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A NSGA-II based approach for multi-objective optimization of a reconfigurable manufacturing transfer line supported by Digital Twin: A case study

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ABSTRACT

In response to the wide range of customer demands, the concept of reconfigurable manufacturing systems (RMS) was introduced in the industrial sector. RMS enables producers to meet varying volumes of demand over varying time periods by swiftly adjusting its production capacity and functionality within a part family in response to abrupt market changes. In these circumstances, RMS are made to swiftly reconfigure their Reconfigurable Machine Tools (RMTs). RMTs are designed to have a variety of configurations that may be conditionally chosen and reconfigured in accordance with specific performance goals. However, the reconfiguration process is not an easy process, which entails optimization of several objectives and many of which are inherently conflictual. As a result, it necessitates real-time monitoring of the RMS's condition, which may be achieved by digital twinning, or the real-time capture of system data. The concept of using a digital replica of a physical system to provide real-time optimization is known as digital twin. This work considered a case study of discrete parts manufacturing on a reconfigurable single manufacturing transfer line (SMTL). Six manufacturing operations are required to be performed on the parts at six production stages. This work uses the Digital Twin (DT) based approach to assist a discrete multi-objective optimization problem for a reconfigurable manufacturing transfer line. This multi-objective optimization problem consists of four objective functions which is illustrated by using DT-based Non-dominated Sorting Genetic Algorithm-II (NSGA-II). The innovative aspect of the current study is the use of a DT-based framework for RMS reconfiguration to produce the best optimum solutions. The produced real-time solutions will be of great assistance to the decision maker in selecting the appropriate real-time optimal solutions for reconfigurable manufacturing transfer lines.

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Pristop z NSGA-II za večkriterijsko optimizacijo prilagodljive proizvodne linije s podporo digitalnega dvojčka: študija primera

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POVZETEK

Kot odgovor na spremenljive zahteve strank je bila v industrijskem sektorju uvedena ideja prilagodljivih proizvodnih sistemov (RMS). RMS proizvajalcem omogoča, da v različnih časovnih obdobjih zadostijo različnim obsegom povpraševanja s hitrim prilagajanjem proizvodne zmogljivosti in funkcionalnosti znotraj družine izdelkov. V teh okoliščinah so RMS narejeni tako, da hitro preoblikujejo prilagodljive obdelovalne stroje (RMT). RMT so zasnovani tako, da imajo različne konfiguracije, ki jih je mogoče izbrati in preoblikovati v skladu s posebnimi cilji. Vendar proces prilagoditve ni preprost, saj je treba upoštevati več ciljev, od katerih so si številni nasprotujoči. Zato je potrebno spremljanje stanja RMS v realnem času, kar je mogoče doseči z digitalnim dvojčkom (DD) ali z zajemom sistemskih podatkov v realnem času. Zamisel uporabe digitalne replike fizičnega sistema za optimizacijo v realnem času je znana kot digitalni dvojček. V tem delu je bila obravnavana študija primera proizvodnje diskretnih izdelkov na prilagodljivi enojni proizvodni liniji. Na obdelovancih je treba v šestih korakih izvesti šest operacij. Raziskava opisuje pristop, ki temelji na digitalnem dvojčku, za pomoč pri reševanju diskretne optimizacije z več cilji za prilagodljivo proizvodno linijo. Optimizacija modela digitalnega dvojčka uporablja genetski algoritem z nedominiranim sortiranjem-II (NSGA-II) za ovrednotenje štirih ciljnih funkcij. Inovativni vidik pričujoče študije je uporaba okvirja, ki temelji na optimizaciji DD, za preoblikovanje RMS. Izdelane rešitve v realnem času bodo v veliko pomoč odločevalcem pri izbiri ustreznih rešitev za prilagodljive proizvodnje linje.

PODATKI O ČLANKU

Ključne besede:
Prilagodljiv proizvodni sistem;
Digitalni dvojček;
Večkriterijska optimizacija;
Evolucijsko računanje;
Evolucijski algoritem;
Genetski algoritem z nedominiranim sortiranjem-II (NSGA-II);
Prilagodljivi obdelovalni stroji;
Pametna proizvodnja

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