Ship Maneuverability, Controllability and Safety

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Division of Global Architecture
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Osaka University, Japan

大阪大学 OSAKA UNIVERSITY

Kazuhiko Hasegawa

He is working for ship manoeuvrability and its control since 1976. He has graduated from Osaka University, Japan in 1974 (BS) and 1976 (MSc). He took his PhD in 1982 (Osaka University). In 1976 he was working as a research assistant in Hiroshima University, Japan and he joined Osaka University in 1983. He is professor there since 1998.
He has also many experiences of short-term and long-term visiting scholars and professors in various universities; University of Twente, the Netherlands, University of Strathclyde, U.K., Pusan National University, South Korea and Ecole Centrale de Nantes, France. He was also invited by many universities and inter-national conferences to give seminars and keynote speeches from U.K., France, Finland, Germany, Belgium, Turkey, Tunisia, India, Bangladesh, Myanmar, Thai-land, Indonesia, Malaysia, Vietnam, China and South Korea, too.
He is also contributing in various academic societies in Japan and also internationally. He is a technical committee member of Marine Application (TC7.2) of IFAC since 2004.

Kazuhiko Hasegawa

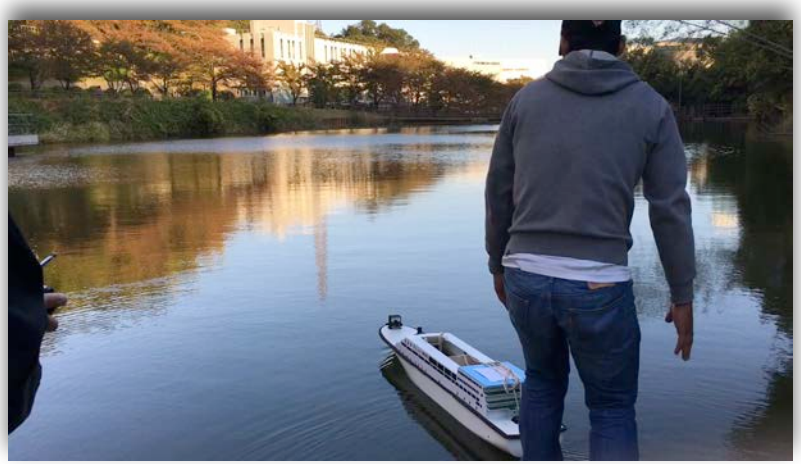
He has engaged in autonomous surface ship control and operation since 1985, and has published first paper on automatic collision avoidance in 1987. He is using fuzzy logic and control to detect risk of collision as well as waypoint navigation. Since then, he is one of the leading researchers in this subject and many visiting scholars and students have learned in his laboratory. He is also one of the leading researchers in automatic birthing control for surface ships. Many researchers have tried to control a ship to birth, but failed because ship is quite unstable in horizontal plane in low speed and due to its strong nonlinearity and rather strong disturbances. He has also conducted many model ship and full-scale experiments to identify ship dynamics and test the control algorithm from his background in naval architecture and ocean engineering. One of the recent model experiments is to investigate the Korean ferry "Sewol", which sank in April, 2014. At this moment he is also engaging on signal conflict in AIS (ship-borne Automatic Identification System) communication and ship accident analysis including "Costa Concordia".
In the seminar he will briefly introduce these research activities to give latest visions in the field of ship automation and accident researches.

Osaka University

Osaka University

Towing Tank, Osaka University

Osaka University



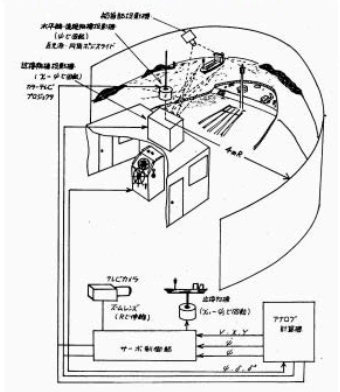
Free-running Pond, Osaka University

Osaka University

Late Prof. Kensaku Nomoto (1926 -2002)

Osaka University

SR151 Ship Handling Simulator (1974)



REVIEW OF HIGH SCHOOL PHYSICS

BUOYANCY

EXPERIMENT(1) PRINCIPLE OF ARCHIMEDES

1. Put stones etc. into a milk pack. Put it into water quietly supported by hands
2. Draw the draught (draft) line, when you feel the balanced point with the weight and the buoyancy
3. Estimate the weight you put into the milk pack.
4. Learn about the significant figures

RESULT OF EXPERIMENT(1)

Describe it in your report

What should you check?

- Try to keep photos, sketches etc. as objective as possible

- What did you feel after the experiment?

- What did you take care, when you conduct the experiment?

- The suggestions to make this experiment more interesting or accurate etc.

EXPERIMENT (2) STABILITY OF A FLOATING BODY

1. Release the hands
2. and observe what may happen.
3. At the equilibrium (balanced) condition, push the milk pack with you hands a little and then release. Observe what may happen.

EXPERIMENT (3)

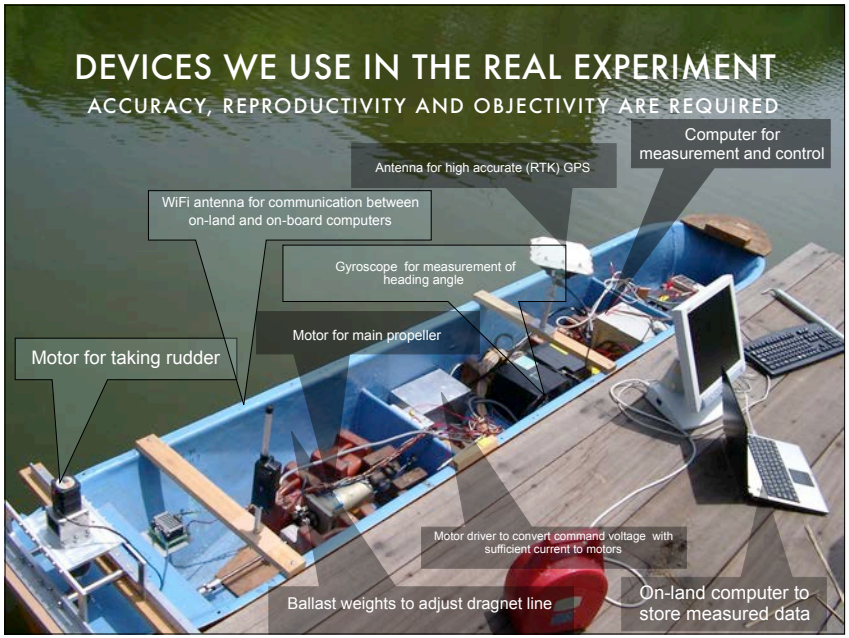
1. Replace stones with water, then observe what may happen

