A cost-effective, multimodal robotics platform

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Presented for:- NIDHI-PRAYAS Grant Programme

22nd October 2020

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Introduction: Root Problem 1.1

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In Agriculture and food production

NECESSITY

- There's a real big focus on food production and crop management which was triggered by the Financial crisis of 2008 which led to peak in food prices and other commodities and also resulted in food riots.
- More than 70% of Indian population lives in rural areas where primary occupation is agriculture. More than 58% of Indian population(2011) depends on the agricultural sector[2].

DEMAND

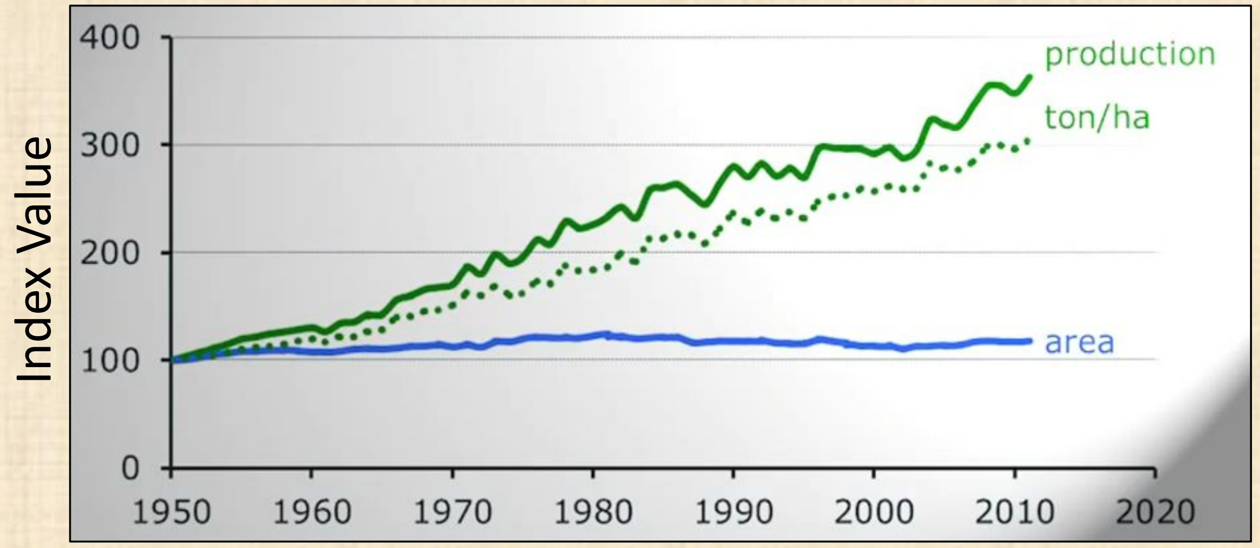
- In the case of India, food demand has not been growing at anything near the rates one would expect from the high economic growth and the high prevalence of unsatisfied food needs. Hence, frequent assertions are made that growth in the demand in India was among the major causes of the food price surges of 2007- 08.[1]
- Over the next 40 years, mankind will need to produce as much food as past 8000 years combined. By 2050, human population will go just over 9 billion (considering moderate growth model). Avg. need for a person is **2000 Kcal/person/day** but the global avg. is **2700 Kcal/person/day**.[3]
- **Demand = population × diet** ; hence, this is another reason for increased demand.

Source:- [1]: World Agriculture towards 2030/2050: the 2012 revision, Nikos Alexandratos and Jelle Bruinsma:- http://www.fao.org/3/a-ap106e.pdf
[3]: Wagenin University , [2]:Deshmukh, Mahadeo & Babar, Nitin. (2015). Population Trend and Agricultural Employment growth in India, [4]: ©Harper Adams University

