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A Bayesian hypothesis testing model for quality control of mass customized cabinet manufacturing process

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Abstract. The demand for customization of cabinets and homes has increased, and customized product components are cumbersome in size and time-consuming. In order to realize the mass production of customized cabinet furniture, research from the custom design, optimization of factory machine production process and quality inspection, as well as the flow of the way, is to realize the fundamental method of large-scale production of cabinet furniture. Based on modern intelligent information processing functions instead of manual ordering, order splitting, and unit parts for reasonable division of classification, optimize the topology of the production line, to achieve modern intelligent production of panels. However, in the production process, there is a lack of on-line inspection of some links, and the yield of the product is affected. This thesis establishes a Bayesian hypothesis testing model based on the topological model of the production line process, and through the actual production data, the defective nodes of the manufacturing process are retraced to achieve the purpose of optimizing the customized production.

Keywords: customized production, topology, intelligent production, Bayesian modeling.

1. Introduction

Cabinets and home furnishings production model has experienced the development process from handmade customization to industrialized mass production and multi-species small batch production. Stimulated by customer demand and manufacturing contradictions, the manufacturing industry began to explore batch customized production of intelligent production line design, to be able to achieve the demand and manufacturing balance point way. This model in the maximum to meet the consumer's personalized needs at the same time taking into account the requirements of large-scale production factories, consumer orders to dominate the production of enterprises, to avoid the risk of product backlog due to inaccurate product and market forecasts brought about by the product [1]. At the same time,

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shorten the production time of customized products, reduce enterprise costs and improve the competitiveness of the industry [1].

However, the modernization of rapid production, multi-variety so that the inconvenience of adjusting production equipment, production and management costs increase, full component detection in the actual production, the input is huge [1,2].

Consumer demand for low-cost, high-quality, short production period of customized products, while the production model of customized products in the characteristics of efficient and rapid production is more difficult to achieve, the difficulty of quality control [2,3].

Customized production standardization needs to be carried out from various aspects, affecting the quality of the product is not only the design, but also involves raw materials, parts matching, production equipment, production processes and procedures, data processing and other factors [2].

Manufacturing enterprises from the customer demand for accurate access, analysis and management capabilities to clarify the key points of customer customization, appropriate discovery and guidance to shorten the design cycle [2]. Through the flexible design of the production line, the multi-species, small-lot production is converted into mass customization production. And then through the enhancement of product tracking and service capabilities to build a communication platform between the enterprise and the user, tracking from customer demand to customized design, production and processing to the construction and installation of the whole process [3].

From the essence of production to analyze, still to achieve generalization, combination, serialization, modular purpose to line intelligent manufacturing [2].In the context of not significantly increase the online testing equipment, the establishment of Bayesian model of the production line, to achieve the product of bad manufacturing station traceability, for enterprises to improve quality control, data AI processing and product testing is of great significance [3,4].

2. Typical Products And Production Lines

2.1. Actual boards

Figure 1. Pre-opening material

Figure 2. After uncoiling

Figure 3. Pre-sealing materials

Figure 4. After sealing

Figure 5. Hole punched

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2.2. Production line introduction

Integration of plate warehouse: the plate warehouse consists of three-dimensional warehouse + 3-story warehouse, three-dimensional warehouse has 8 sets of single-extension stacker cranes, 3-story warehouse in front of the warehouse, a total of 4,332 storage spaces, to realize the integration of raw materials in and out of the warehouse, plate out of the warehouse, paste the plate in and out of the warehouse, and the distribution of plate operations. On the first floor, raw materials are put into storage, plain boards are put out of storage, and labeled boards are put into storage. The second floor is for the operation of board distribution and raw material supply. The third floor is for board matching operation. Each layer is set up with the function of cache position dynamically allocated according to the operation situation.

Lineside warehouse: Lineside warehouse consists of lineside cache warehouse, RGV, gantry loading mechanism, roller, elevator, RGV is mainly responsible for docking the materials transported to the elevator from the stand-up warehouse and carrying the materials to the lineside cache warehouse or gantry loading mechanism, the gantry loading mechanism is responsible for executing the sorting of materials, and through the roller, the sorted materials will be transported to the open material area for processing.