RESULT OF EXPERIMENT (3)

1. Why? - Principle of science

DEVICES WE USE IN THE REAL EXPERIMENT

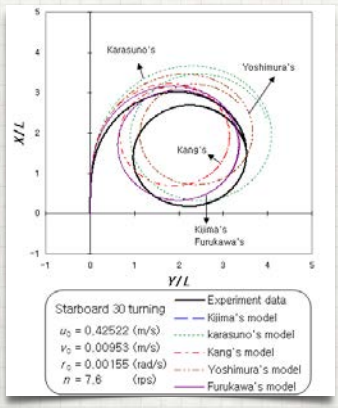
ACCURACY, REPRODUCTIVITY AND OBJECTIVITY ARE REQUIRED



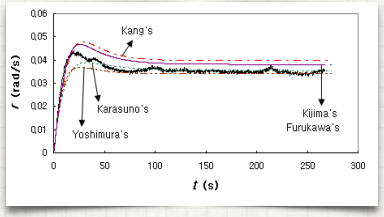
PRECISE MEASUREMENT IS ONLY POSSIBLE USING THESE DEVICES

GET MORE GENERAL CONCLUSION, COMPARING THE THEORY BEHIND OR WITH COMPUTER SIMULATION

Trajectory



Rate of turn



PRINCIPLE OF SCIENCE

Creativity, Originality, Humanity and Sociality are important factors, when you conduct experiment.

IN REALITY

July 23, 2006

FEATURE

Cougar Ace: The Great $103 Million Snafu at Sea

A huge seagoing car carrier tips over in the North Pacific and costs Mazda 4703 cars.

http://www.caranddriver.com/features/cougar-ace-the-great-103-million-snafu-at-sea

"snafu: a condition of being mess(US slung)

IT HAPPENS IN KOREA, TOO

Occurred on April 16th, 2014,
304 passengers, mostly high-school students and crew were killed,
172 survived.

What may happen on this ship in the next moment?

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- RESULT (1)

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RESULT (2)

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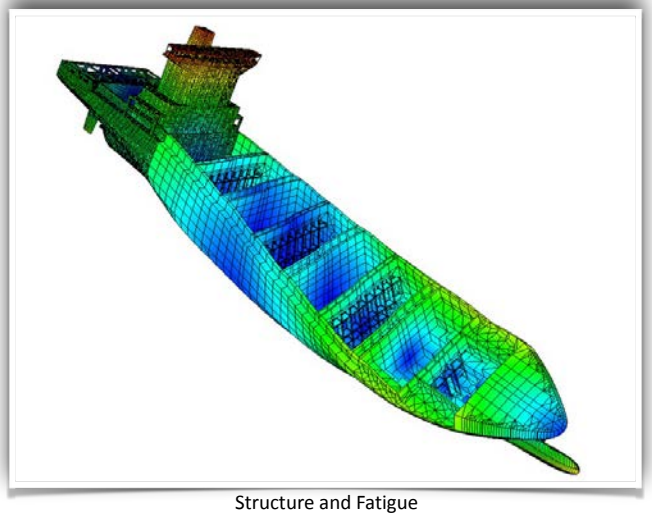
Ship Safety Research Initiative, Osaka University

Ship Safety Research Initiative, Osaka University

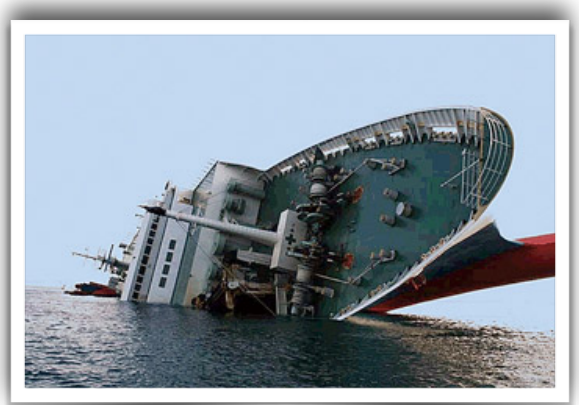
Structure and Fatigue Failure

Ship Safety Research Initiative, Osaka University



Structure and Fatigue

Ship Safety Research Initiative, Osaka University



Capsizing

Ship Safety Research Initiative, Osaka University

Dynamic Stability

Ship Safety Research Initiative, Osaka University

Collision

Ship Safety Research Initiative, Osaka University

Agrounding

Support Vessel

http://www.offshoreenergytoday.com/singapore-based-emas-marine-secures-charters-for-4-ahts-vessels/

and its Simulator

EMAS, Singapore

Simulator for Harbour Manoeuvring

Taiwan Ocean University, Taiwan

Simulator for River Barge

http://telematin.france2.fr/?page=chronique&id_article=47182

Ship Motion and Interaction nearby a Lock

http://www.lockeffects.ugent.be/EN/kc_conf_locks_call_EN.htm

River Transportation

Huanpujian, Shanghai China

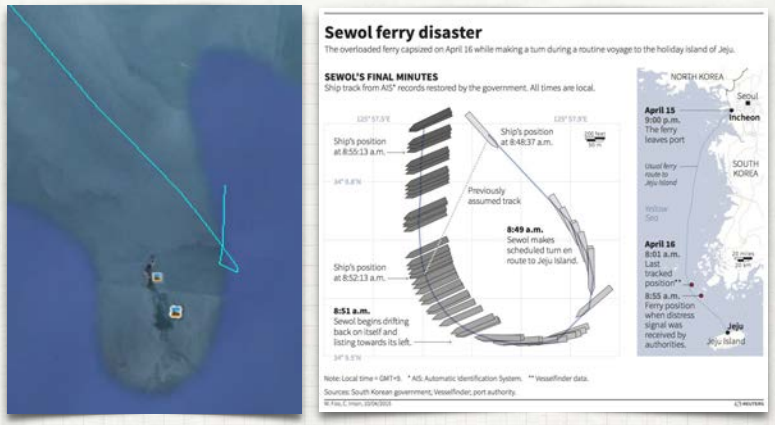
Ship Motion in Current

Upper Mekong River, Myanmar

Ship Motion in Current

INVESTIGATION OF THE ACCIDENT OF THE KOREAN FERRY "SEWOL" IN 2014

Where did it happen?

