

Robotic coal mining technology

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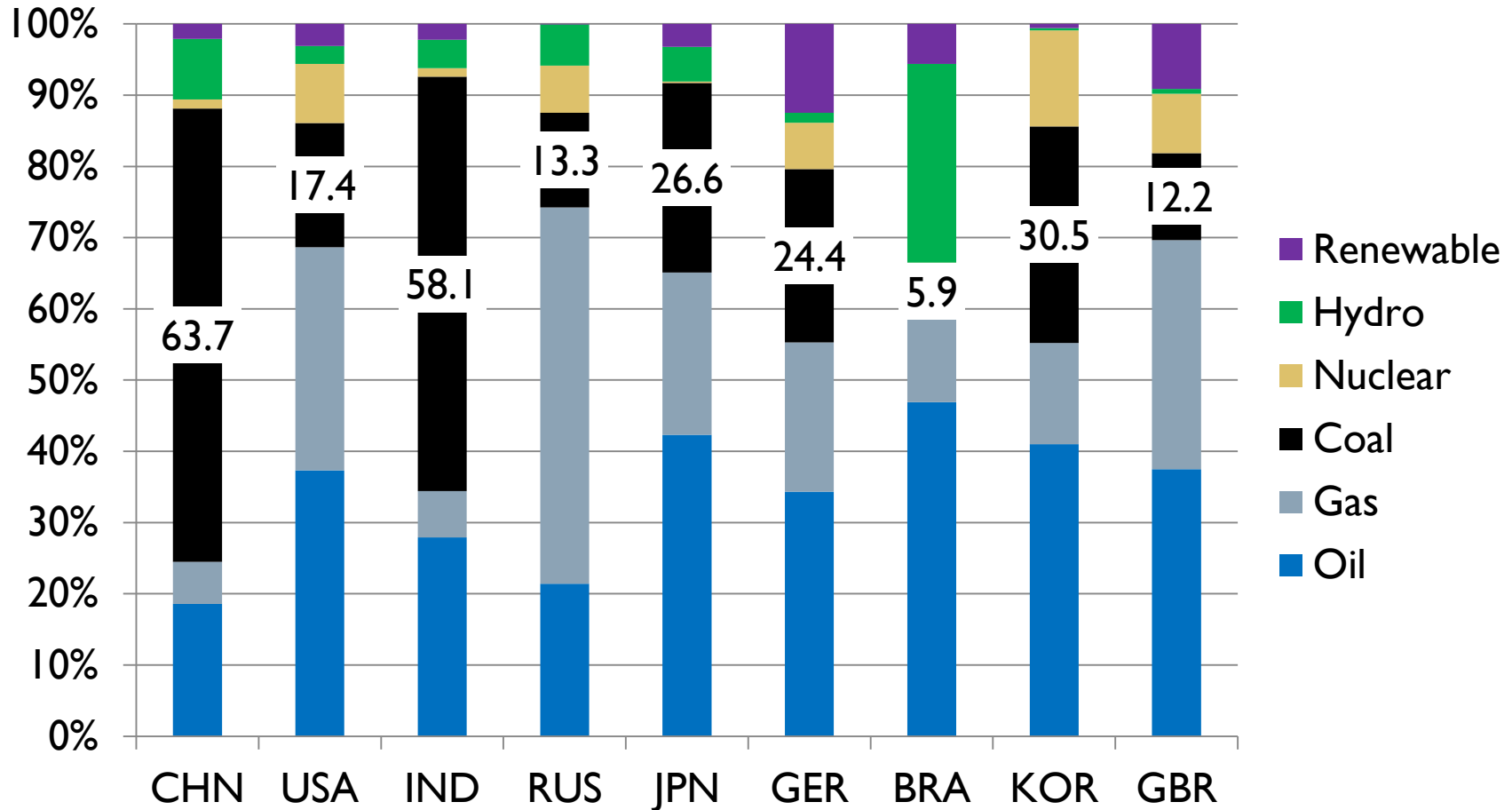
Outlines

1. Coal energy changes and its three-decreasing in China
2. Recent researches in coal mine robotization in China
3. Applications of robotic mining technology in China

1 Coal energy changes and its three-decreasing in China

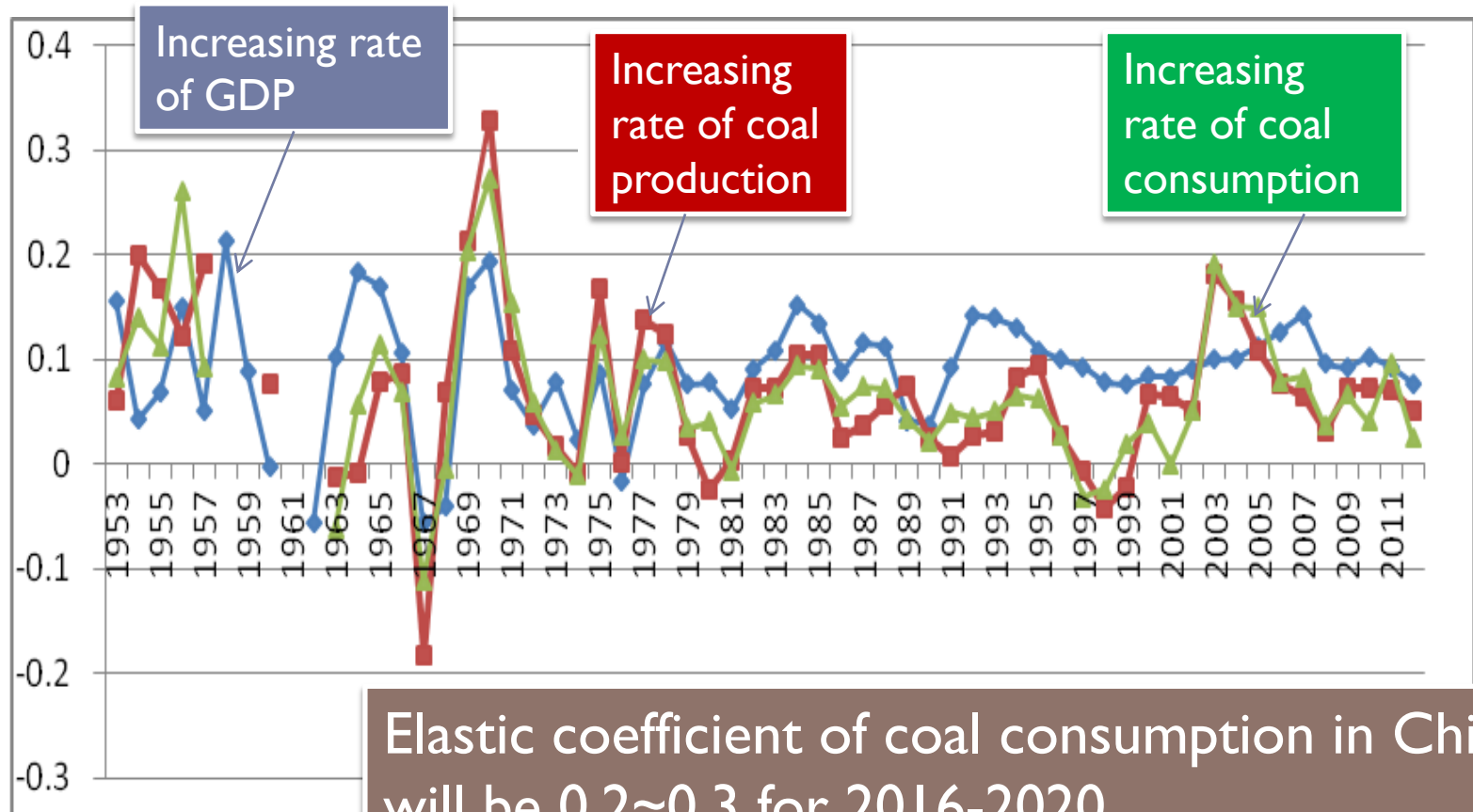
Coal is main energy supply for China(63%), 29% for the world