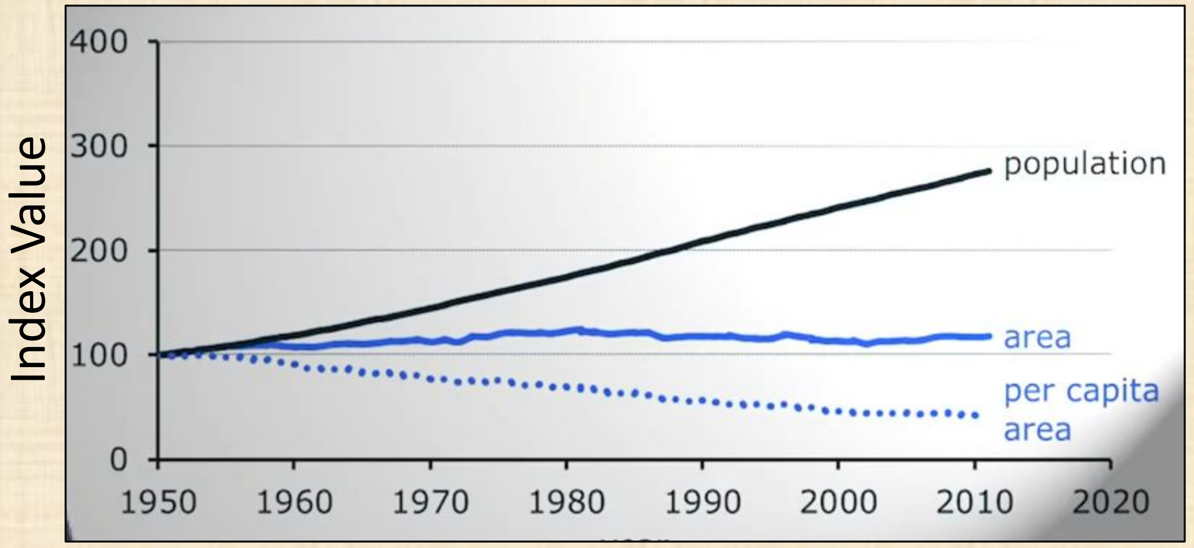
Introduction: Root Problem 1.1

EFFICIENCY

GLOBAL GRAIN PRODUCTIVITY (1950-2012)[5]

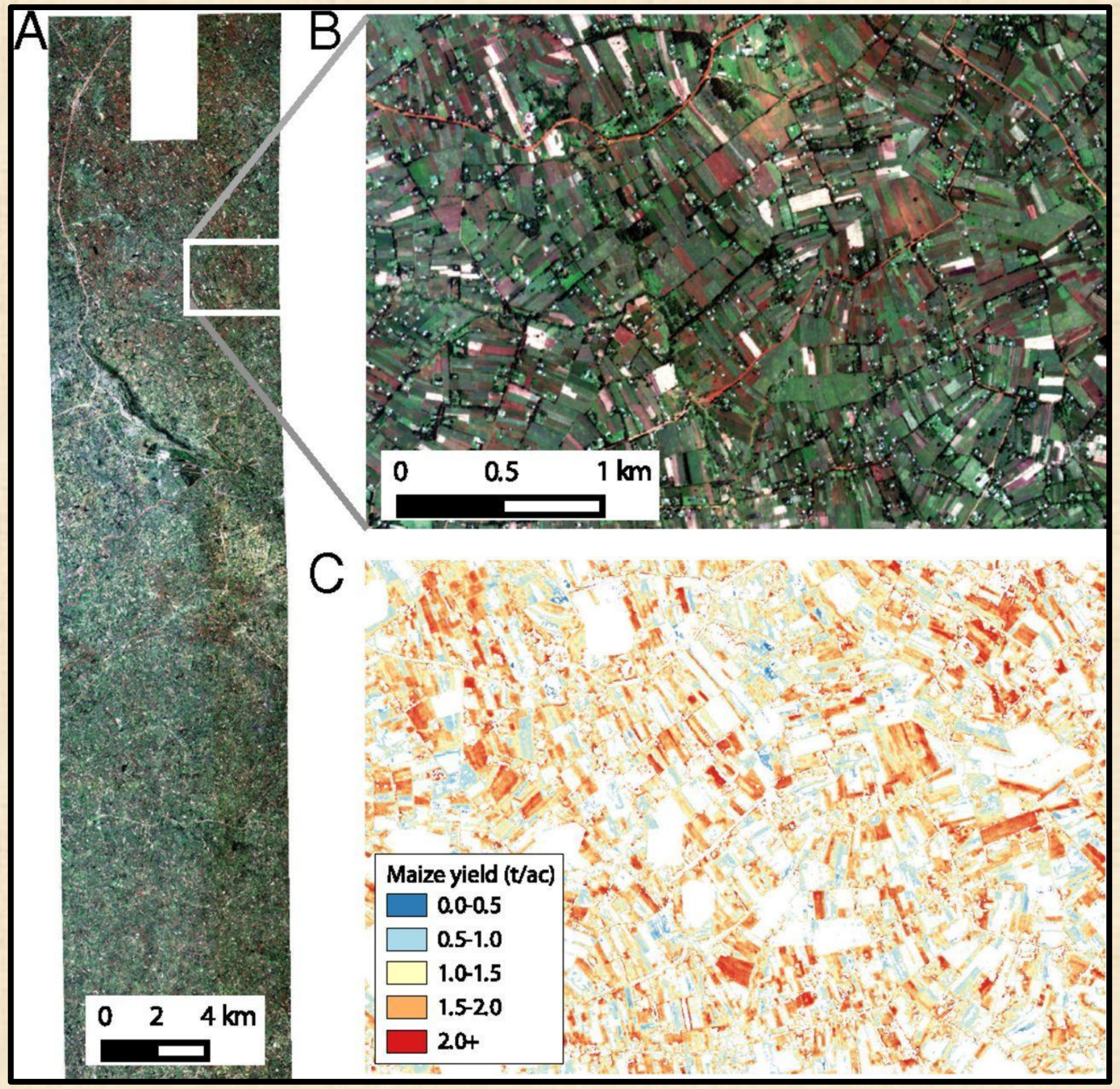


GLOBAL GRAIN ACERAGE (1950-2012)[6]



- With every harvest session, nutrients are taken off the field and soil fertility is declined. Fertility is regained by leaving the land fallow (for about 15-30 years) (can be increased by adding manure).