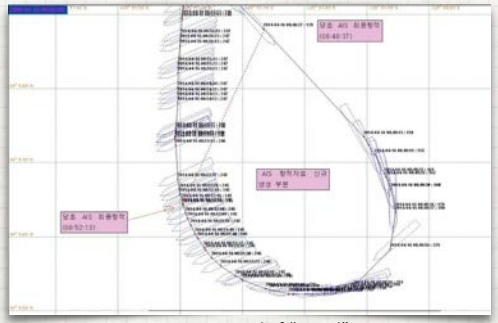


SOME FACTS OF THE INCIDENT

✓ Departure was delayed about 3 hours, because of deep fog.

✓ The officer ordered the course instead of rudder angle, when it changes the course at the place.

✓ It leaned about 45 deg. probably due to turning, then the engine has stopped and drifted by current.



AIS record of "Sewol"

MODEL SHIP

MODEL SHIP (SCALE 1/75)

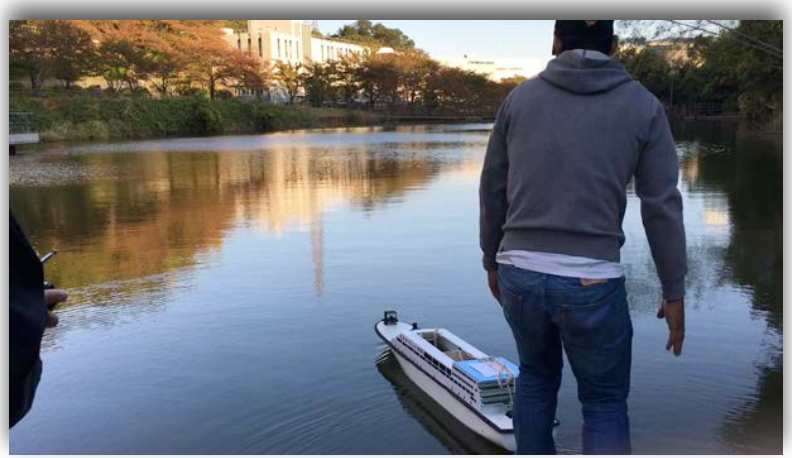
L (O.A.)	1.9 [m]
L (P.P.)	1.76 [m]
Bm	0.29 [m]
dm	7.67 [m]
Cb	0.46

The model is too small to install high accuracy instruments.

MEASUREMENT SYSTEM (2)
- DIRECT ROLL ANGLE MEASUREMENT -

↑Camera

Ship Safety Research Initiative, Osaka University



Sewol model experiment, Osaka University, 2015

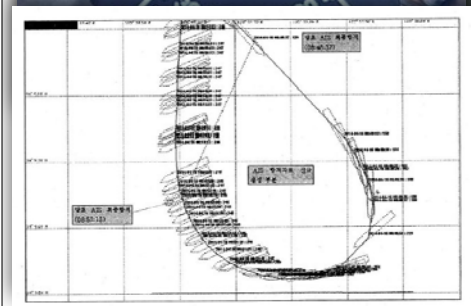
Ship Safety Research Initiative, Osaka University

Sewol model experiment, Osaka University, 2015

Ship Manoeuvrability

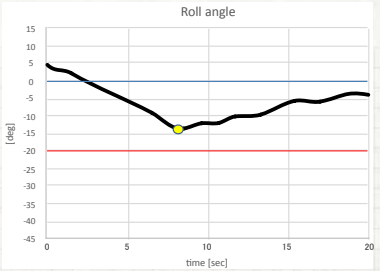
TOP-VIEW, SIDE-VIEW AND ON-BOARD CAMERAS

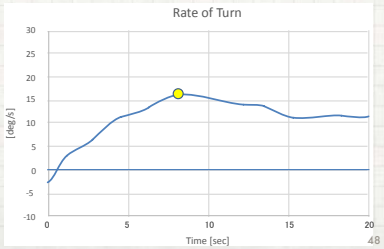
Ship Safety Research Initiative, Osaka University