Energy consumption structure in 2015

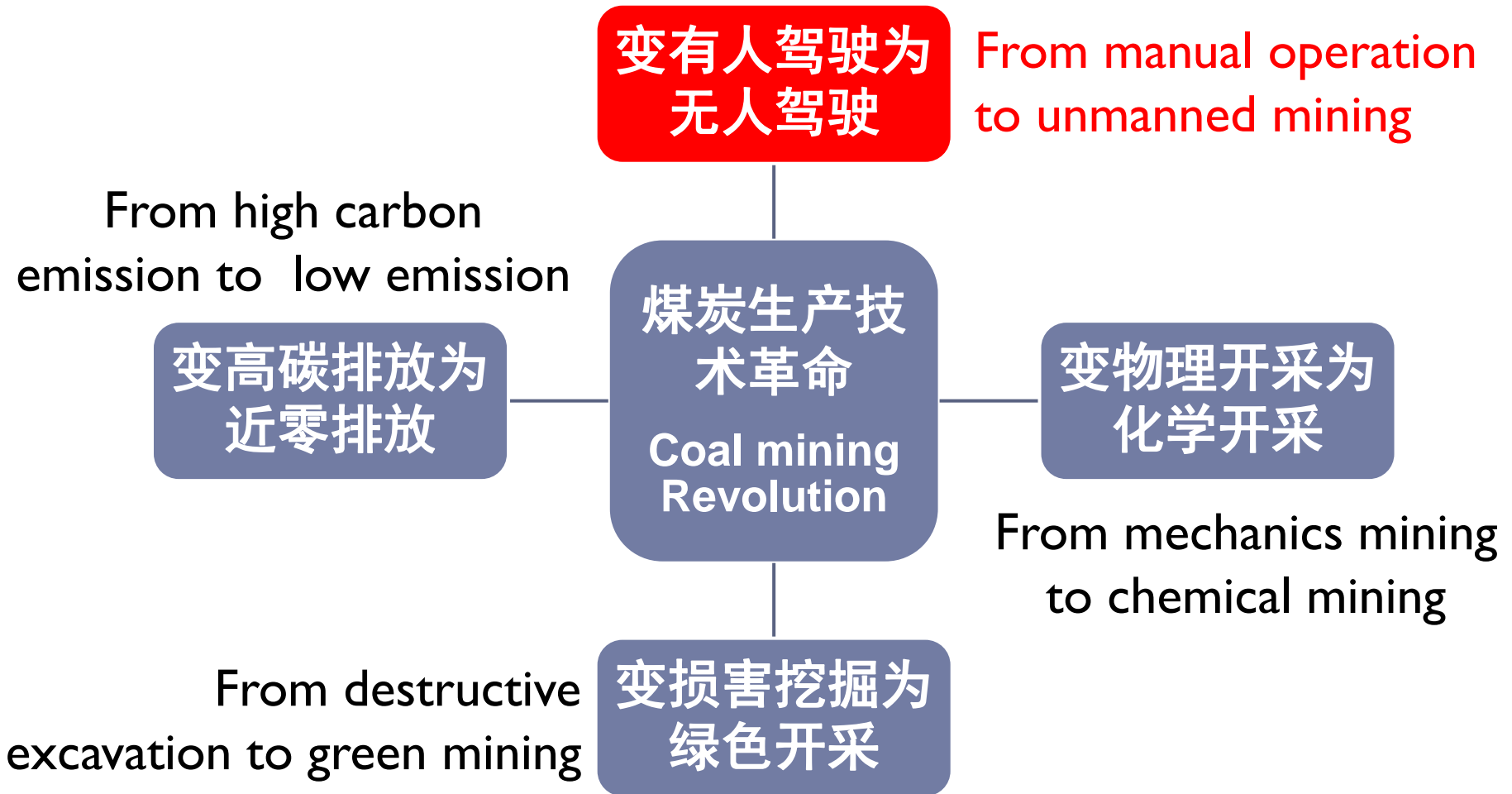


Dependency of GDP growth to coal production growth in China

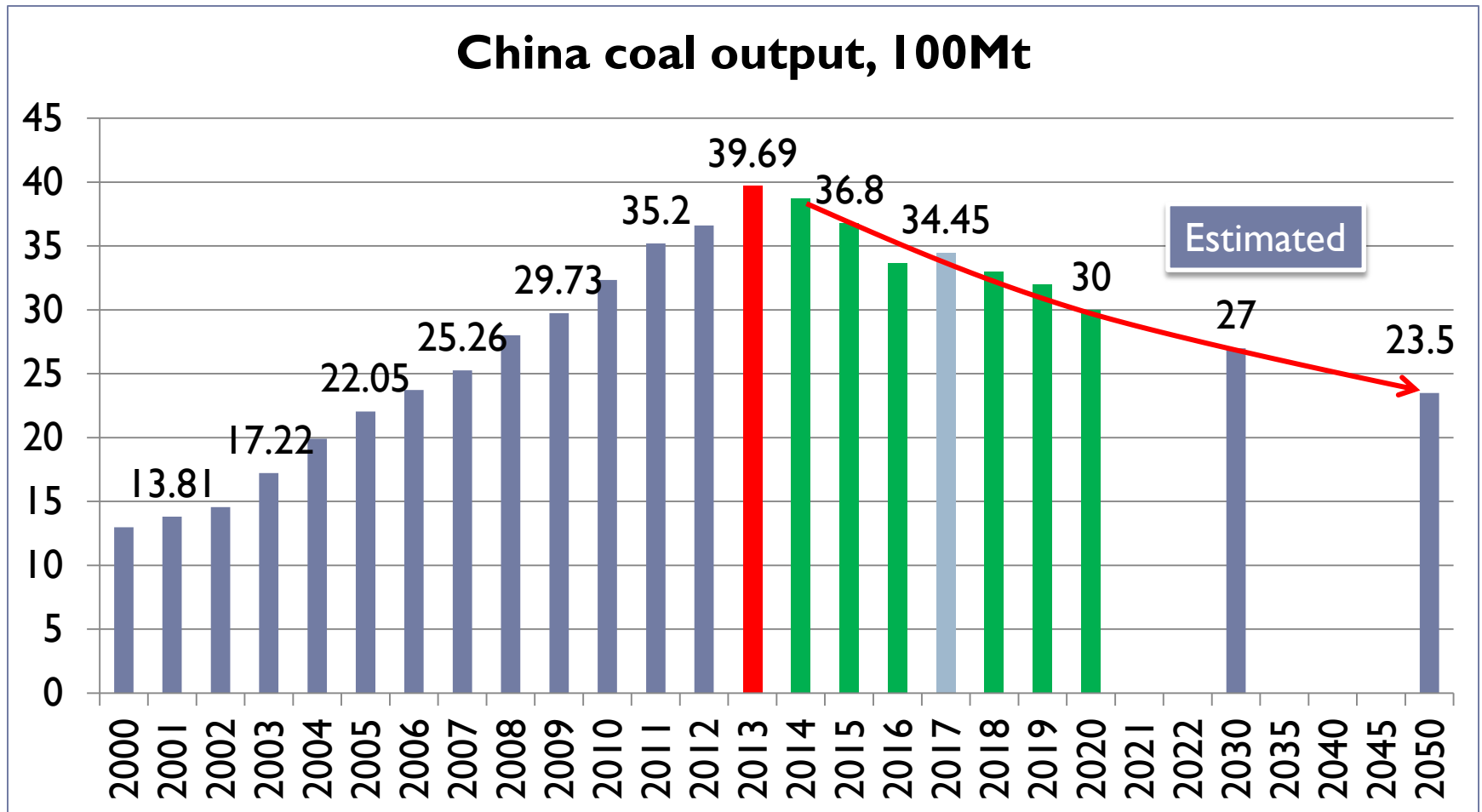
Elastic coefficient of coal consumption, China



Coal mining technology revolution in China, 2016-2030

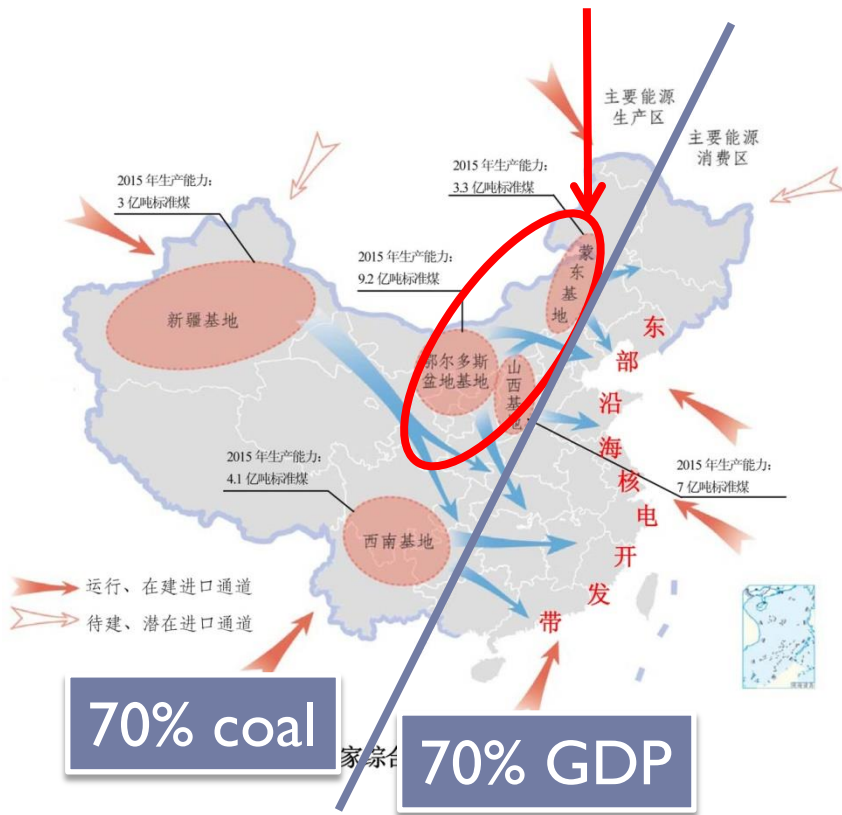


Decreasing of coal production in China



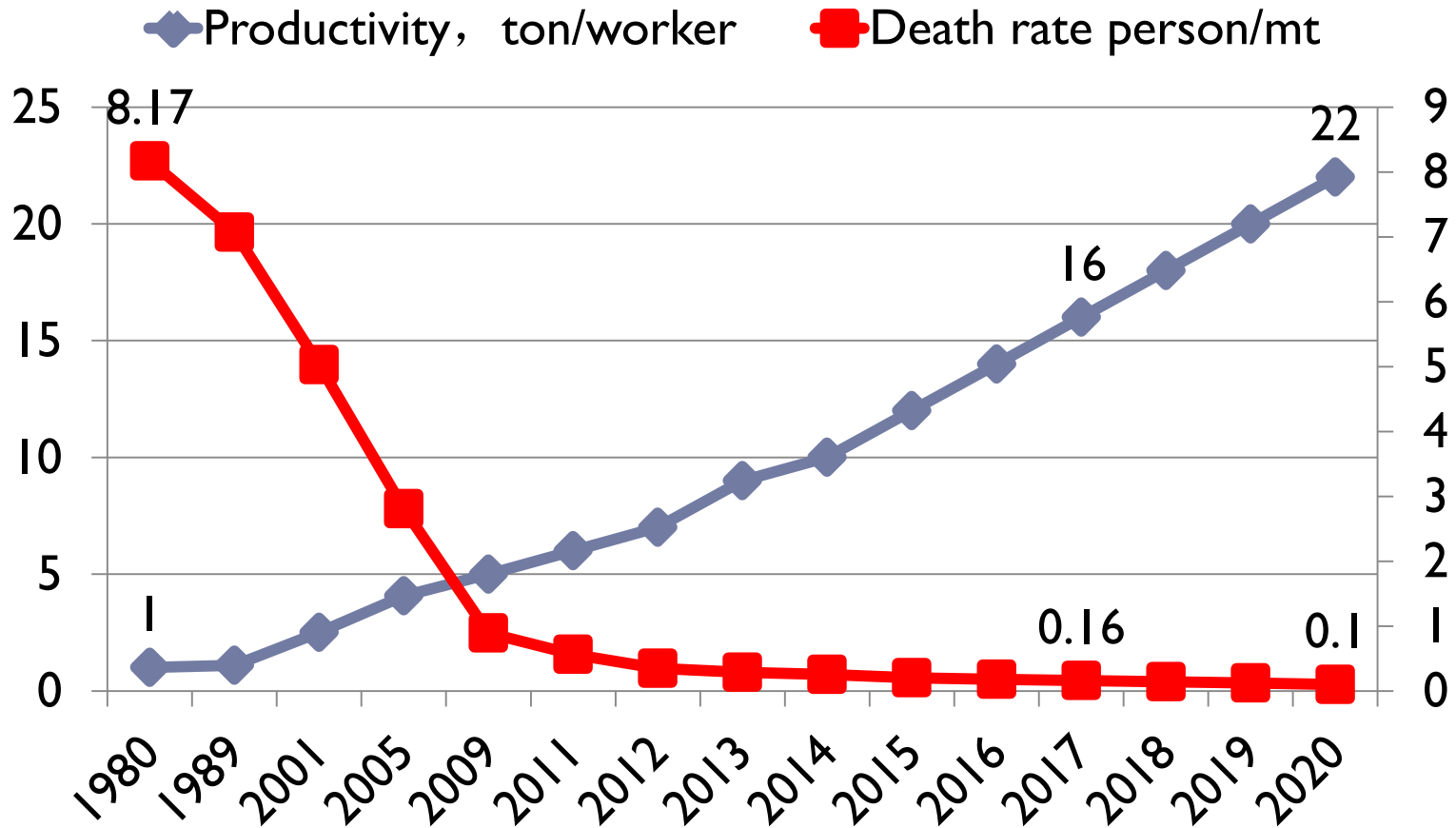
Decreasing of coal mines in China

1782 coal mines
3 gigaton, 68.2%

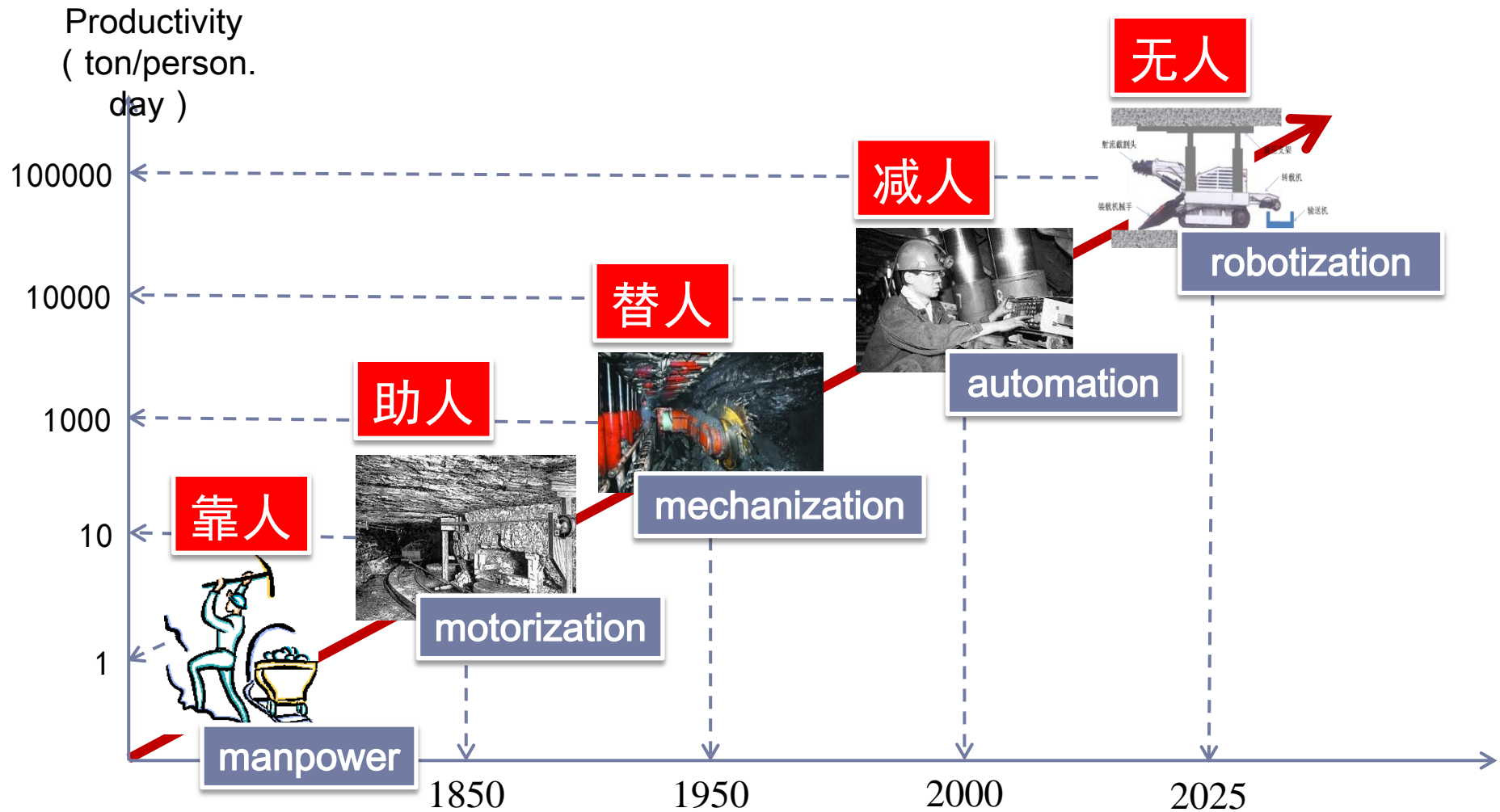


- ▶ By 2017, there are 4,980 coal mines nationwide with a total capacity of 4.36 gigaton.
- ▶ 3907 mines in production with capacity of 3.34 gigaton ;
- ▶ 2061 mines output <0.3 megaton, 5.1% ;
- ▶ 1914 mines output 0.3~1.2 megaton, 5.3% ;
- ▶ 1005 mines output >1.2 megaton , 69.9% .