Opening area: The opening area consists of electronic saws and rollers. It is responsible for sawing the board into small boards; the roller receives the boards conveyed from the gantry loading mechanism and conveys them to the corresponding electronic saw equipment for processing according to the requirements, and the labeling and sorting of large and small boards are carried out by manual labor after processing. Especially emphasized, this part realizes the upper and lower automatic streaming, and realizes the subsequent process to deal with the big and small boards separately [3-5].

Edge sealing line: The edge sealing line is composed of double-layer roller, edge sealing machine, code scanner and CCD detection mechanism. Double-layer roller receives the boards processed by electronic saw, differentiate them according to the size of boards, big boards go to the upper line, small boards go to the lower line, before entering the edge banding machine, scan through the code scanner, the central control system reads the edge banding process flow, and sends out the corresponding edge banding instruction to the four edge banding machines to change the band, change the glue pot and so on automatically, and then enter into the edge banding machine to process, and then enter into the CCD detection organization to detect the result of the process after the processing [4,5]. After that, it will enter the CCD detecting organization to detect the processing result, and then enter the row drilling process.

Drilling line: drilling line consists of six-sided drill, roller, hedgehog cache warehouse, chain cache warehouse, CCD detection mechanism, scanner, the roller receives the plate from the edge sealing area, through the scanner, into the six-sided drill for processing, if the six-sided drill are in the processing state, the plate to be processed into the chain cache warehouse or hedgehog cache warehouse waiting for the completion of the processing of the rollers transported to the CCD detection mechanism for detection, the detection results of normal plate into the three-dimensional drilling process. After the processing is completed, it will be transported to CCD inspection organization for inspection, and the normal boards will enter the three-dimensional sorting area, and the abnormal boards will enter the manual area.

Three-dimensional sorting area: three-dimensional sorting area consists of bookshelf cache warehouse, sorting robot, roller, chain cache warehouse, is responsible for sorting boards according to the order requirements, the roller receives the boards from the drilling area, the sorting robot according to the board information will be sorted to the corresponding bookshelf cache warehouse, when the boards are flush with the sets of sorting robots will be sorting the boards on the roller to move to the packaging area [3,5].

Packing area: the packing area is composed of paper cutter, automatic sealing machine and roller, which is mainly used for the packing process of flush set boards.

Finished product warehouse: finished product warehouse consists of three-dimensional warehouse + 4 floors warehouse, three-dimensional warehouse has 19 sets of single reach stacker cranes, 4 floors warehouse in front of the warehouse, the first floor is the goods delivery area, set up 16 delivery platforms, through the conveyor with the telescopic belt conveyor automatically transported to the wagon loading and delivery; the second floor is the warehousing area, the goods from the workshop through the elevator to the second floor, through the link to enter the three-dimensional warehouse, the empty pallets are automatically refluxed to the production workshop; the third and fourth floors as the stocking area The third and fourth floors are used as stocking area or hardware sorting area, with the function of in and out of the warehouse [3-6].