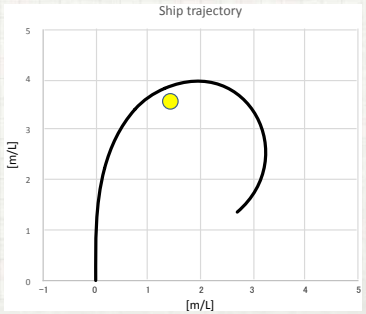


Sewol model experiment, Osaka University, 2015

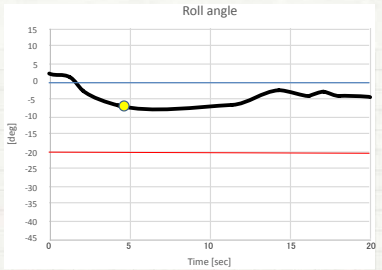
2. GM=0.9 M, Δ=35 DEG

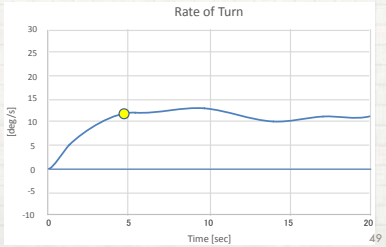


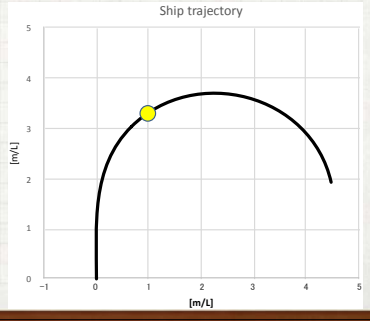




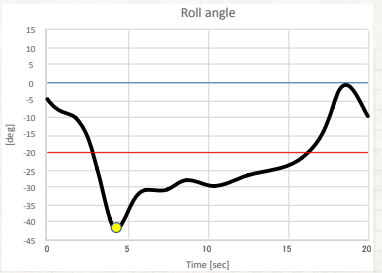
4. GM=0.6 M, Δ=35 DEG

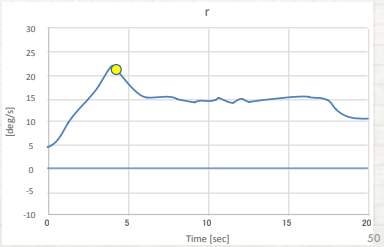


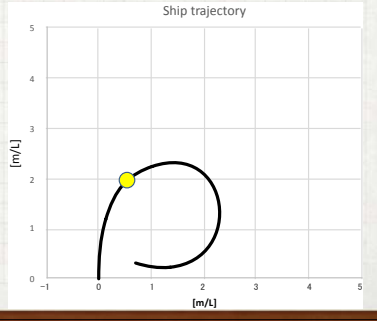




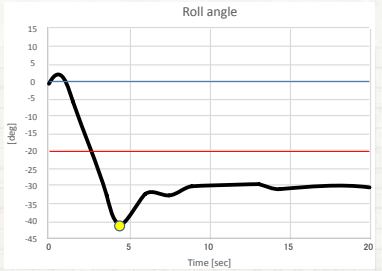
6. GM=0.3 M, Δ=35 DEG

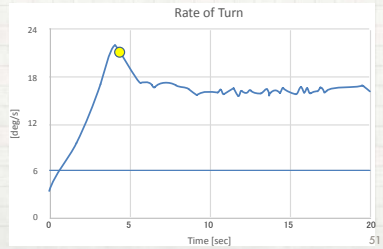


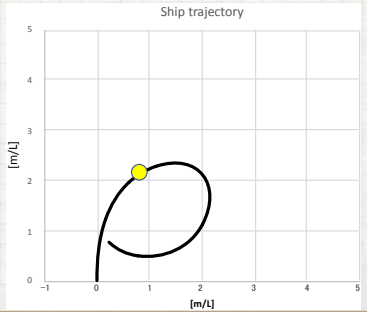




8. GM=0.2 M, Δ=35 DEG

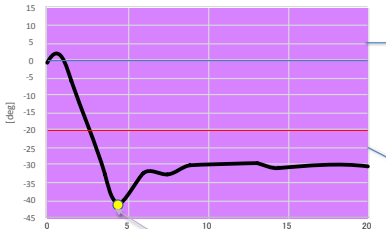




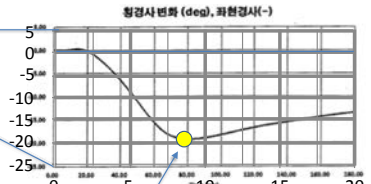


Comparison btw Exp. and Sim.

Roll angle (GM=0.2, δ=35)

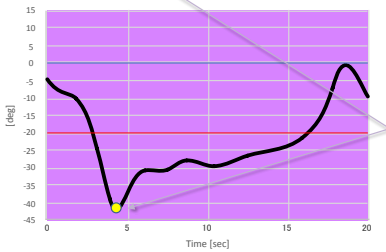


(GM=0.59, δ=35)



Maximum Heeling Angle =-19.2 deg.

Roll angle (GM=0.3, δ=35)

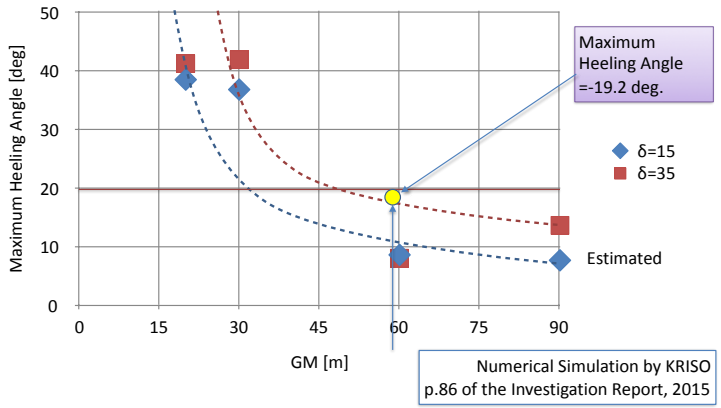


Numerical Simulation
by KRISO
p.86 of the Investigation Report, 2015

Maximum Heeling Angle exceeds 20 deg.

Free-running Experiments
by Osaka University

Relation between GM and maximum heeling angle in initial turning



MOTIVATION

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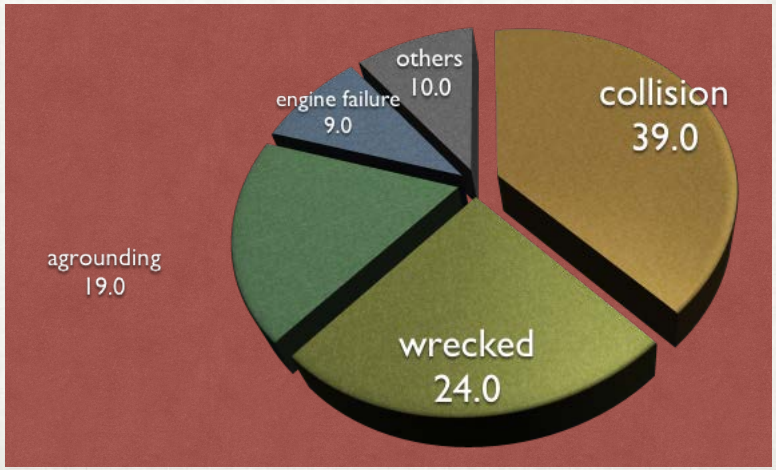
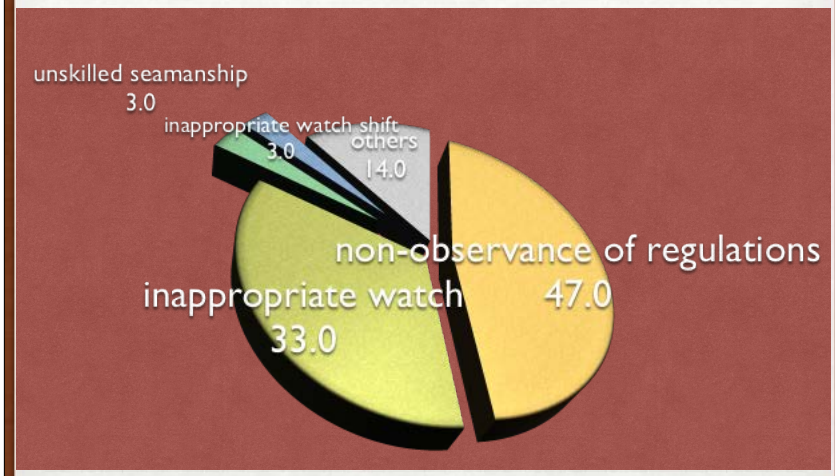
STATISTICS OF SHIP ACCIDENTS (BY KINDS)