Global Grain Productivity (1950-2012)	Global Grain Acreage (1950-2012)
In 60 years, production increased three folds; because of enormous yield per hectare and hardly any area expansion.	As population has also increased three folds, per capita area has decreased to less than quarter of hectare per person.



Maize yield map for the study region, 2015.
(A and B) One-meter image from Terra Bella of the study region (A) and zoom-in of that image (B),
(C) Yield map of the zoomed-in region for pixels classified as maize.[7]

Source:- *[5]: FAOstat, [6]: FAOstat, [7]: Satellite-based assessment of African yields: Marshall Burke, David B. Lobell Proceedings of the National Academy of Sciences Feb 2017, 114 (9) 2189-2194; DOI: 10.1073/pnas.1616919114*

Introduction: Root Problem 1.2

Soil Erosion

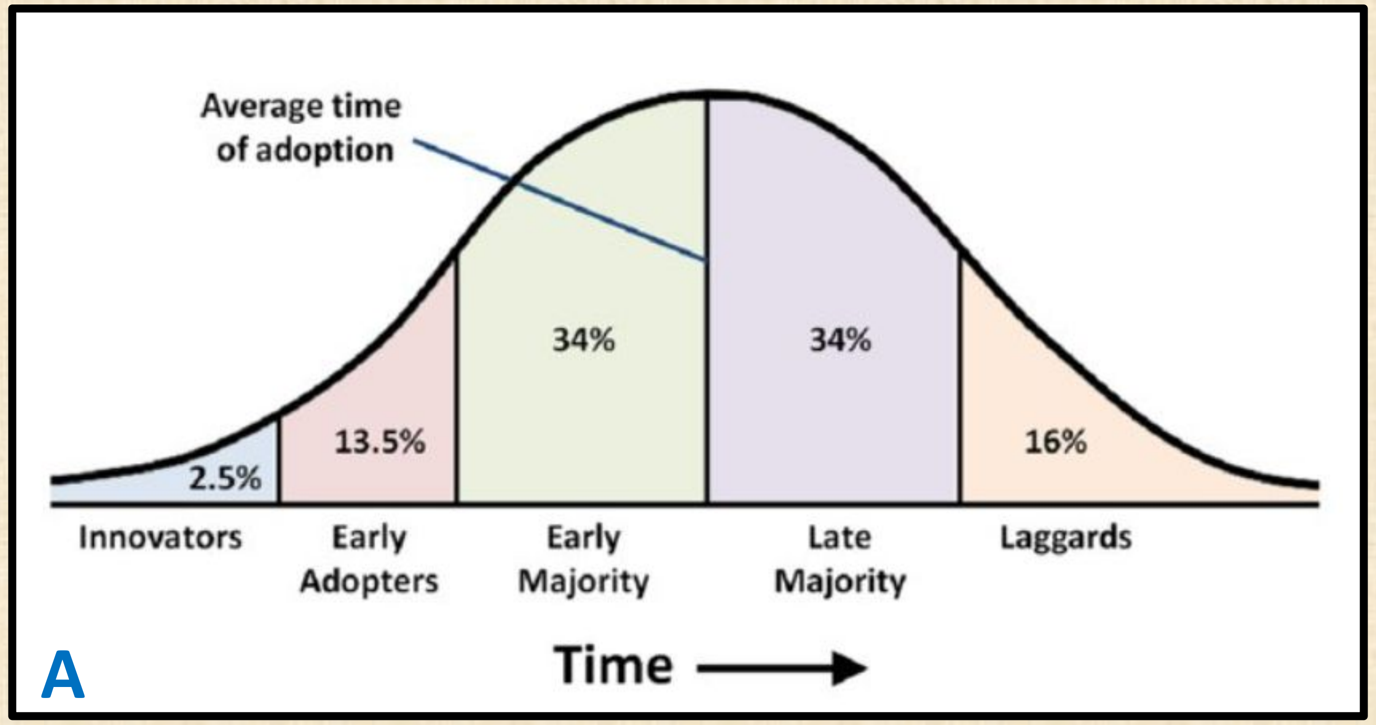
NECESSITY TO TACKLE

- It takes **2000 years** for the creation of just **10cms** of fertile soil. Every year, 13 million hectare forests are cut down[8]. Inadequate cultivation of fields, monoculture and farming on slopes also add up to the problem.
- After harvest, fields are left open and unprotected which accelerates erosion.
- 24 billion tonnes of fertile soil was lost in 2011 alone → 3.4 tonnes/person worldwide. Erosion costs down to 490 billion dollars loss worldwide.
- Available arable land per inhabitant will reduce down to half by 2050[9].
- Soils play a key role in carbon and nitrogen cycle, thereby help to combat climate change.
- **Sustainable soil management** can contribute to greater storage of carbon from the atmosphere in the soil. In the next 25 years, this process could help to fix or "sequester", some 10% of the man-made CO_2 emissions.[10]

INNOVATION ADOPTION CURVE

A: Only a small group of innovators are early adopters[11]. Building stone bunds; or terraces on all the steep sloping lands is not a simple yes/no decision. This is a perfect time to start!