Decreasing of mine accident death in China



Robotic mining is the future trend of coal industry



Robotic mining will be realized in China coal mines



Intelligent key processes, robots replace the key posts, intelligent production process, intelligent factories in key fields.

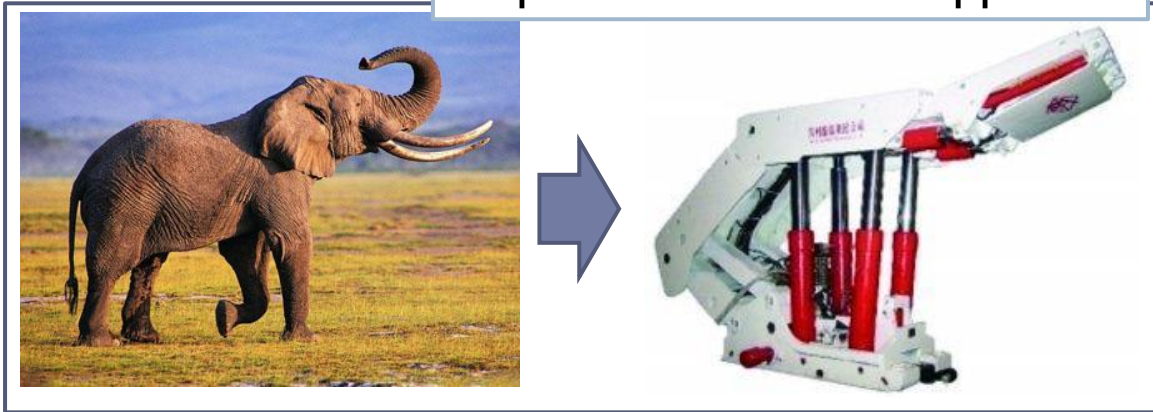
China energy
technology revolution
innovation plan
(2016 -2030)

Increasing coal exploration efficiency and intelligence level. The key coal mine area basically realizes the unmanned mining in working face.

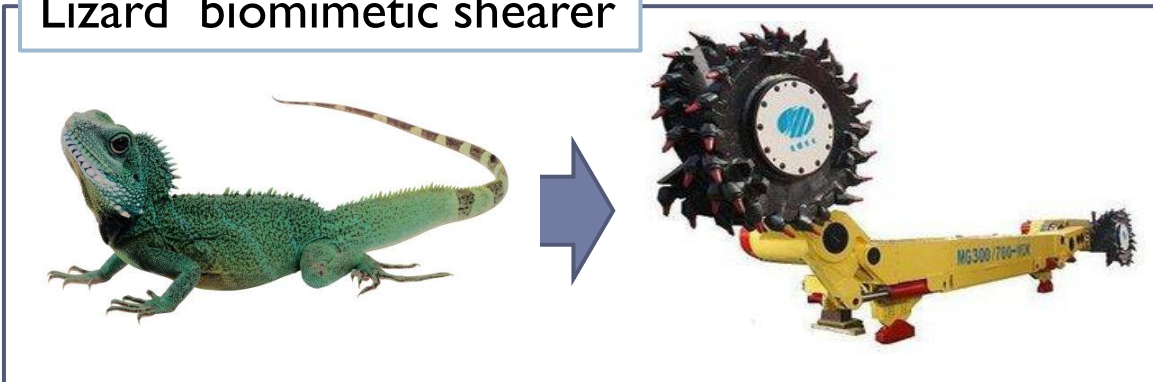
2 Recent researches in coal mine robotization in China

Mining robotic learns from animals

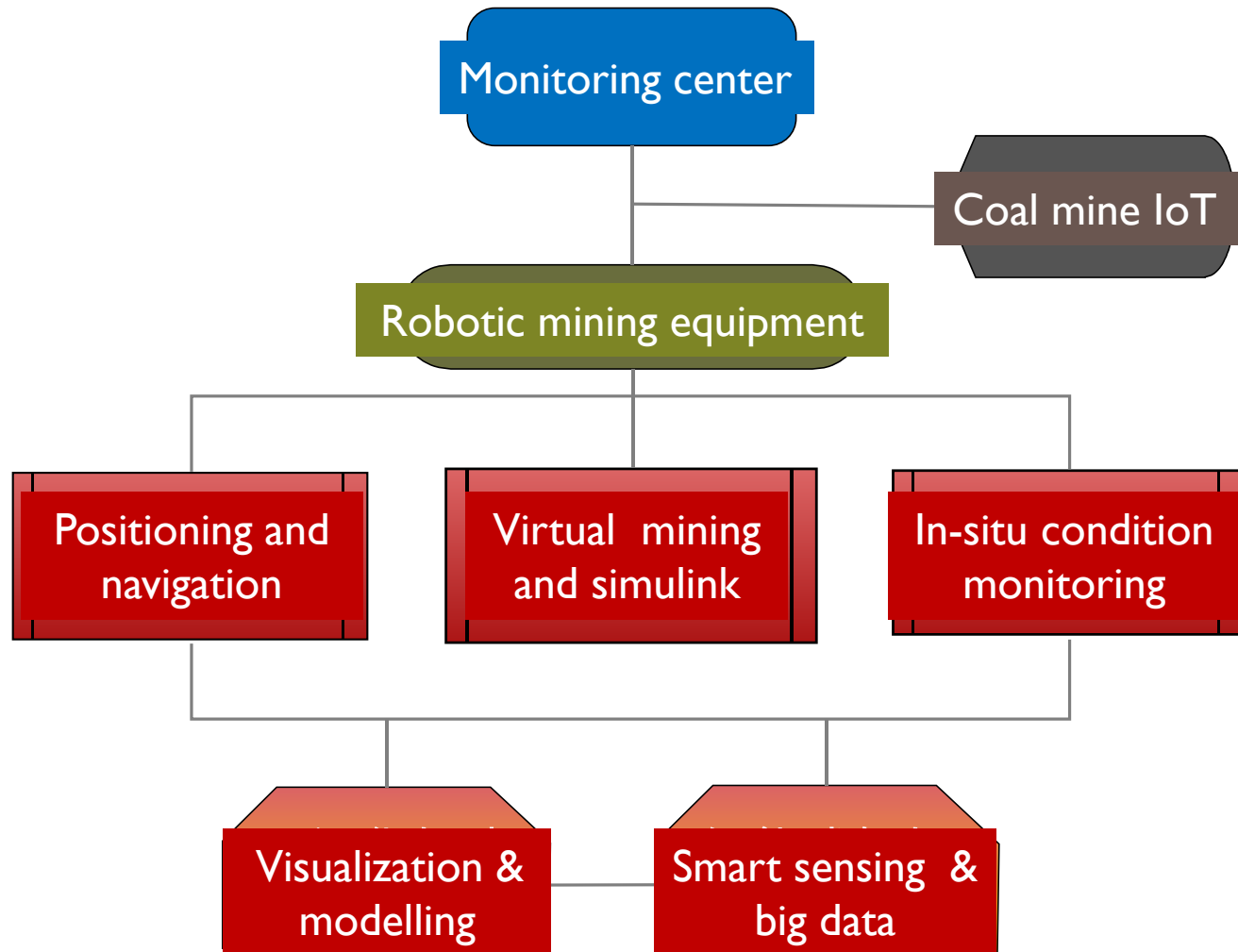
Elephant biomimetic supporter



Lizard biomimetic shearer

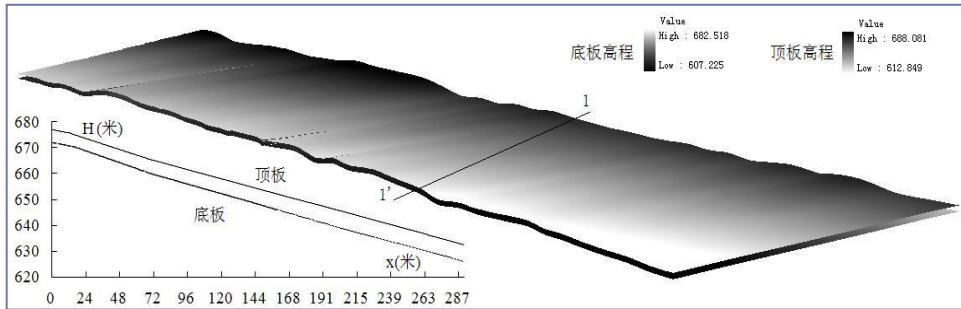
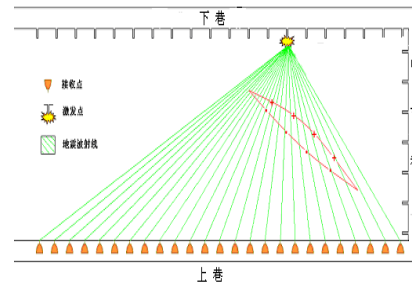
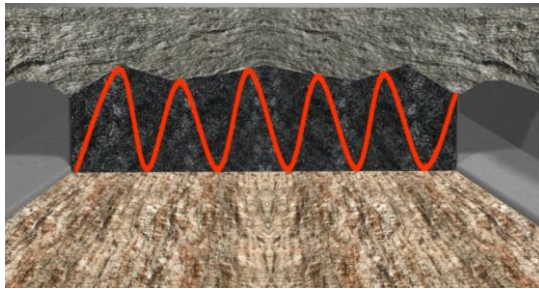


Technical framework of underground robotic mining



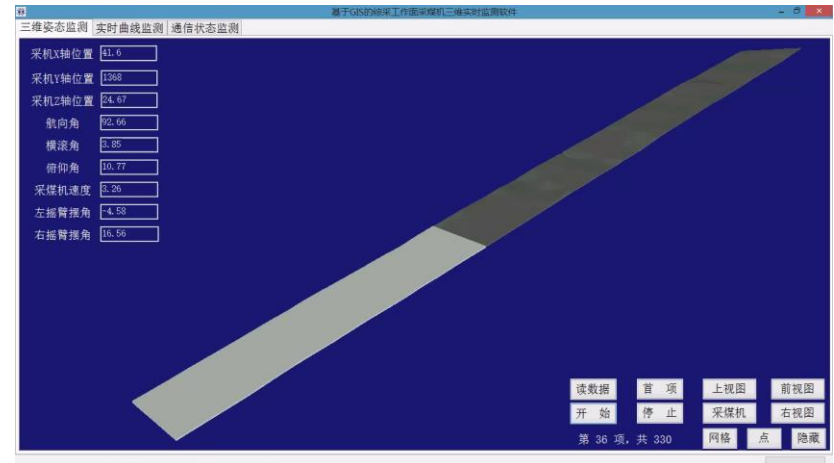
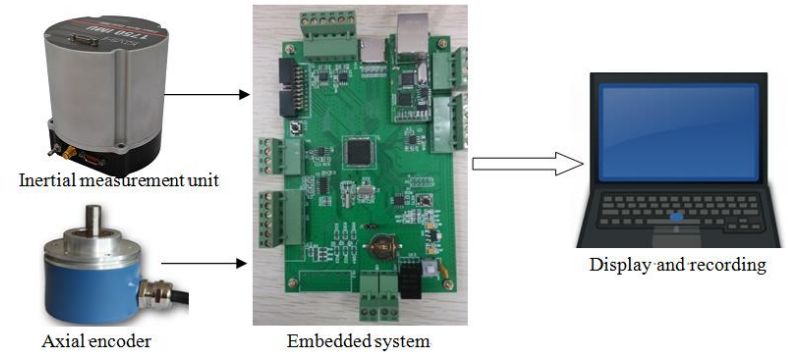
2.1 Localization based on inertial navigation + coal seam GIS