55

STATISTICS OF SHIP ACCIDENTS (BY CAUSES)



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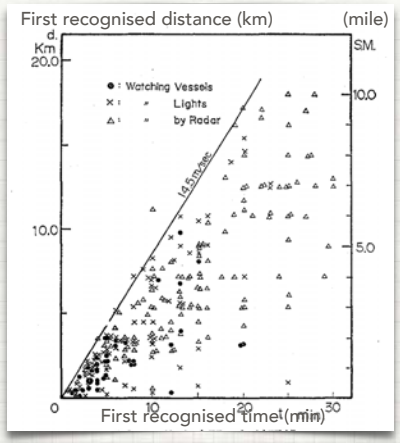
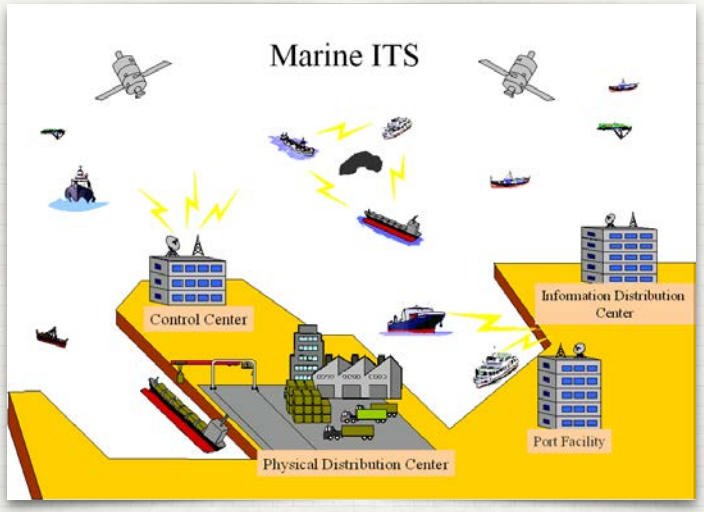
FIRST RECOGNISED TIME AND DISTANCE

- from the court documents



K. Ohnaka: Reliability of Watch Systems in Collision Avoidance, Journal of Navigation, Japan, Vol.62, pp.89-96, 1980.

CONCEPT OF MARINE ITS



AUTOMATIC COLLISION AVOIDANCE AND MARINE TRAFFIC SIMULATION

AUTOMATIC COLLISION AVOIDANCE SYSTEM

1987

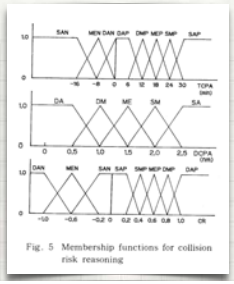


Fig. 5 Membership functions for collision risk reasoning

Table 2 Control rules for collision risk reasoning

		T						
		SAN	MEN	DAN	DAP	DMP	MEP	SMP	SAP
D	DA	SAN	MEN	DAN	DAP	DMP	MEP	SMP	SAP
C	DM	SAN	SAN	MEN	DMP	MEP	SMP	SAP	SAP
P	ME	SAN	SAN	SAN	MEP	SMP	SAP	SAP	SAP
A	SM	SAN	SAN	SAN	SMP	SAP	SAP	SAP	SAP
	SA	SAN	SAN	SAN	SAP	SAP	SAP	SAP	SAP

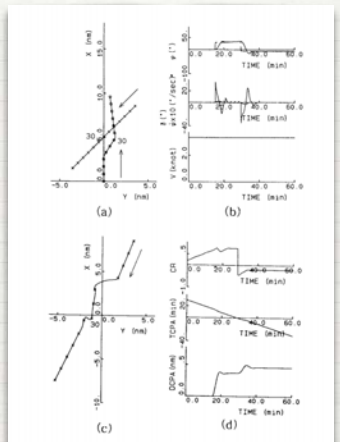
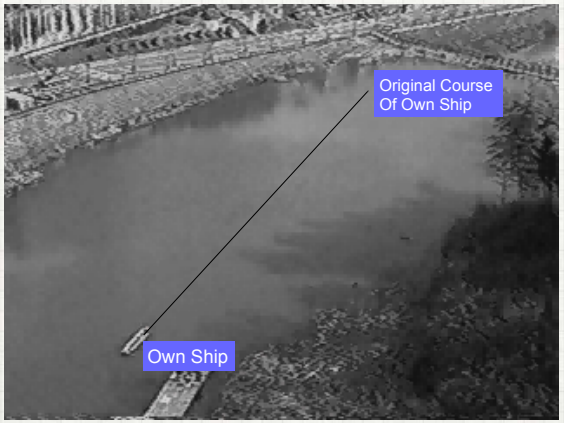


Fig. 14 Simulation of collision avoidance manoeuvre by fuzzy control (Type I)

WORLD FIRST EXPERIMENT OF AUTOMATIC COLLISION AVOIDANCE WITH (VIRTUAL) MULTIPLE SHIPS

2002

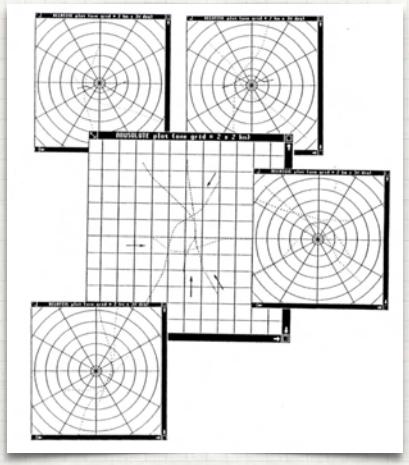
WORLD FIRST EXPERIMENT OF AUTOMATIC COLLISION AVOIDANCE WITH (VIRTUAL) MULTIPLE SHIPS, 2002