B: A gully in a cropped field and the exposure of bare rocks[12]. The region is severely struck by soil erosion! *Image courtesy:- ©MSEC*



Source:- *[8], [9]: IASS, [10]: UN Climate Conference in Paris, December 2015. https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement, [11]:-Diffusion of Innovation,(Everett Rogers, 1962.) https://books.google.co.in/books/about/Diffusion_of_Innovations.html?id=zw0-AAAAIAAJ&redir_esc=y, [12]: Water Policy briefing, Issue 16: http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb16.pdf*

Introduction: Root Problem

1.2

EXAMPLE SITUATION

Case Study: Central Rift Valley, Ethiopia

- This is a highly degraded area and taking measures to control soil erosion is a must to safeguard this land from total degradation[13].

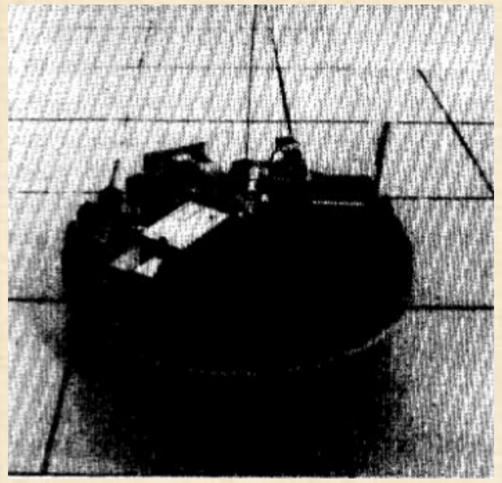
Perception of Water Erosion: **92%** → Investing in Erosion Control: **46%** → Areas with erosion control practices: **20%**

- Similarly, remote sensing of wildfires is an important aspect.
- Digging up canals and building up of 'bundways' can be done.

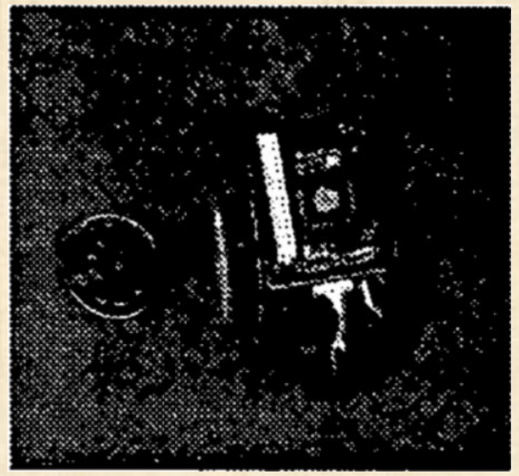
Source:- *[13]:* Agricultural development in the Central Ethiopian Rift valley: A desk-study on water-related issues and knowledge to support a policy dialogue, Huib Hengsdijk & Herco Jansen

Current status: Research and Industry 2.1

Evolution, Industry grade innovations



Holonomic wheeled platforms (Pin et al., 1994)



Robomote (Sibley et al., 2002)

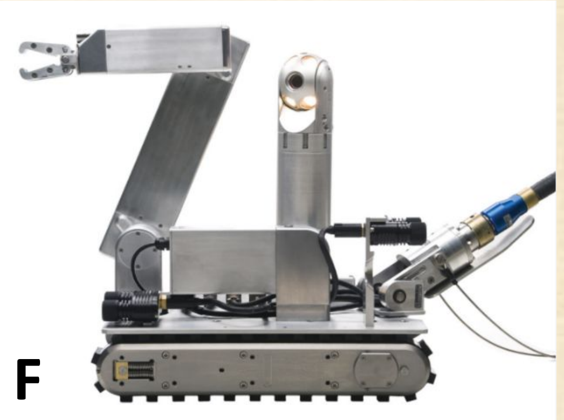


Image Courtesy:- *A,B: Digital Farmhand, C: Mantis and Shrimp, C: LadyBird, E: Vinobot, F: Versatrax 450 TTC, G: ANYmal, H: Cobalt, I:Cody , J: Packbot, K: FarmBot, L: Fetch,*