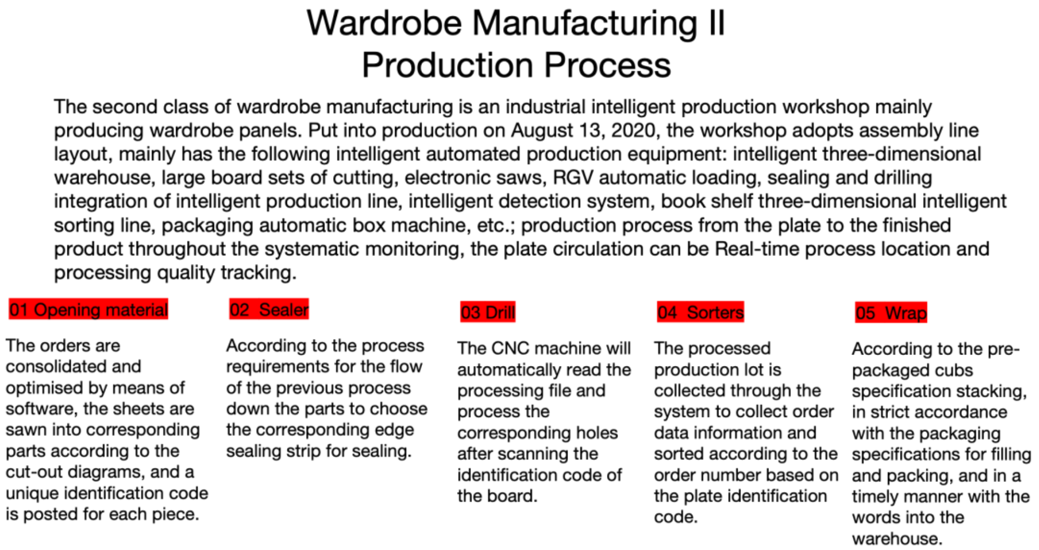

Figure 6. Introduction of production line

3. Edge-Oriented Link Detection With A Priori Probability Statistics

3.1. Edge Banding Inspection Parameter Detection Link and Test Algorithm Implementation

Figure 7. Edge Banding Side Below Finish Inspection

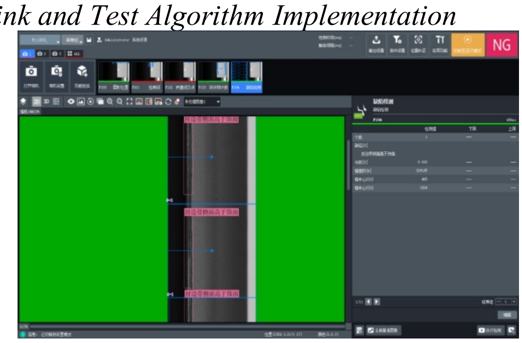

Figure 8. Edge Band Side Above Finish Inspection

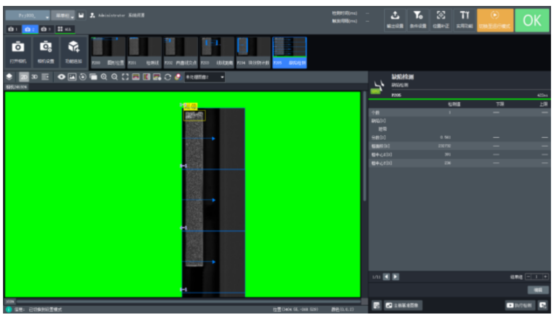

Figure 9. Short Tape Detection

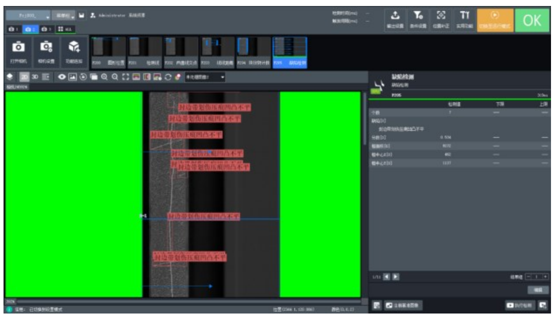

Figure 10. Surface scratches and indentations

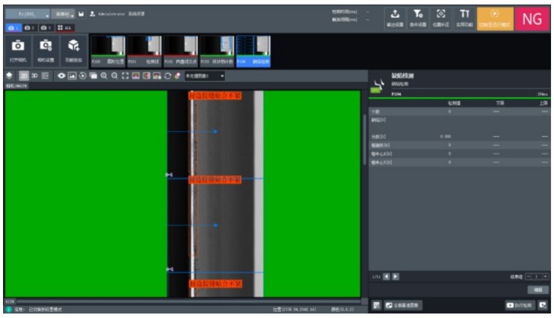

Figure 11. Seam sealing

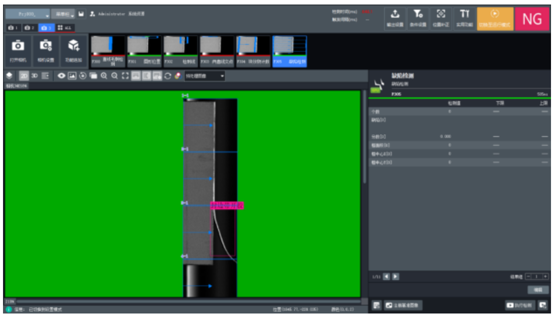

Figure 12. Gluing Detection

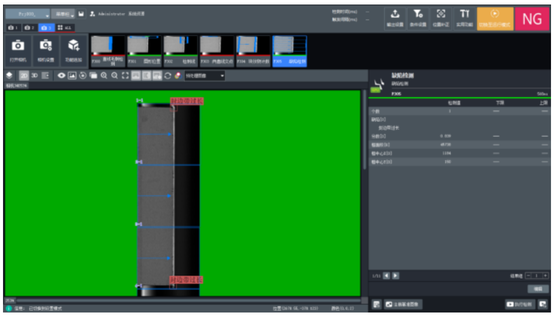

Figure 13. Sealing tape too long

3.1.1. Statistical results

The algorithm of the algorithm sampling and testing of 40 boards, four sides of a total of 160 pictures; which sample library total picking 300 boards, four sides of a total of more than 1,400 pictures.

Table 1. Statistical results.

Defect type	Detection effect	Problems	In-bank detection rate	Out-of-bank detection rate
Sealing edge short strip	Good	Part of the small area of the short belt is not detected	95%	75%
Sealing edge too long	Good	Individual length exceeds the small undetected, later can be optimized to solve the problem	95%	75%