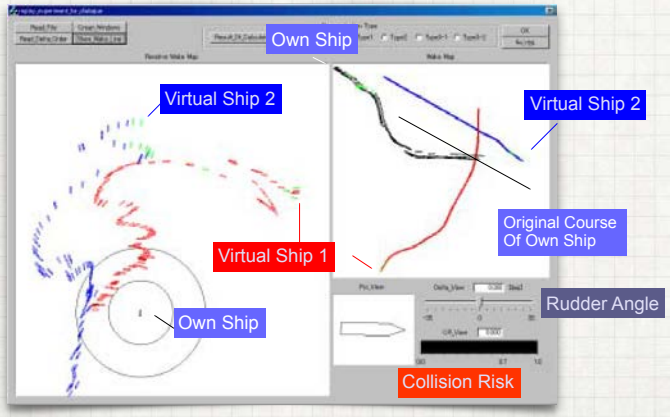
WORLD FIRST EXPERIMENT OF AUTOMATIC COLLISION AVOIDANCE WITH (VIRTUAL) MULTIPLE SHIPS, 2002

SHIP AUTO-NAVIGATION FUZZY EXPERT SYSTEM (SAFES)

1990-



WORLD FIRST EXPERIMENT OF AUTOMATIC COLLISION AVOIDANCE WITH (VIRTUAL) MULTIPLE SHIPS, 2002



MARINE TRAFFIC SIMULATION

IN 1980S AND BEFORE

Fig.1 Marine Traffic Simulator with Human Operators [33, 34]

[34] Y. Fujii, T. Makijima and K. Hara: Marine Traffic Engineering (in Japanese), p.135, Kaibundo Shuppan, Kobe, 1981.
[35] A. Nagasawa: Marine Traffic Simulation Including Collision Avoidance, Navigation, Bulletin of JIN, 80, pp.28-34, June, 1984.

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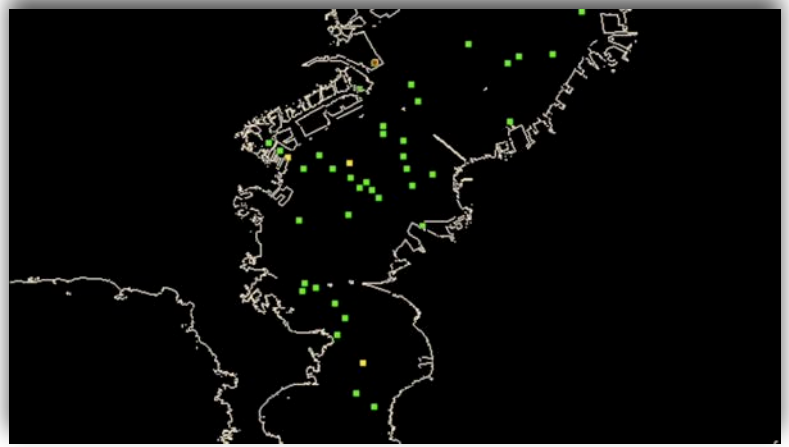


Automatic Ship Collision Avoidance System in Tokyo Bay

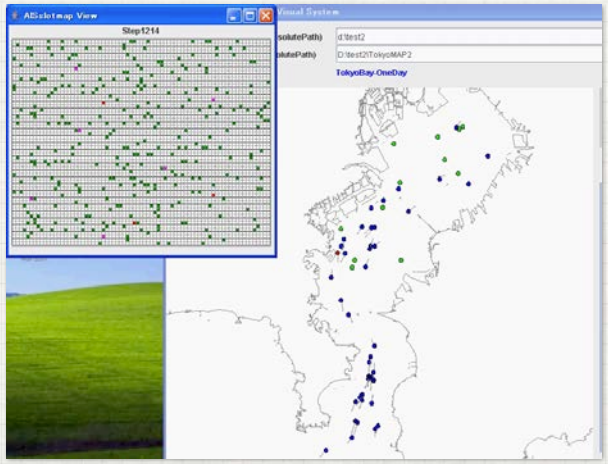
Marine Traffic Simulation

MARINE TRAFFIC SIMULATION

TOKYO BAY, 1990

WITH AIS COMMUNICATION SIMULATION

TOKYO BAY, 2006

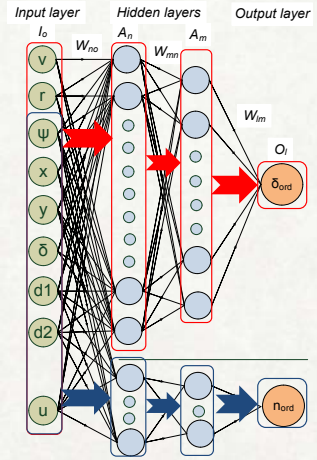


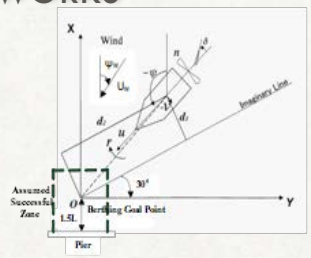
Ship Safety Research Initiative, Osaka University

Intelligent Ship Handling Simulator

AUTOMATIC BERTHING/DEBERTHING

NEURAL NETWORKS



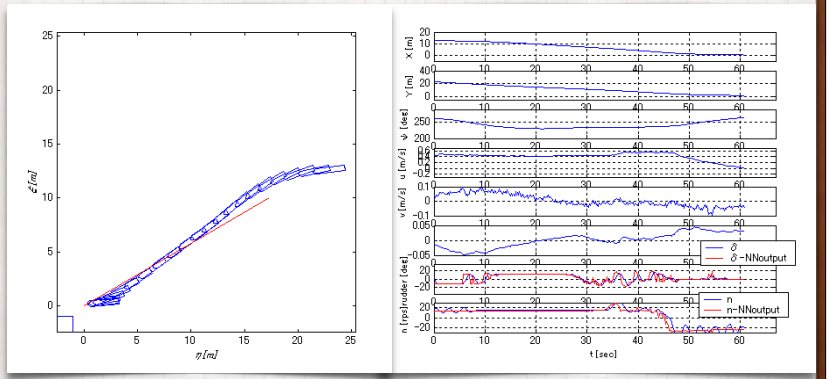


- Mean squared error (MSE) is used as evaluation function and Lavenberg-Marquardt algorithm in training.