Current status: Comparision

2.2

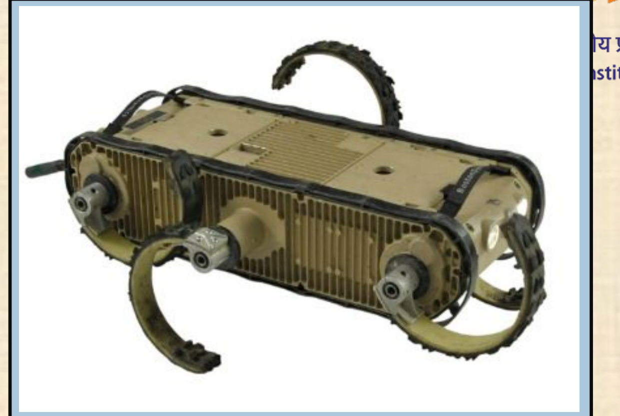
Rapyuta(Mohanarajah et al., 2015)
Advantages: Compact, differential drive base, Cloud comuting environment,cost
Disadvantages: Locomotion on rough terrain

Stretch (©Hello Robot)(2020)
Advantages: Diff. 2 wheel drive, 6 arm, 4DoF manipulator
Disadvantages: Cost is around 18k USD, height cons

Husky UGV(©Clearpath Robotics)
Advantages: ROS API support, high resolution encoders, dead-reckoning
Disadvantages: Weight(50 kgs), Locomanipulation

Cassie(©Agility Robotics)
Advantages: 5hrs battery, custom-design transmissions in actuators
Disadvantages: No manipulators, 300k USD, Toppling

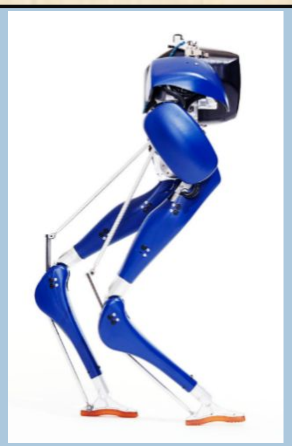
Jackall UGV(©Clearpath Robotics)
Advantages: Onboard PC, ROS sync with rviz, connectivity
Disadvantages: Climbing, motion planning in congestion



Jackall UGV(©Clearpath Robotics)
Advantages: Modular design, pose and state estimation, 6hrs bb
Disadvantages: Adaptability for ext. sensors,computation

Turtlebot(©Willow Garage)
Advantages: Kinect integrated, built in bump sensors, cost,
*Disadvantages:*Climbing, designed for flat surfaces and for building maps only

Segway(©DEKA and Segway)
Advantages: Transport, dual control comp.
Disadvantages: Width constraints, small chassis and difficult integration



Cassie(©Agility Robotics)
Advantages: 5hrs battery, custom-design transmissions in actuators
Disadvantages: No manipulators, 300k USD, Toppling and cross fall

SwagBot(©UYSD)
Advantages: Omnidirectional, grazing and livestock monitoring
Disadvantages: Problems passing narrow lanes, size constraints

Bonirob(©Deepfield Robotics)
Advantages: Plant recognition, weed removal integrated
Disadvantages: Size, weight and cost

RIPPA™(USYD)
Advantages: Autonomous spot spraying, row following
Disadvantages: Works for a fixed row length, curves as in terrace farming are difficult

Solution: System Specifications

3.1

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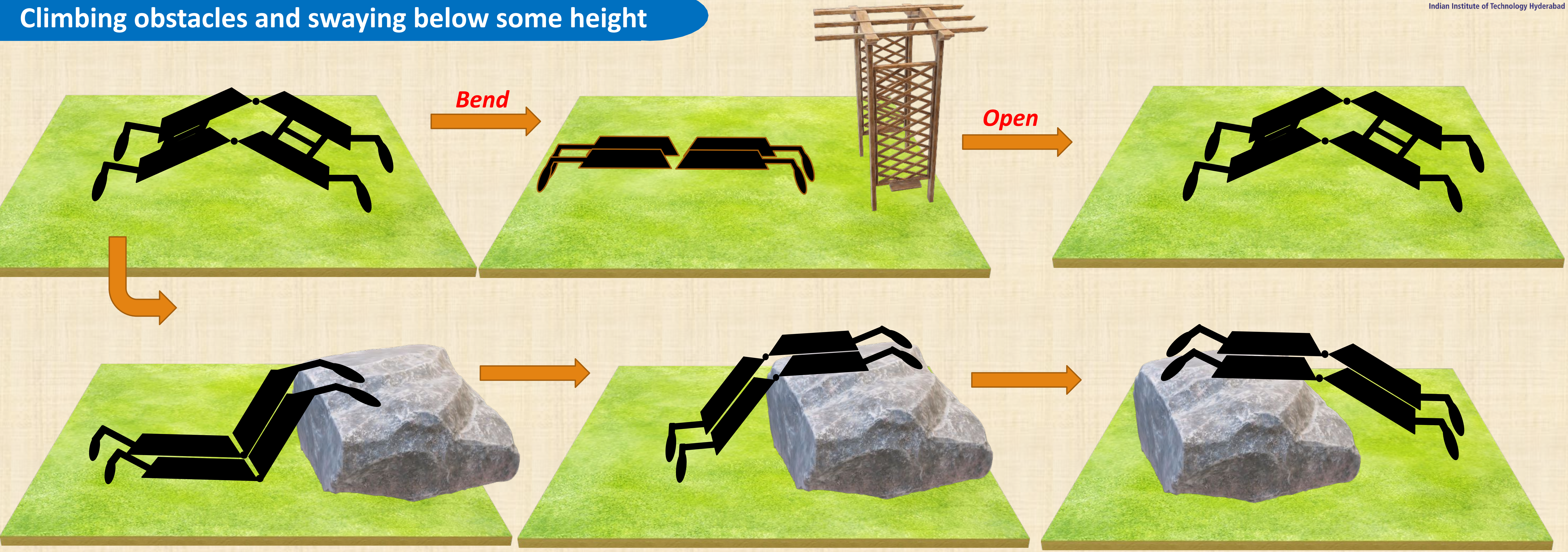
Climbing obstacles and swaying below some height



