of the youBot to finally move the (arm + platform) according to the configuration and orientation that the user desires.
- The trajectory followed by the arm will be recorded for any repetitive manipulations that may occur. Thus, after a task has been

done once, the exact same task can be replayed any number of times because the trajectory followed by the arm was recorded. This is the powerful copy mode of CopyBot to make the repetitive tasks a breeze!

Add-ons for CopyBot

- The onboard camera will be used to learn about basic objects so that they can be detected and tracked as the camera moves. This will enable the CopyBot to intelligently carry on these tasks in future, even if the object has been slightly displaced from its last position.
- The microphone will be interfaced with myRIO using FPGA technology as mentioned before. This will take instruction from the surrounding users for simple tasks and emergency stop. Thus, redundant interfaces using speech and gesture will be implemented leading to better control.



System Architecture Diagram

Challenges

Challenges are just opportunities in disguise. We too had many such opportunities in disguise in course of developing the system control interfaces.

- Handling the inverse kinematics and porting the open source IK library in LabVIEW is still being learned using NI white papers for using external code in LabVIEW.
- Installing the Robot Operating System (ROS) on Ubuntu and using Gazebo after building the binaries from source code was a challenge in itself.
- Communication between two computer using LabVIEW has been set up over our home network; Amazon Web Services(AWS) Cloud has also been set up but will need further configuring for easy transfer of coordinated data over the cloud.
- Wit.ai is still being explored and used for basic application to later implement it in our product.
- Machine learning using OpenCV will be quite a load of learning experience and challenge that we look forward to.

Scope

- CopyBot will become an indispensible tool for research and education in the domain of robotic manipulations.
- It can be used directly by the people with disability in legs to carry out their day-to-day tasks, thus making their life easier.
- It can be integrated in middle to high class homes. This will give the users the power to carry out tasks at home from anywhere in the world.
- It will give users the power to carry out manipulations in areas where humans cannot directly reach.
- CopyBot will go a long way in proving to be the users' personal assistant, thus users do not have to be concerned about menial tasks.

This product will get kick started if this idea gets selected in NIYantra by leveraging the power of the RIO architecture.

Our YouTube playlist link for NIYantra

[https://www.youtube.com/playlist?list=PLGdf7_7xJgaIzd8fhI1eyafnkhAkhEiGp]