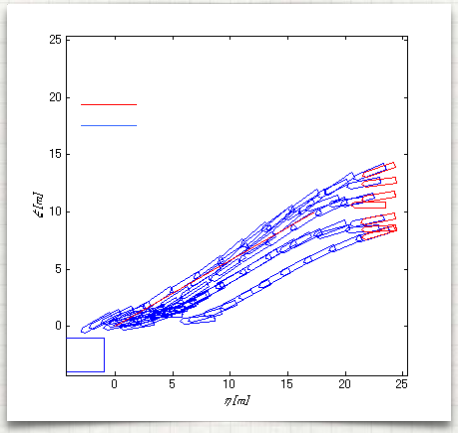
AUTOMATIC BERTHING EXPERIMENT (1993-)

AUTOMATIC BERTHING EXPERIMENT (2004)

AUTOMATIC BERTHING EXPERIMENT (2004)

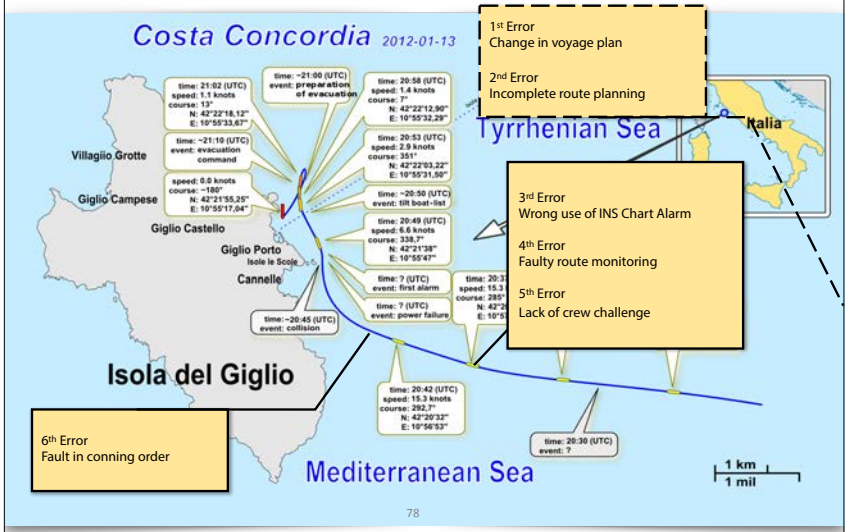


AUTOMATIC BERTHING EXPERIMENT (2004)

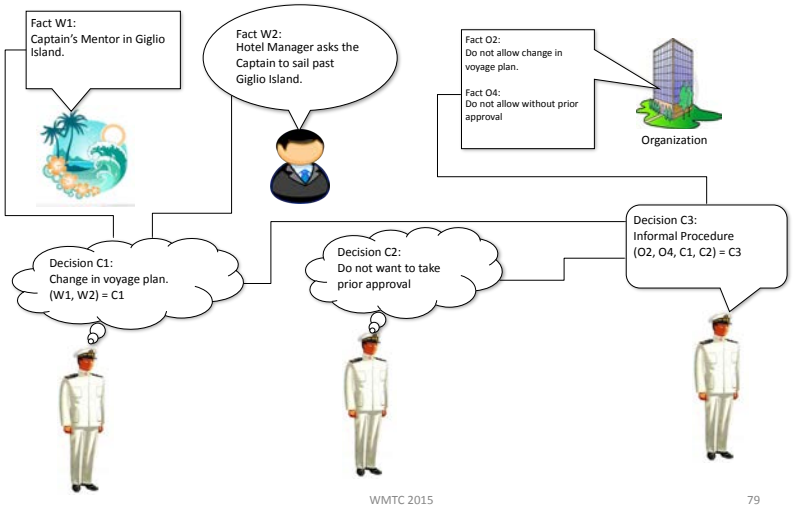


RESEARCH FOR ACCIDENT ANALYSIS

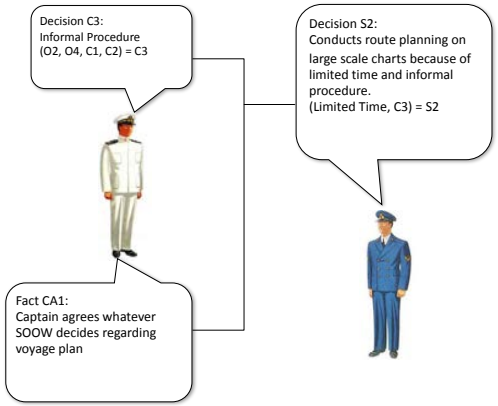
ACCIDENT OF COSTA CONCORDIA, ITALY, 2012



First Error (Change in Voyage Plan)

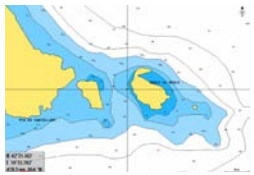


Second Error (Route Planning)

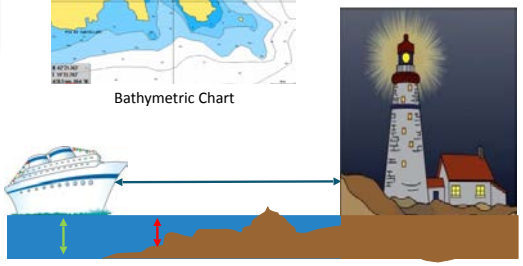


Third Error (INS Chart Alarm)

Fact S4:
Chart alarm was set to go on if the radar distance is 2000m or less. The alarm was not set for crossing 10m bathymetric line.



Bathymetric Chart



Fourth Error (Route Monitoring)

Decision C3:
Informal Procedure
(O2, O4, C1, C2) = C3

Fact S2:
Route planning conducted on large scale charts.
(Limited Time, C3) = S2

Decision J4:
No danger observed

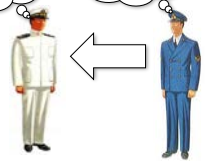
Fact J2:
No crew challenge
(J4, C3 = J2)

Fifth & Sixth Error
(Faults in Crew Challenge and Conning Orders)

Guests in the Bridge

No Danger

No Danger



Decision C5:
Captain's orders were not correctly transferred/ executed to helmsman.