Solution: System Specifications 3.2

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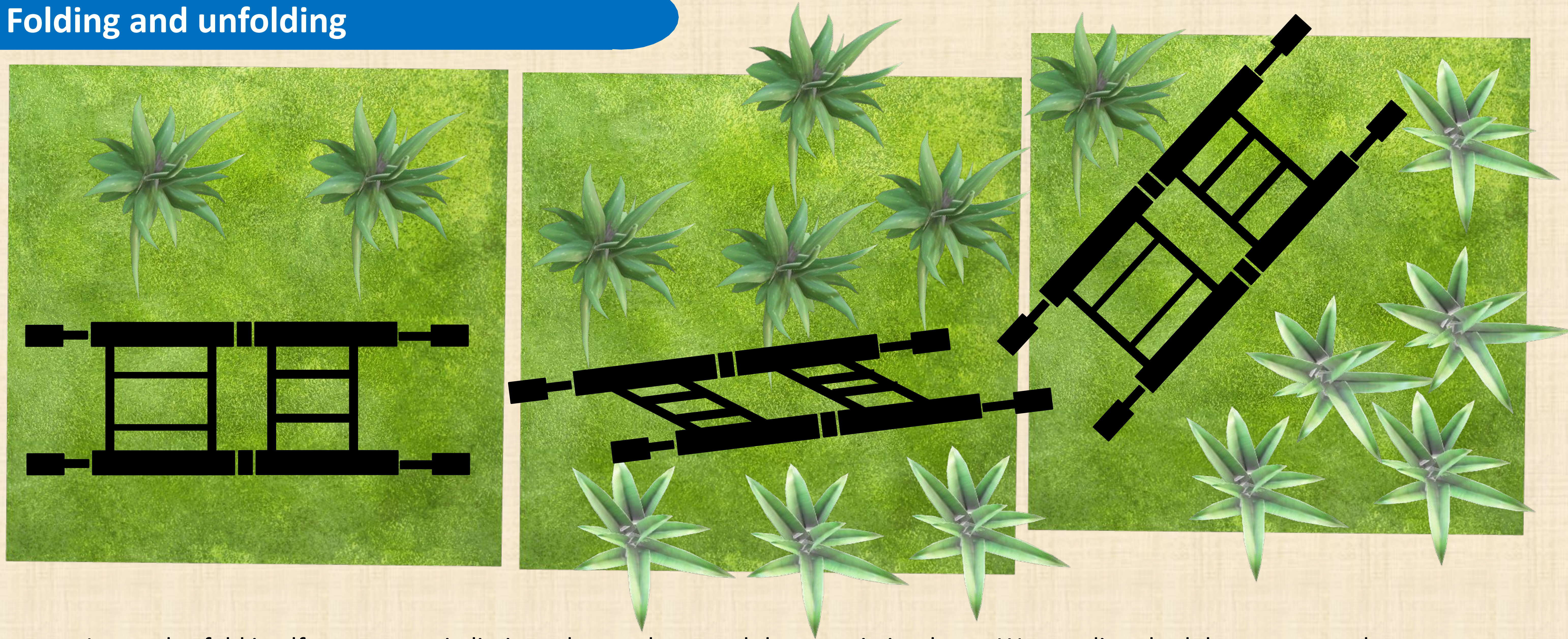
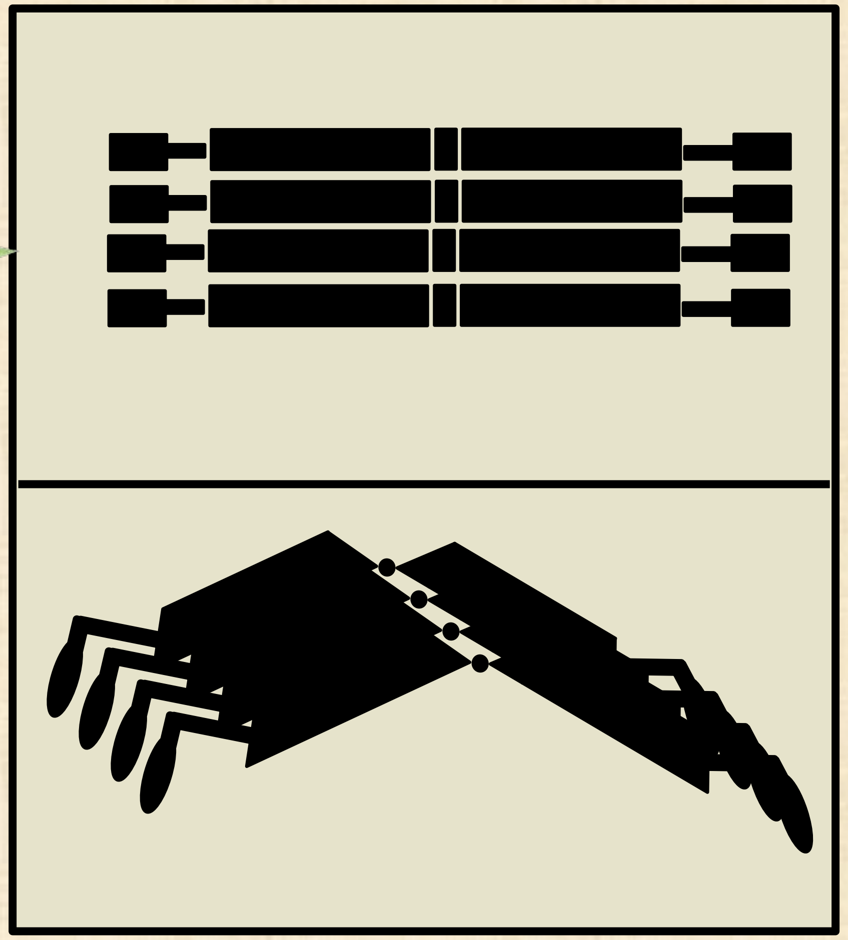
Folding and unfolding