Building coal seam GIS map by seismic wave CT

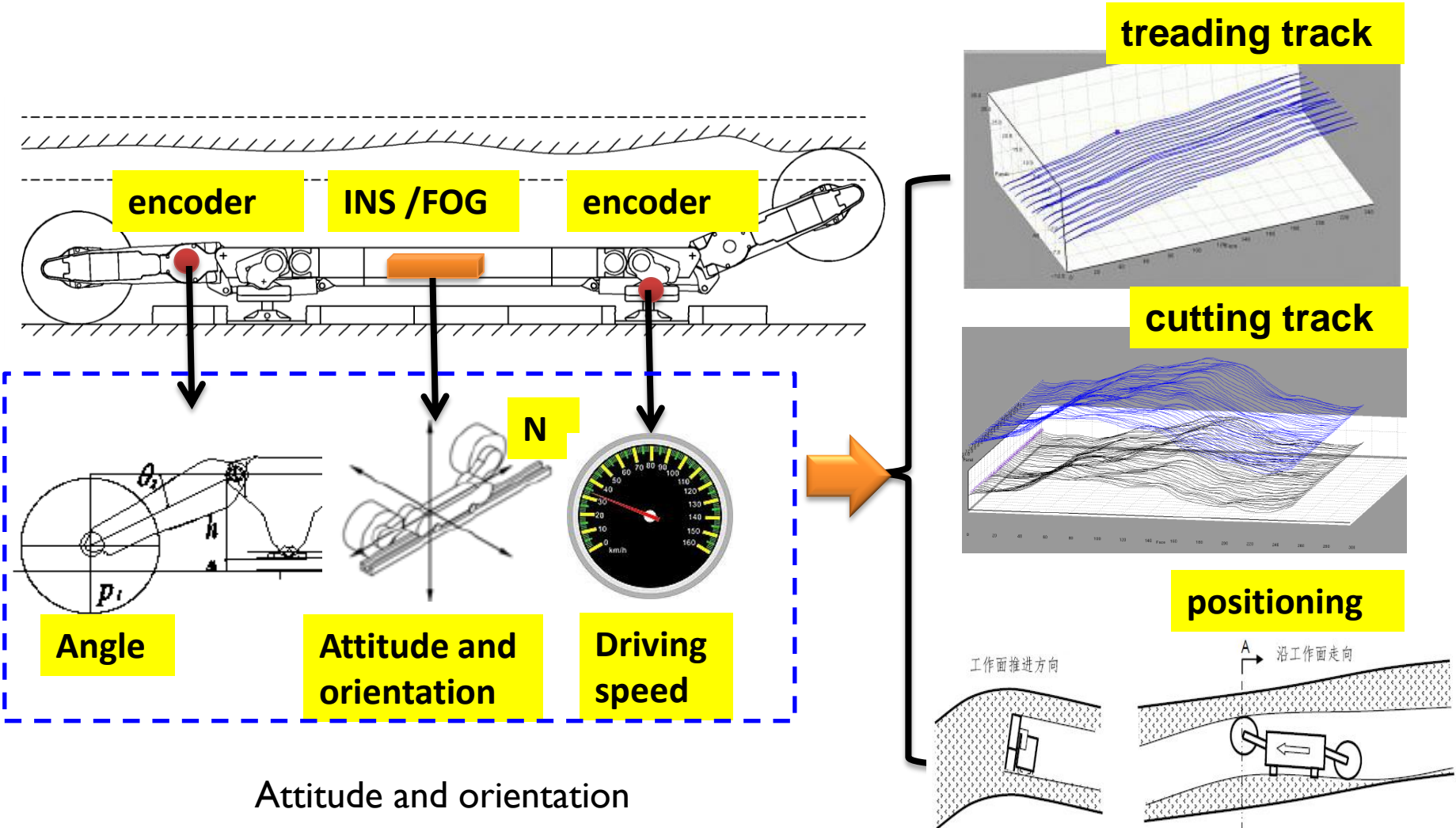


- Experimental results: position error is about 50mm /300m.

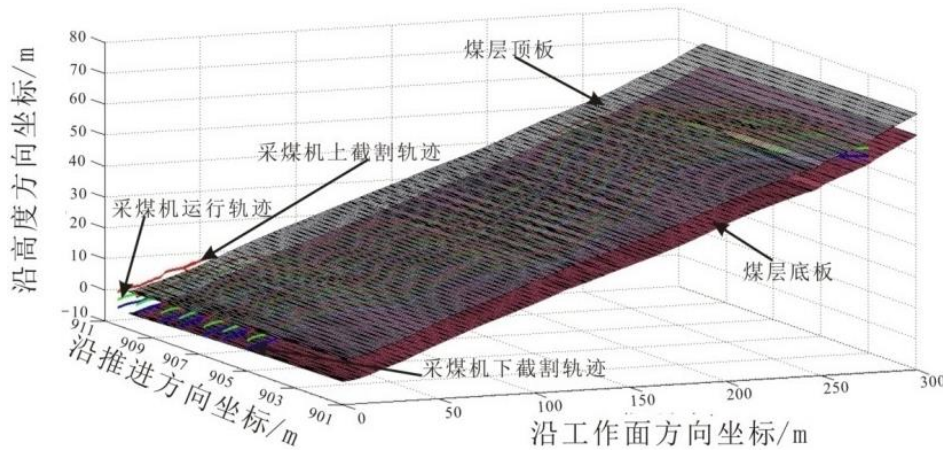
Inertial navigation system



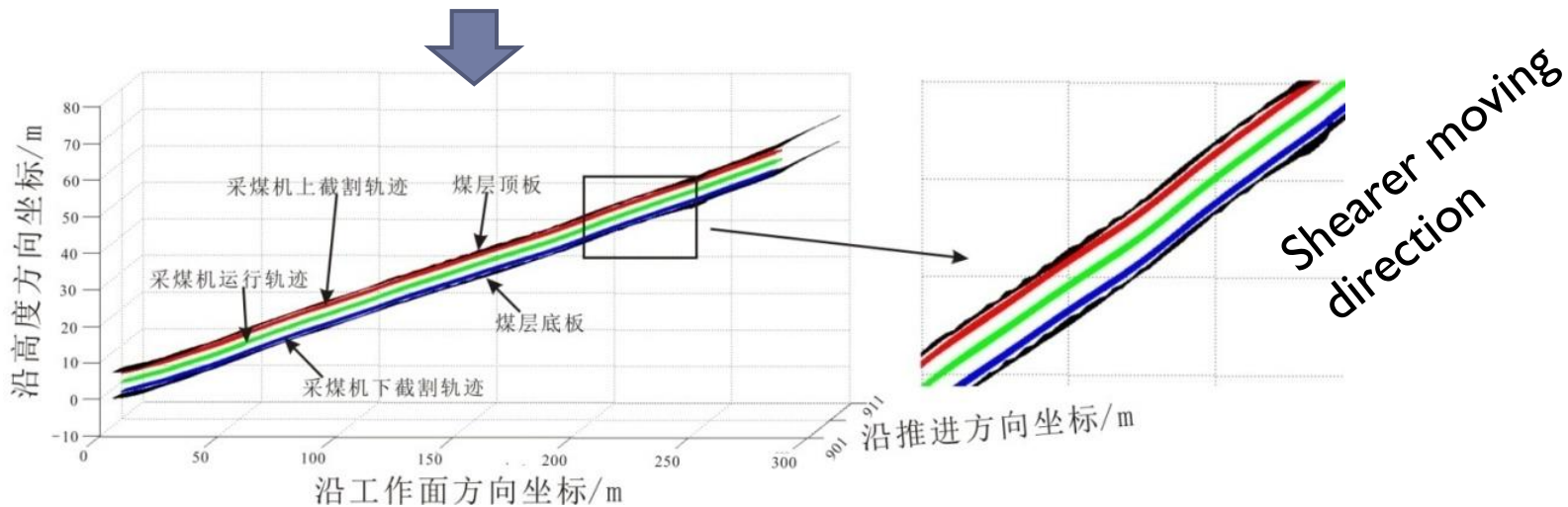
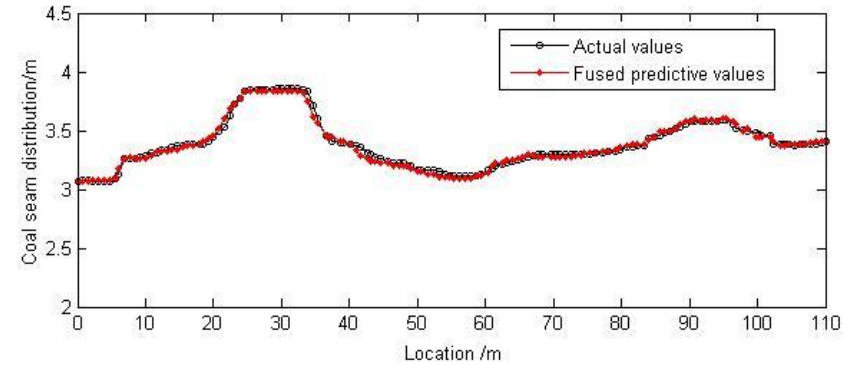
Attitude, orientation and positioning for coal seam shearer



Automated navigation strategy of long wall shearer

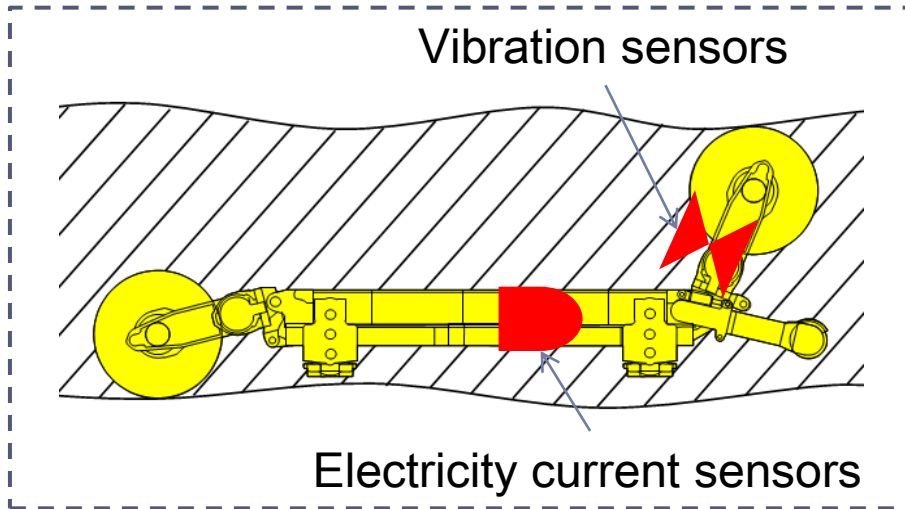


Field test results



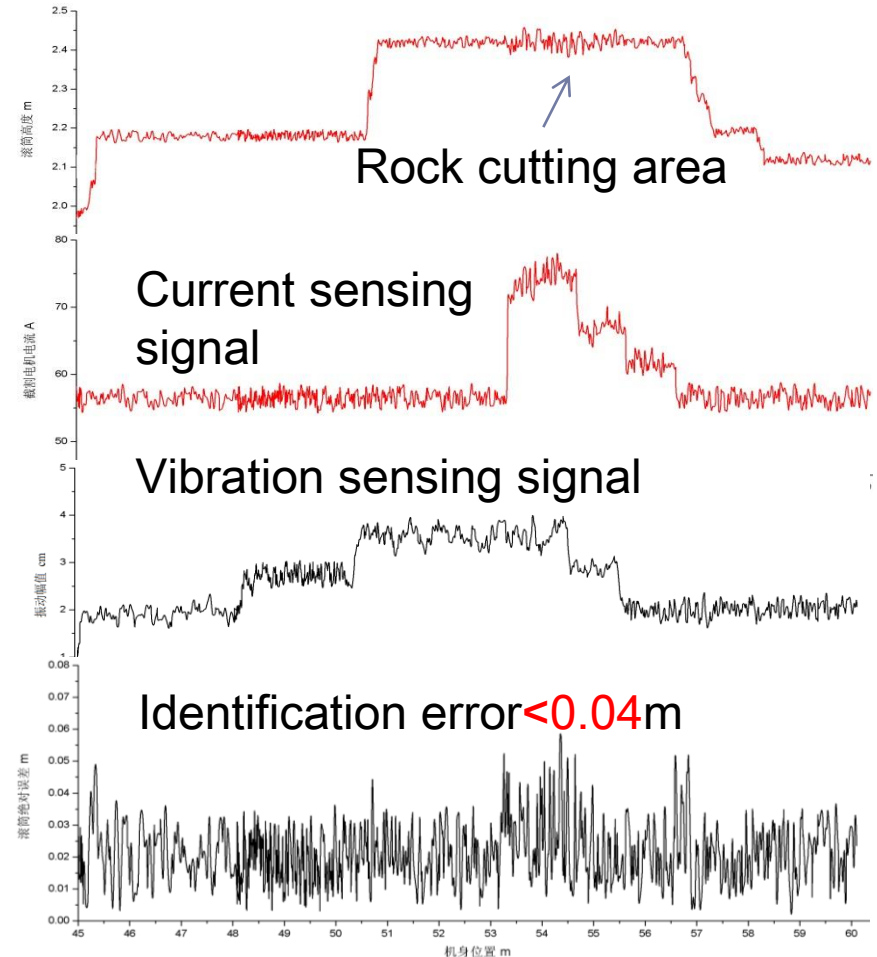
2.2 Automatic identification of coal-rock interface