Helmsman

Fact S3:
At the final stage of the approach the Captain took over command form SOOW. During this period no alarm/danger was observed and valuable time was lost .

PREDICATE AND PROPOSITIONAL LOGIC

Structure of a Logic

```
Premise 1,
Premise 2,
Premise 3
…
…
Premise n,

---------------------------
Conclusion.
---------------------------
```

Predicate Variables

Example of a Logic

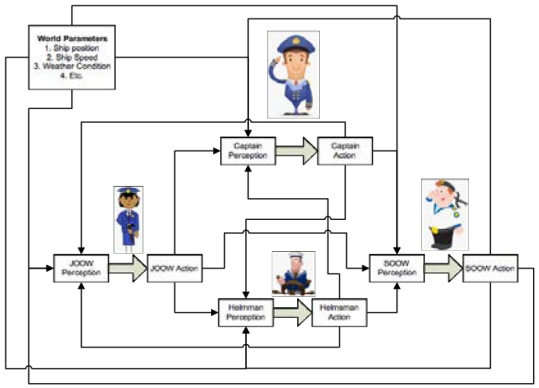
```
Ship has speed.

Engine stopped.

Bow thruster shutdown.


-----------------------------
Ship is uncontrollable.
-----------------------------
```

Predicate Logic

Propositional Logic

AGENT BASED PERCEPTION-ACTION MODEL

Schematic Representation of Crew Perception-Action

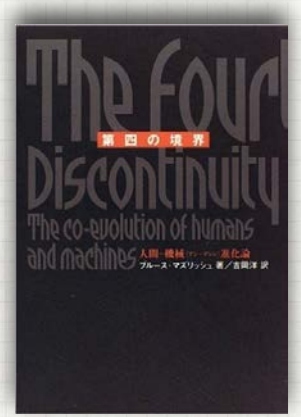


THE FOUR DISCONTINUITY

In Control Engineering

THE FOUR DISCONTINUITY

BRUCE MAZLISH

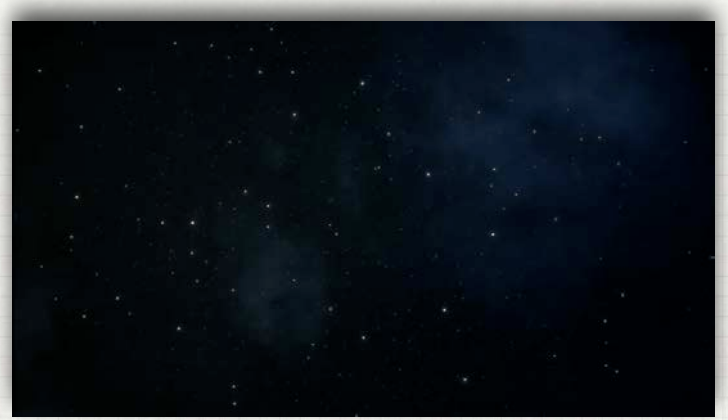


1. The discontinuity between nature and religion - Nicolaus Copernicus: On the Revolutions of the Heavenly Spheres, 1543.
2. The discontinuity between human and monkey - Charles Darwin,:On the Origin of Species, 1859.
3. The discontinuity between me and others - Carl Jung: Die Beziehungen zwischen dem Ich und dem Unbewuβten, 1984.
4. The discontinuity between human and robot -

IS A ROBOT A FRIEND OR AN ENEMY?

http://www.theguardian.com/sport/video/2014/mar/11/table-tennis-high-speed-robot-video

COGNITIVE QUADCOPTER



https://www.ted.com/talks/raffaello_d_andrea_the_astounding_athletic_power_of_quadcopters

WHERE DO WE NEED ROBOTS?

https://www.youtube.com/watch?v=x4-LofPS6FA

DARPA ROBOTICS CHALLENGE, 2015

http://www.theroboticschallenge.org/

FUTURE ROBOTS

SHOULD BE ...

http://www.theroboticschallenge.org/

AUTONOMOUS CATAMARAN FOR STUDENT COMPETITION

ROBOTX COMPETITIONS, 2014

ROBOTX COMPETITIONS, 2014

ROBOTX COMPETITIONS, 2014

ROBOTX COMPETITIONS, 2014

ROBOTX COMPETITIONS, 2014

http://www.robotx.org/

ROBOTX COMPETITIONS, 2014

THIS YEAR AT HAWAII, DEC. 2016

CONCLUSIONS

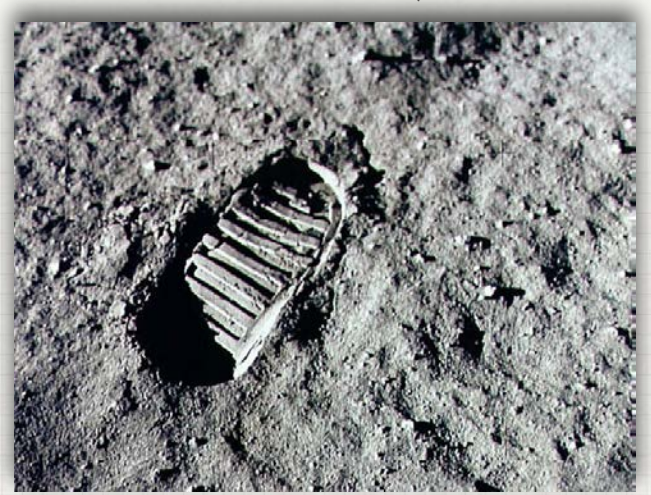
Ship Safety Research

We are seeking for safer sea including hard, soft and these integration system

Ship Safety Research Initiative, Osaka University

SUGGESTIONS

IT WAS ONE SMALL STEP, BUT …



Neil Armstrong, 1969

Stay hunger, keep foolish

Late Prof. Yalel Odabasi (1945 -2009)

TOYOTA
FOR EXAMPLE

Mitsubishi (1870-), TOYOTA (1890-), Panasonic (1918-) , Honda (1946-) and so on were founded and now they are world-leading companies, but did you know what is the origin of TOYOTA, for example? It has started from a company manufacturing human-powered textile loom machine in 1890.

TOYOTA
WHAT IS LOOMING MACHINE?

TOYOTA

HARD TIME IS THE CHANCE!

Toyota Automatic Looming Machine