- It can also fold itself upto a certain limit as shown above and then regain its shape. We can directly club up many such units as shown on the right.
- Additional tools will be hooked with the support structure. These will include sowing(leadscrew mechanism), Watering(tilted cup mechanism) and ploughing (barrel at one end and other end open).

Source:- *[14]: Roland Siegwart and Illah R. Nourbakhsh. 2004.Introduction to Autonomous Mobile Robots. Bradford Company, USA.*

Overview of components and budget

4.1

INR 17K + INR 13k = INR 30 K

Sensors:- (Heading, perception):-
1.Realsense T265 (includes two fish-eye sensors, an IMU and a VPU where we can run SLAM algorithms directly)
2. Realsense D435(wide field of view and upto 10m range,Realsense SDK 2.0)



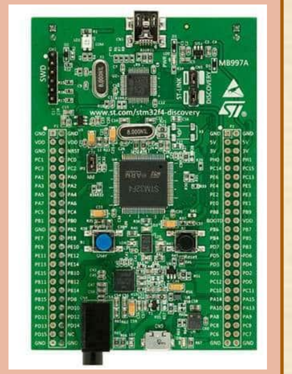
INR 12K + INR 5.6k + INR 3k= INR 20.6K

Wheel/motor sensors, actuators:-
- **Motors:-** The Faulhaber series 3272 motors(32mm d, 72mm l) would be a good choice.[15]
- **Gearbox:-**Series 32/3 are compatible with the given motor
- **Wheel encoders:-** CUI Devices’ AMT-102 rotary encoder at each motor
- **Swedish wheels**

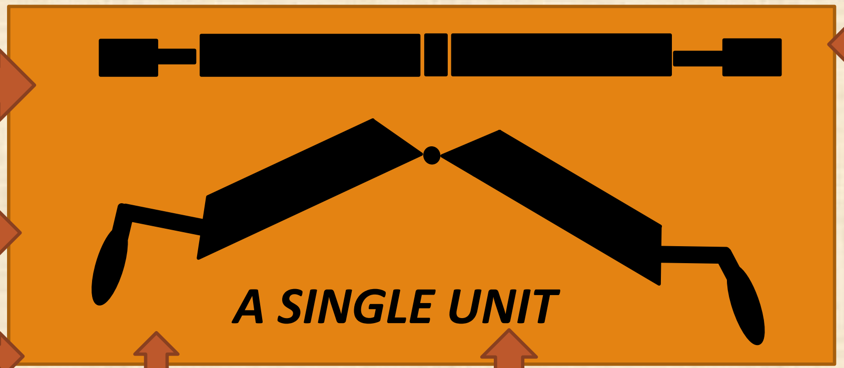


INR 7k

Controllers:-
1.STM-32 based development board for joint level control in each actuator