- Multi - information fusion method



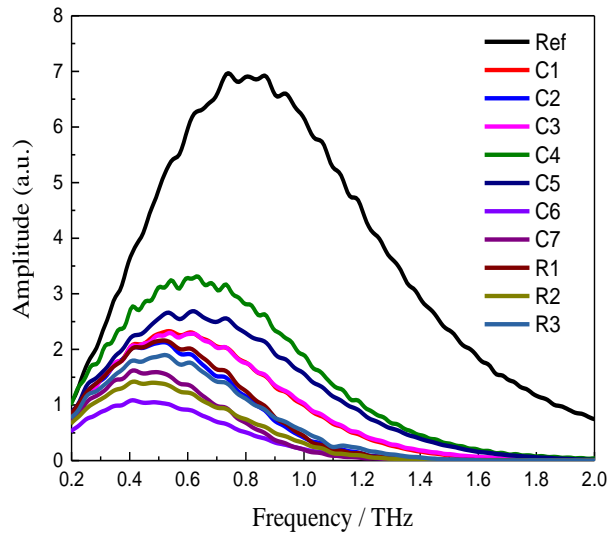
Information fusion method

$$m(X) = K \left(\sum_{A_1 j \cap A_2 p \cap A_i q} [m_1(A_{1j}) m_2(A_{2p}) \cdots m_i(A_{iq})] \right)$$

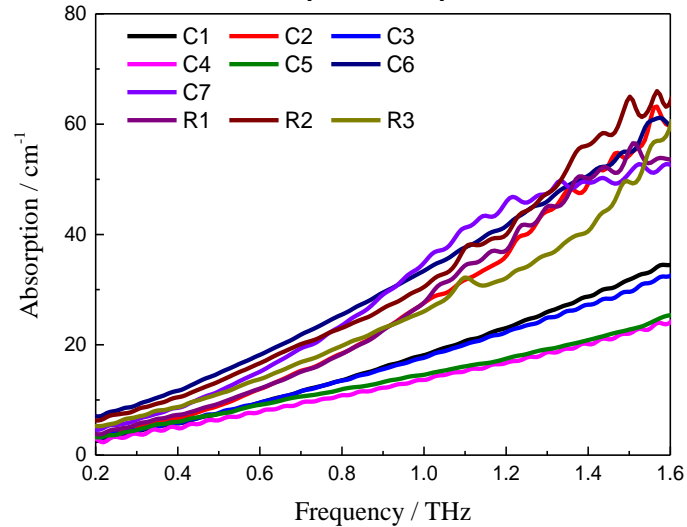


Coal-rock interface identification by terahertz method

Wave in frequency domain

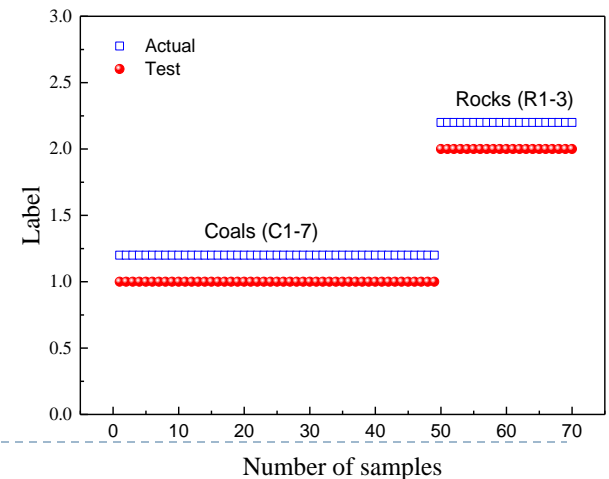
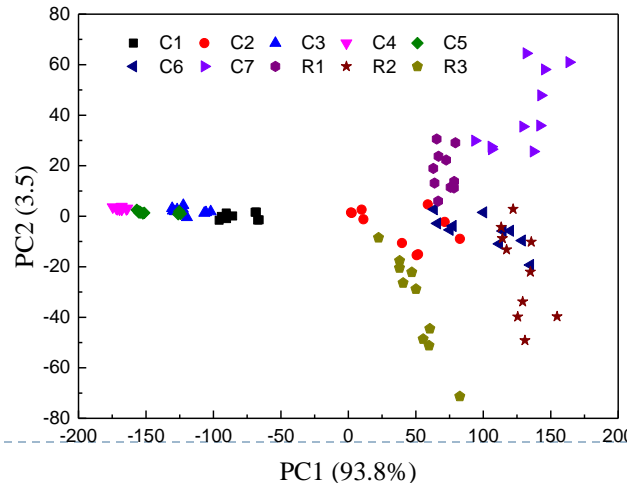


Absorption spectrum



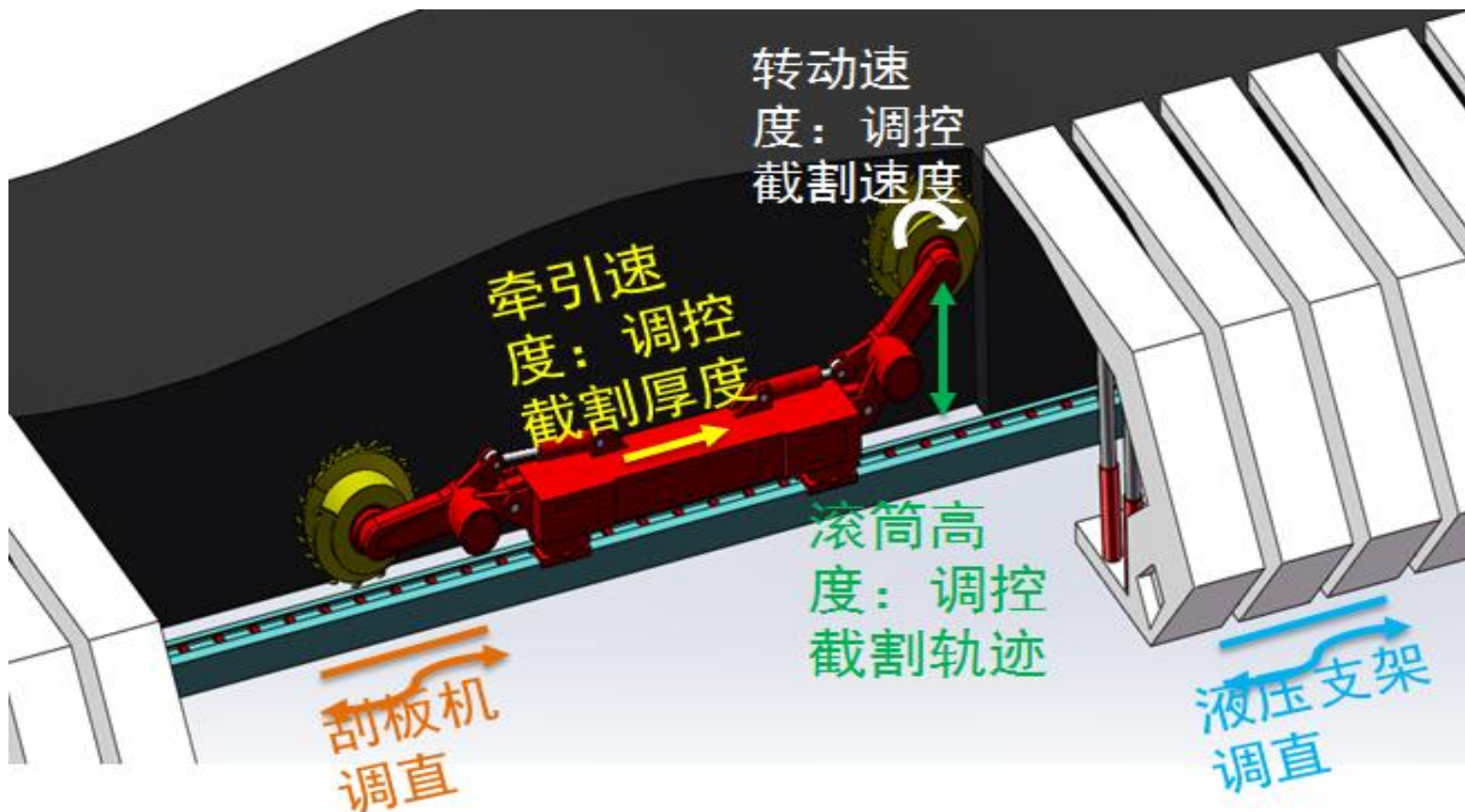
High lorentz model

$$\varepsilon(\omega) = \varepsilon_{\infty} + \sum_{j=1}^n \frac{A\omega_{Tj}^2}{\omega_{Tj}^2 - \omega^2 - i\omega\gamma_j}$$



2.3 Automate steering of long wall shearer

Self-adaptive control of four parameters

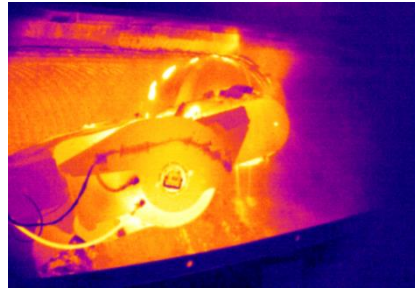


① Adaptive control of driving speed

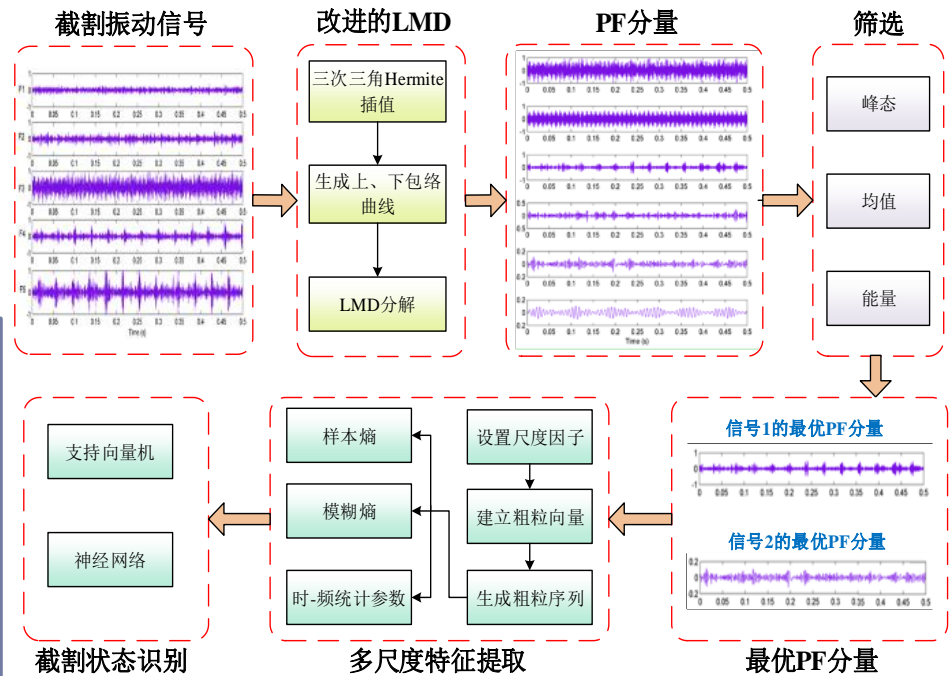
- Proposed the online accurate identification and control of cutting models based on the fusion perception of cutting sound, vibration and thermal imaging