Sealing edge open glue	Good	/	99%	85%
Poor sealing of edges	Good	Individual small gaps not detected, can be optimized later to solve the problem	97%	85%
Edge band higher than the finish	Good	Individual features are not obvious and can be optimized later.	97%	85%
Edgebanding below finish	Good	Individual characteristics are not obvious, can be optimized later to solve the problem	95%	85%
Surface scratches, indentations and pits	Normal	Individual shallow scratches not detected, can be optimized at a later stage	98%	85%

4. Production Line Modeling

Such as tree-structured factor graphs, consisting of variable nodes and factor nodes, describing joint probability distributions $f(X)f(X)f(X)f(X)$.1,2,3, represent the manufacturing type opening process station machine, 4,5,6,7 represent the sealing process station machine, 8,9 represent the hole making process station machine. Add some pictures of the actual production line station machines [5,6].

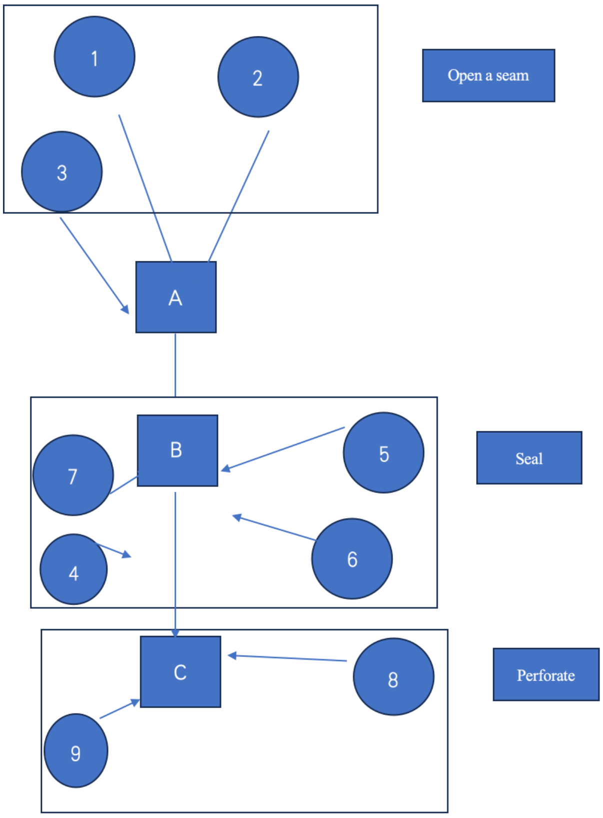

Figure 14. Topology of the production line

Disregarding the transfer rule for the moment, the probability density model of the workpiece after machining on the production line is as follows.

$$f(X) = f_A(x_1, x_2, x_3) f_B(x_4, x_5, x_6, x_7) f_C(x_8, x_9) \tag{1}$$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9$ is an independent random variable.