IMU/Gyro:- BMI055 IMU (Integrated in the stereo camera), tilt, cliff and bump sensors

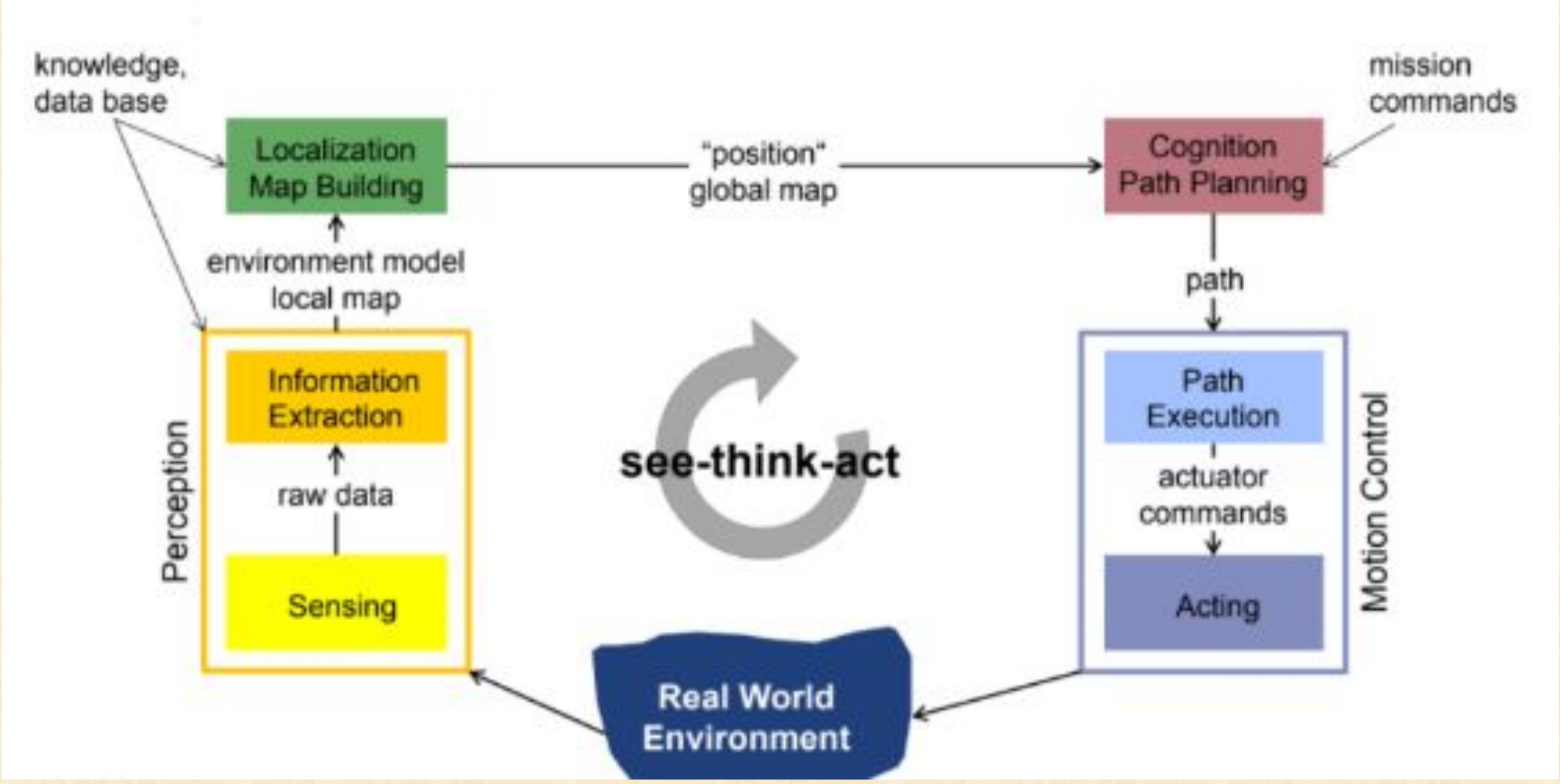


INR 20k

Computer:-
- 1. ASUS Tinker Board
- UP Developer Board with Intel® Atom™ x5-Z8350 Processor SoC


Software:-
- 1. **Operating system:-**Ubuntu Linux 20.04
- Localization framework and navigation using ROS Melodic Morenia and some other available Python APIs

Frame materials:-
- Aluminium
- MDF (Medium Density Fibrerods)
- Carbon fibre rods, etc.



Source:- *[14]: Roland Siegwart and Illah R. Nourbakhsh. 2004.Introduction to Autonomous Mobile Robots.[15]:* https://www.faulhaber.com/en/products/series/3272cr
[16]: https://www.faulhaber.com/en/products/series/323/,

THANK YOU!