transducer

thermal imaging

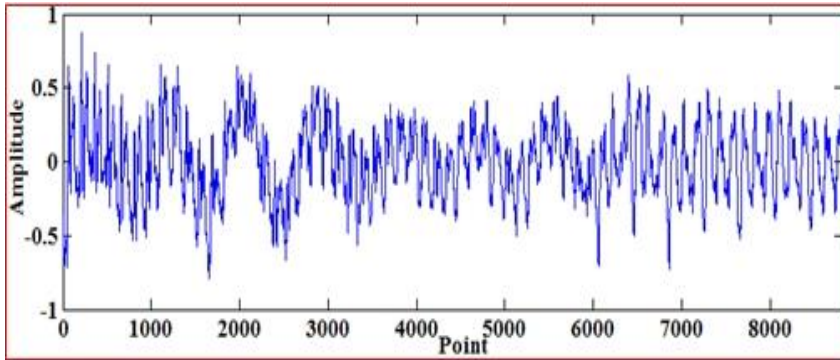


Identification arithmetic

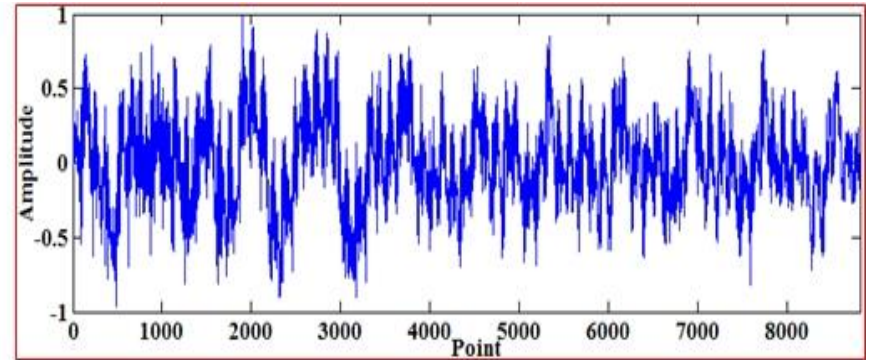


- The recognition rate of no-load, cutting of floor, roof and hard coal seam is about 95%.
- Error of the actual speed to the set speed is 0.025m/min.

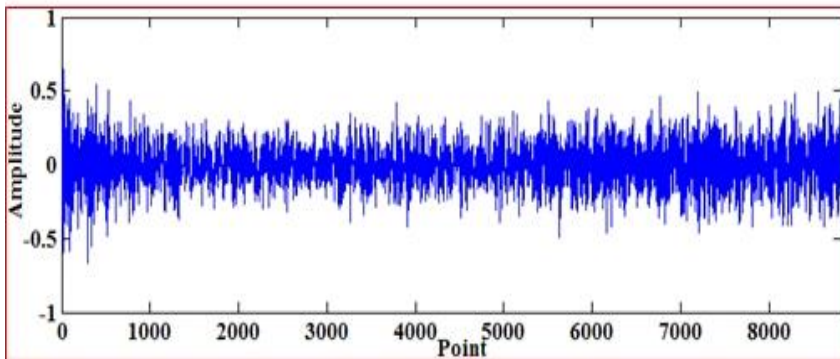
Recoded cutting sound signal



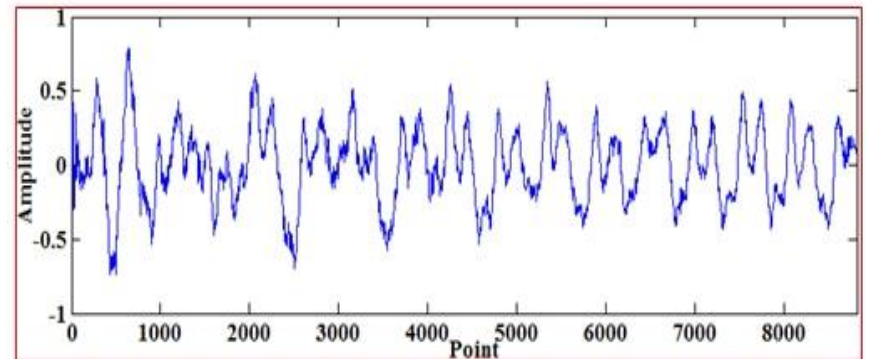
Cutting coal



Cutting rock



Dirt band

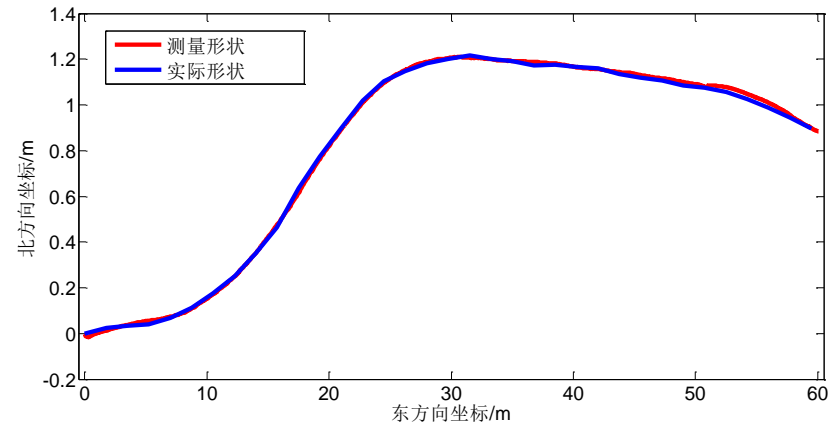
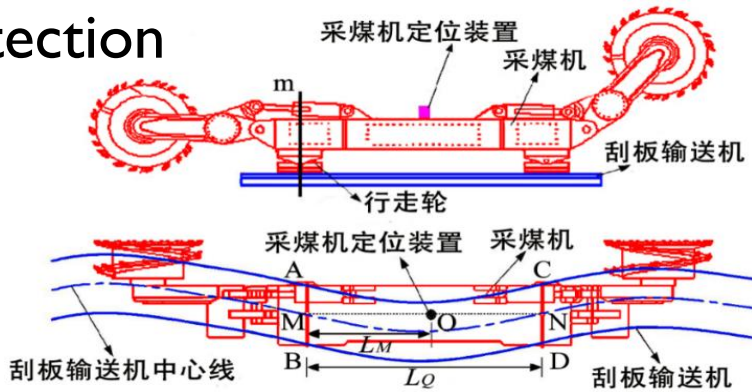


No-load

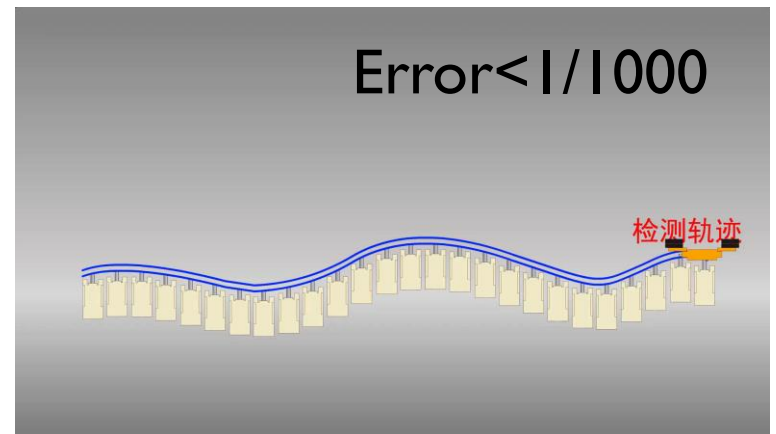
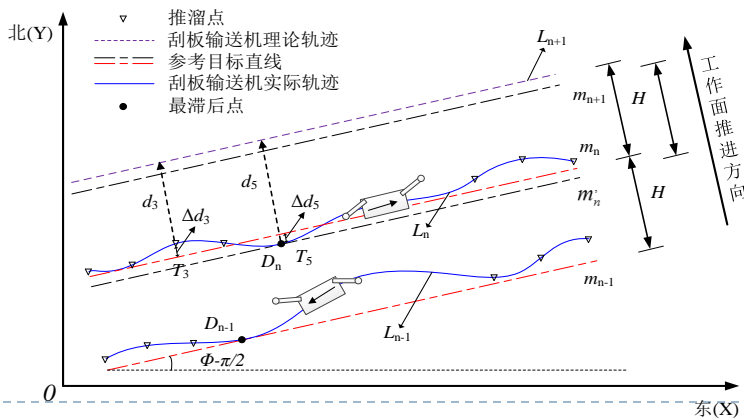
②Automate straightening of conveyor rail

- Developed the automatic straightness detection, straightening reference algorithm and rectifying technology.

detection

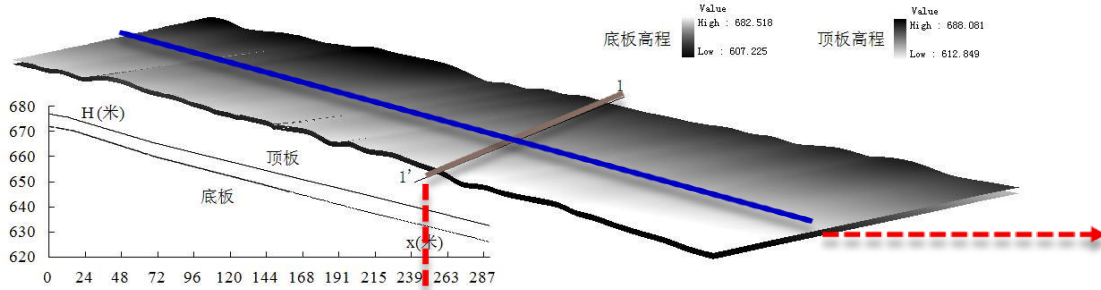


reference algorithm



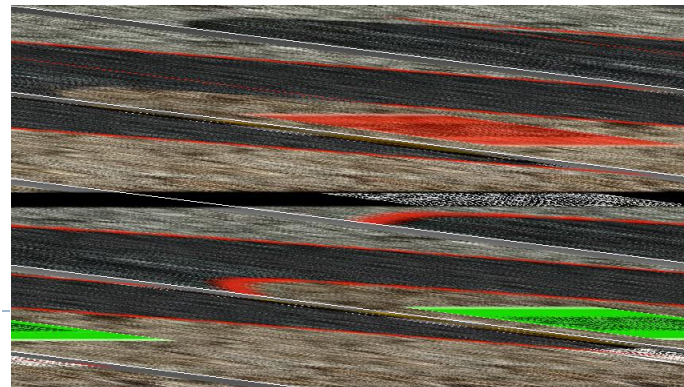
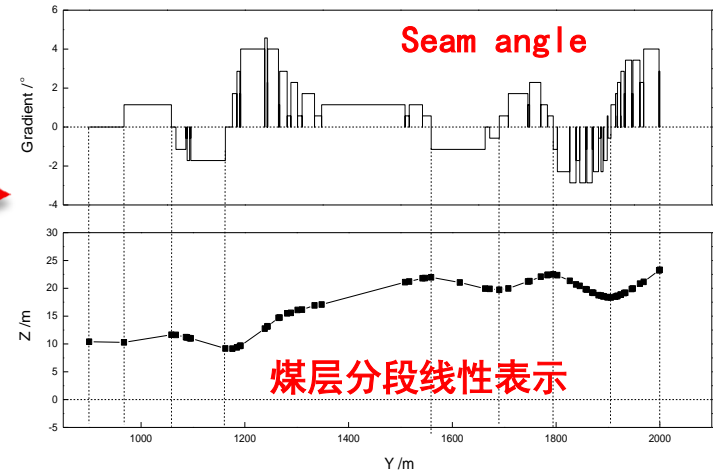
③Automate height adjustment of cutting drum

- Double-direction adaptive height adjustment method for shearer drum is firstly developed based on the coal seam GIS.