The joint distribution function for the opening process of f_A is

$$F_A(x_1, x_2, x_3) = \int_{-\infty}^{x_3} \int_{-\infty}^{x_2} \int_{-\infty}^{x_1} f(x_1, x_2, x_3) dx_1 dx_2 dx_3 \tag{2}$$

The probability distribution function of the edging process for f_B is

$$F_{B(x_4, x_5, x_6, x_7)} = \int_{-\infty}^{x_7} \int_{-\infty}^{x_6} \int_{-\infty}^{x_5} \int_{-\infty}^{x_4} f(x_4, x_5, x_6, x_7) dx_4\, dx_5 dx_6 dx_7 \tag{3}$$

$f(x_3)$is the probability density function of the random variable.

The probability distribution function of hole making for f_C is

$$F_C(x_8, x_9) = \int_{-\infty}^{x_8} \int_{-\infty}^{x_9} f(x_8, x_9) dx_8 dx_9 \tag{4}$$

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$f(x_1, x_2,, x_3)$,$f(x_4, x_5, x_6, x_7)$,$f(x_8, x_9)$is the probability density function of the random variable. $f_A f_B f_C$ is an independent random event in the manufacturing system.

The product model based on the modeled production line is then defined as $f(X) = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9)$ a random variable function of 9 random variables (the amount of detection features).

5. Production Line Traceability Model Based On Bayesian Hypothesis Testing

5.1. Bayesian modeling of process links

According to the data of product sampling (100 unqualified workpieces), the defective rate of incoming material is 5.18%, the defective rate of opening process is 37.4%, the defective rate of sealing process is 57.19%, and the defective rate of hole making process is 0.16%. Excluding the defective rate of incoming material, the three process links of the production line are defined as full probability events, defined as $P_{A,} P_{B,} P_C$, in which incoming material and open material are combined [7].

Based on Bayes' theorem:

$$P(A|B, C) = \frac{P(A)P(B|A)P(C|A, B)}{P(B)P(C|B)} \tag{6}$$

5.2. Bayesian network modeling for workplace hypothesis testing

Take the modeling of the edge sealing process as an example, based on the production line model, it is assumed that four independently operating workstation machines complete the edge sealing process. $f_B(x_4, x_5, x_6, x_7)$ is the joint probability density of the process link, $f_B(x_4)$, $f_B(x_5)$, $f_B(x_6)$, $f_B(x_7)$is the a priori probability density function for each station, based on the head -to-head model adopted for the sealing process loop in the production line model, which is expressed as follows:

$$p(x_4, x_5, x_6, x_7, B) = p(x_4)p(x_5)p(x_6)p(x_7)p(B|x_4, x_5, x_6, x_7) \tag{7}$$

The two sides of the formula are paired to find the integral:

$$\sum_B p(x_4, x_5, x_6, x_7, B) = \sum_B p(x_4)p(x_5)p(x_6)p(x_7)p(B|x_4, x_5, x_6, x_7) \tag{8}$$

Under the condition that the Bayesian posterior probability of the process is obtained, the local probabilistic model back localization is modeled as follows, where the probability is computed with the station labeled 4:

$$p(x_4) = \frac{p(x_4, x_5, x_6, x_7)}{p_B p(x_5)p(x_6)p(x_7)} \tag{9}$$

6. Calculation Cases

6.1. Part I Bayesian test for process segmentation

Based on the Bayesian hypothesis testing formula in (6), defined as follows, known incoming and opening, sealing, hole-making three processes in the unqualified samples in the proportion of 42.58%, 57.19%, 0.16% as the a priori probability, assuming that the three processes do not affect each other, the hypothesis testing of the calculation of the case is described as.

Sampling workpiece inspection sealing and hole-making qualified workpieces, incoming and open material process failed a posteriori probability calculation. Incoming material and opening, sealing link qualified, hole-making process failed a posteriori probability calculation. As well as incoming material and open material, hole-making qualified, sealing link unqualified a posteriori probability calculation.