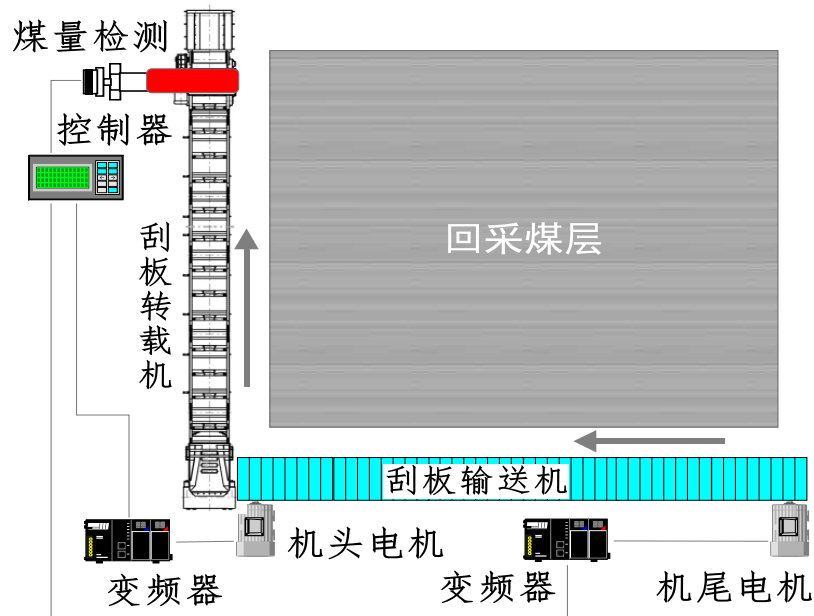
cutting height adjustment

shift height adjustment

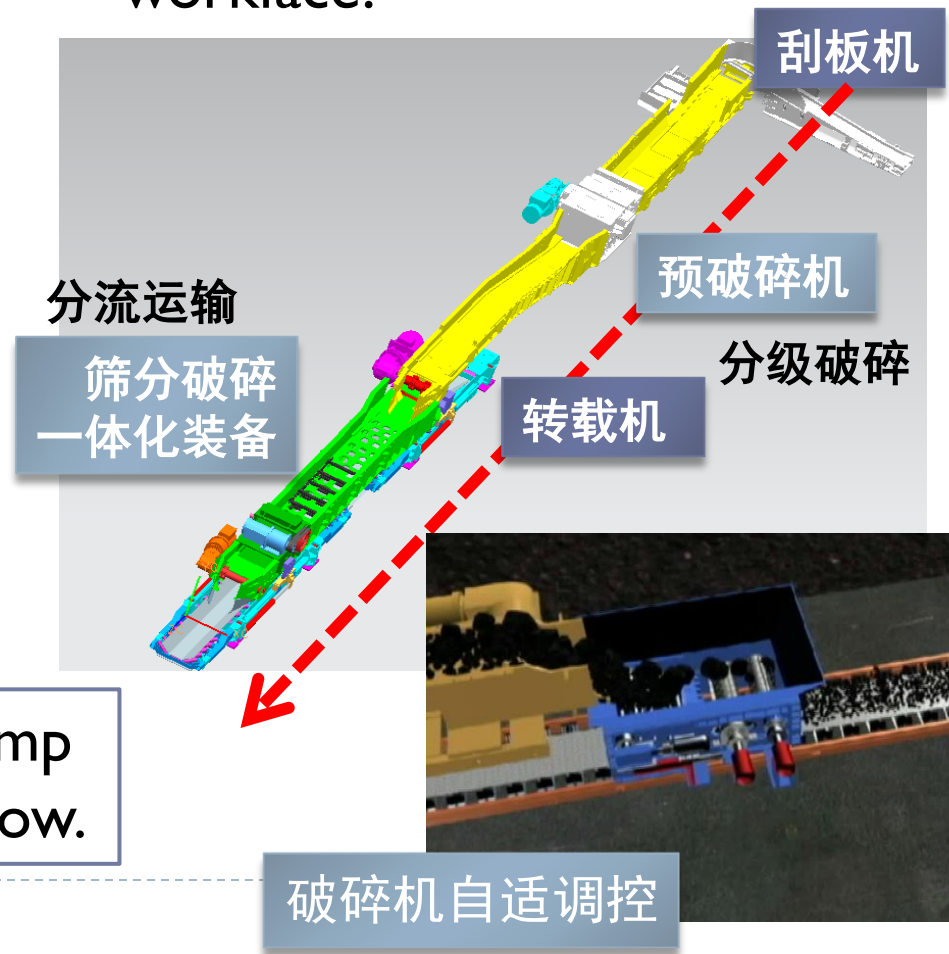


④ Automate adjustment of coal flow

- On line measurement and feed-back control for coal flow on scrape conveyor



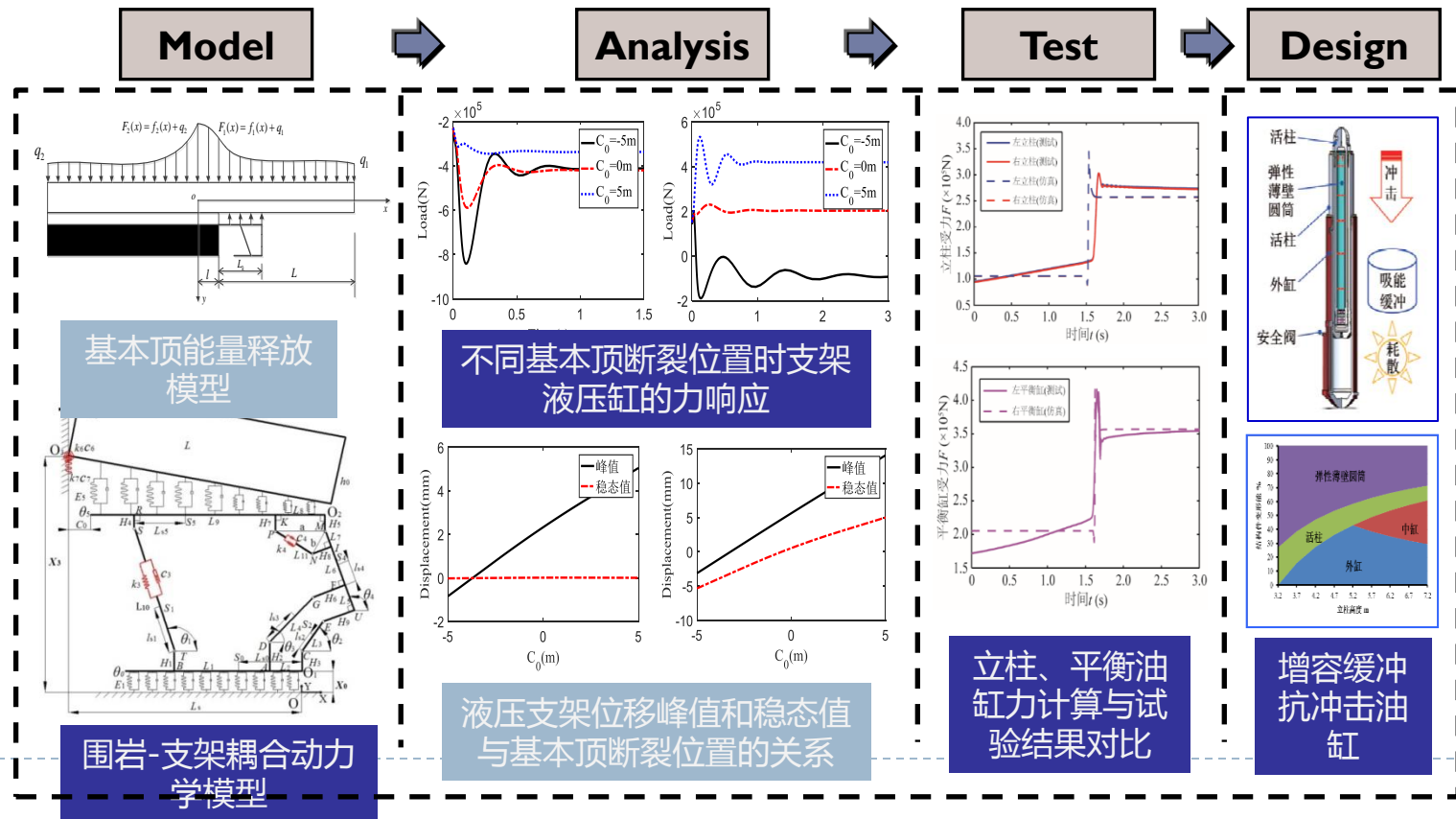
- Two stage crushing and two grade transportation on workface.



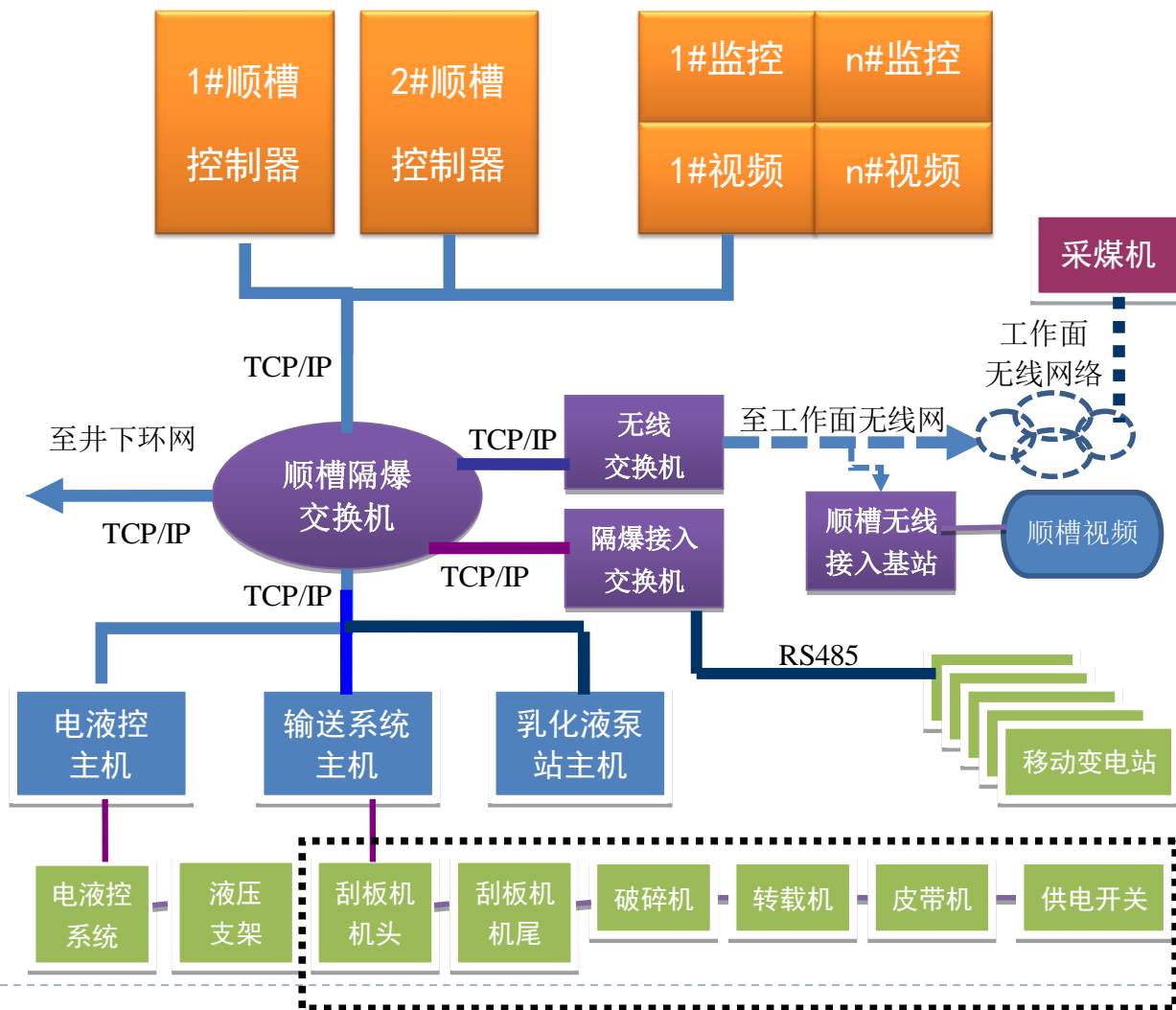
- Improve the productivity of lump coal and smoothness of coal flow.

2.4 The adaptive model for hydraulic support

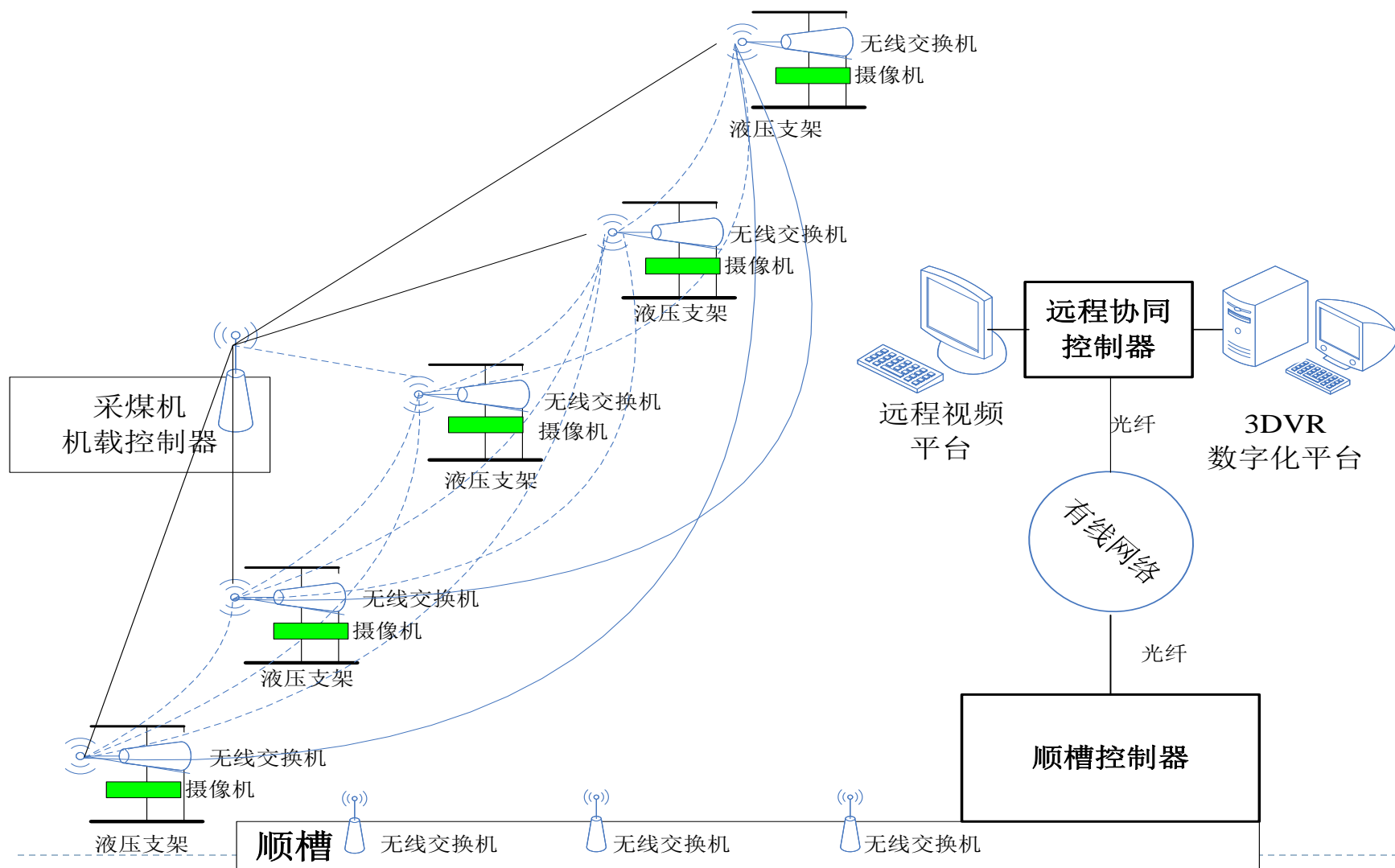
- ▶ The coupling dynamic model of surrounding rock –supporting mechanism–dynamic medium is established.



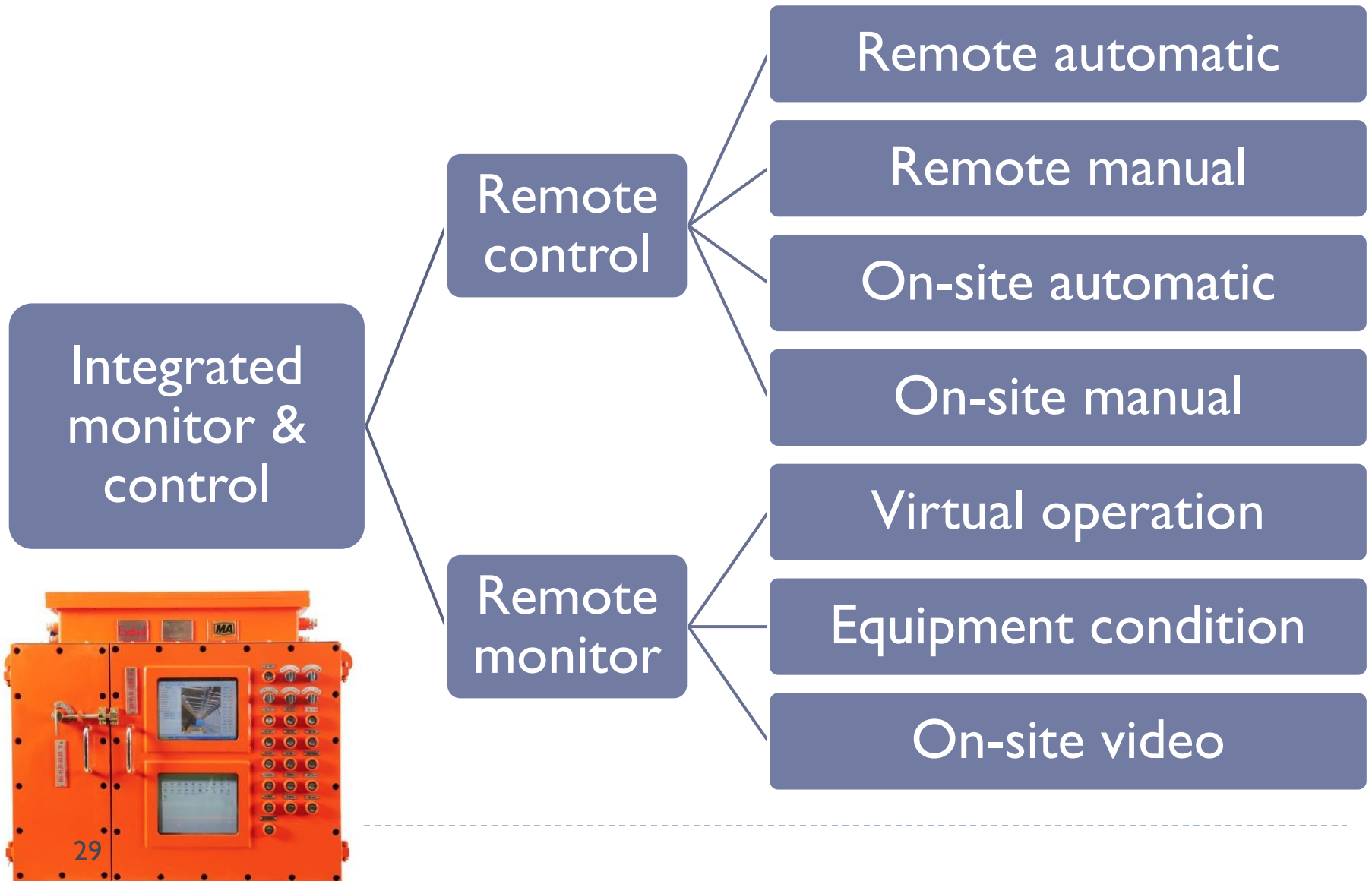
2.5 Internet of things for mining workface



Wireless transmission system



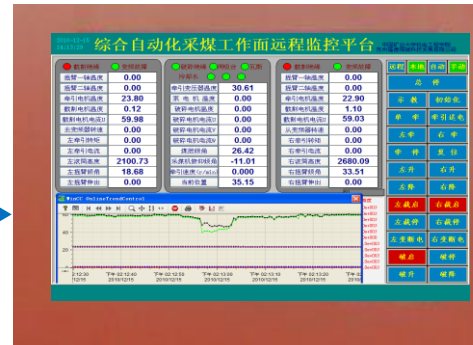
2.6 Remote monitoring & control



Control unit at working face



Virtual display



Condition display



Video display

3 Applications of robotic mining technology in China

Robotic mining technology is applied in coal mines in China

- In the past five years, unmanned mining concept has been popular recognized. Over 70 unmanned coal mining workface have been built, 70% works are reduced.

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号煤矿

同煤同
忻煤矿

枣矿付
煤公司

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界煤矿

兖矿转
龙湾矿

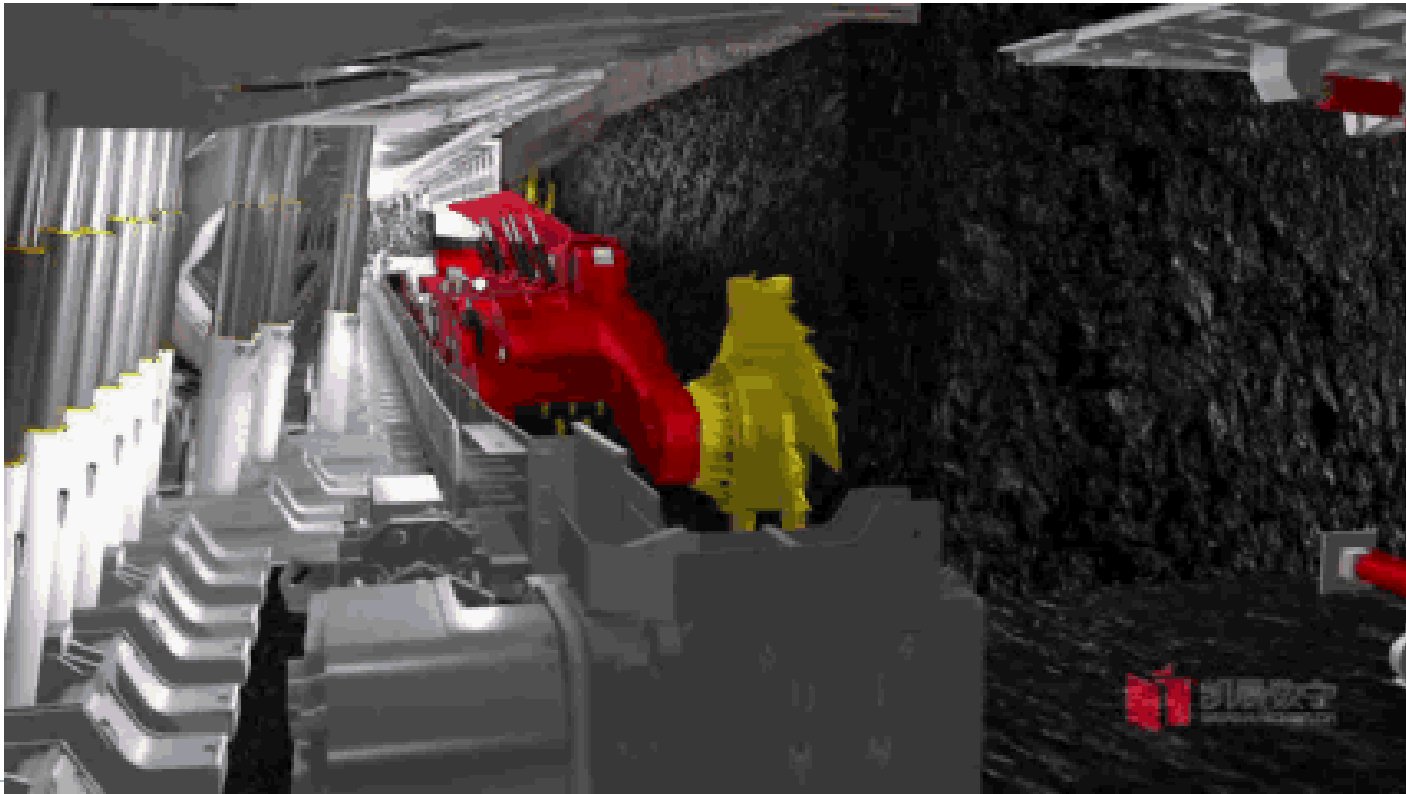
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淮南张
集煤矿



Example at Xiegou Coal Mine

- ▶ Xiegou coal mine reaches the annual output upto 10 megaton, the mining workface has 6 workers, acting for remote monitoring and controlling.



Summary remarks

- ▶ Robotic mining promotes the unmanned mining for coal mines being more safety and more efficient.
- ▶ Automatic sensing, autonomous learning, independent decision-making ability are three key issues for robotic mining.
- ▶ China has planned to popularize the unmanned mining working face in 2030, by robotic technology. Nowadays, over 70 working faces of underground coal mine are in unmanned operation.

Thank you for your attention.