For Eq. (6) $P(C|B)$ $P(B|A)$ $P(C|A, B)$, the hard-to-observe conditional probabilities are assumed here to be binomial distributions for the sake of modeling, denoted $X \sim B(n, p)$.

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6.2. Part II Inspection of Machine Position Numbers within a Single Process Section

Based on the calculation method in session 6.1, it can be concluded that $P(B|A,C)$,That is, under the incoming material and the opening and hole making sessions are qualified, the Bayesian test of unqualified edge sealing process. Based on the formula (9) can be calculated separately within the edge sealing process link unqualified workstation probability calculation [7].

6.3. Calculation result

Calculations according to 6.1 and 6.2 complete the retrospective localization of the production process. The results of the calculations are as follows.

Assuming that the nonconformity rate of the workpiece after each process step is recorded as, and there are four possibilities, assuming 0.01, 0.05, 0.10, 0.25, the following a priori information is available for the sample parameters:

$$P(p = 0.01) = 0.6$$
$$P(p = 0.05) = 0.3$$
$$P(p = 0.10) = 0.08$$
$$P(p = 0.25) = 0.02$$

Likelihood function can be obtained as: that is, under the assumption that the failure rate of the sample is a certain value of the conditions of the sample distribution, assuming that the failure rate of the sample is 0.01, 0.05, 0.10, 0.25, 5 samples in a failed likelihood estimation, according to the binomial distribution have:

$$P(r = 1|n = 5, p = 0.01) = 0.048$$
$$P(r = 1|n = 5, p = 0.05) = 0.2036$$
$$P(r = 1|n = 5, p = 0.10) = 0.3280$$
$$P(r = 1|n = 5, p = 0.25) = 0.3955$$

Based on Bayes' theorem it can be concluded that the event A "one out of five samples fails",$B_{i=}p_i$

$$p_1 = 0.01, p_2 = 0.05, p_3 = 0.10, p_4 = 0.25$$

Table 2. Bayesian Calculation Table of Event A.

Failure rate	Prior probability	Likelihood	Priori*Likelihood	Posterior probability
0.01	0.6	0.048	0.0288	0.232
0.05	0.3	0.236	0.06108	0.492
0.10	0.08	0.328	0.02624	0.212
0.25	0.02	0.3955	0.00791	0.064

For the unqualified workpieces, the proportion of each process 42.58%, 57.19%, 0.16%, redefine the event A "5 samples have an incoming material and opening material failure", "5 samples have a sealing edge failure," "One of the 5 samples fails in hole making". Based on the assumptions made in 6.1, and Equation (6) the a posteriori probability of process localization can be calculated as

$$P(r = 1, \text{Incoming material}|n = 5, p = 0.01) = 0.0024$$
$$P(r = 1, \text{Cutting}|n = 5, p = 0.05) = 0.076$$
$$P(r = 1, \text{Banding}|n = 5, p = 0.10) = 0.1875$$
$$P(r = 1, \text{Pore making}|n = 5, p = 0.25) = 0.0006$$

Table 3. Bayesian Calculation Table of Event B.

Failure rate	Prior probability	Likelihood	Priori*Likelihood	Posterior probability
0.01	0.6	0.0024	0.0288	0.00144
0.05	0.3	0.076	0.06108	0.018324
0.10	0.08	0.1875	0.02624	0.0020992
0.25	0.02	0.0006	0.00791	0.0001

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Based on the calculation of the posterior probability, and Equation (9), it is possible to backtrack the calculation of the probability of the station labeled 4, where it can be assumed that $f_B(x_4)$, $f_B(x_5)$, $f_B(x_6)$, $f_B(x_7)$,is binomially distributed.

7. Conclusion

Customized cabinet production based on intelligent production line not only realizes the use of data-driven real-time docking between production and operation, system and system, system and equipment, in tandem with intelligent production and marketing end, after-sales end and other operational modules, and realizes flexible and dynamic configuration networked in the vertical integration of the smart factory, which brings about the quality inspection problem as well as the topological localization of the manufacturing point of contact with more and more importance. The computation based on Bayesian hypothesis testing model gives a feasible computational model for the manufacturing link localization under a given topology with a priori probability, and the computational method of the Bayesian model is given.

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