

ΜΕΘΟΔΟΙ ΒΕΛΤΙΣΤΟΠΟΙΗΣΗΣ ΓΙΑ ΠΡΟΒΛΗΜΑΤΑ ΔΡΟΜΟΛΟΓΗΣΗΣ ΟΧΗΜΑΤΩΝ ΜΕ ΑΥΤΟΝΟΜΑ ΕΝΑΕΡΙΑ ΟΧΗΜΑΤΑ (DRONES)

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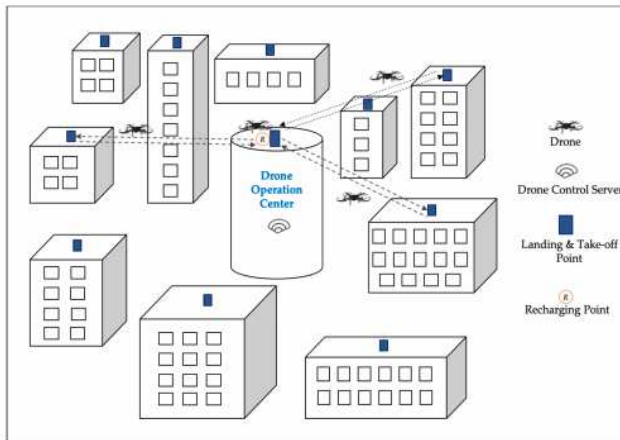


Διάρθρωση παρουσίασης

- Περιγραφή του προβλήματος
- Μεθόδοι αρχικοποίησης
- Μεθόδοι βελτίωσης
- Υπολογιστική μελέτη
- Συμπεράσματα και μελλοντικές κατευθύνσεις



Περιγραφή του προβλήματος(1/4)



Σχήμα: drone based parcel delivery



Περιγραφή του προβλήματος(2/4)

- Το κάθε ένα από τα κτήρια έχει οροφή.
- Η οροφή ενός εκ των κτηρίων χρησιμοποιείται σαν drone operation center.
- Τα drones λειτουργούν σε hub and spoke δίκτυο, το κάθε ένα από τα drones μπορεί να κουβαλήσει το πολύ ένα πακέτο. Επίσης κινούνται μόνο από το drone operation center σε κάποιο από τα κτήρια και πίσω πάλι στο operation center (Ferrandez, Harbison, Weber, Sturges, and Rich 2016).
- Χρησιμοποιούνται περισσότερα από ένα drones. Ο αριθμός τους είναι προκαθορισμένος.



Περιγραφή του προβλήματος(3/4)

- Γενικά τα drones χρησιμοποιούνται για να υποστηρίξουν τους κλασικούς τρόπους μεταφοράς και όχι να τους αντικαταστήσουν. Σε αυτή την περίπτωση αποτελεί αποκλειστικό μέσο μεταφοράς.
- Ο αριθμός της ζήτησης από κάθε κτήριο είναι γνωστός.
- Η απόσταση του κεντρικού κτηρίου από τα υπόλοιπα κτήρια μπορεί να υπολογιστεί με χρήση της ευκλείδειας απόστασης.



Περιγραφή του προβλήματος(4/4)

Table 1. Delivery drone specifications in the case study.

Item	Unit	Value
Vehicle mass	kg	8
(Maximum) Payload mass	kg	2
(Average) Cruising velocity	km/h	50
Power transfer efficiency for motor and propeller	-	0.5
Lift to drag ratio	-	3
Power consumption of electronics	kWh	0.1
Battery consumption	kWh	0.6
Battery capacity	kW	1.54
Recharging time (to full)	hour	1.5
Operating hours	hour	9
Incidental working hours (take-off, landing, loading and dropping packages)	hour	0.25

Σχήμα: Drone specifications



Κατηγορίες προβλημάτων

- (small) 2 drones and 10 destinations
- (medium) 4 drones and 20 destinations
- (large) 10 drones and 50 destinations
- 20 διαφορετικά προβλήματα για κάθε μέγεθος.
- 1 - 10 απόσταση. (τυχαίος πραγματικός αριθμός)
- 1 - 5 καθημερινή ζήτηση πακέτων. (τυχαίος ακέραιος αριθμός)



Construction Heuristic 1 (Kim, Moon, and Jung 2020)

- While there are open containers
 - stack the smallest block to the container with the largest free space.
 - create a power set made out of the blocks in the container.
 - select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
 - move the selected subset to the end of the container. Remove charging time
 - calculate the total length of the container.
 - if the total length of the container $>$ operation time
 - undo the last stacked block and close the container.



Συνολικό μήκος των πακέτων (Total Length of Blocks)

Name of the block	Total Length
0	0.688
1	0.756
2	0.806
3	0.828
4	0.842
5	0.914
6	0.932
7	0.95
8	1.121
9	1.14

Πίνακας: ΣΥΝΟΛΙΚΟ ΜΗΚΟΣ ΤΩΝ ΠΑΚΕΤΩΝ (TOTAL LENGTH OF BLOCKS)



Παράδειγμα Construction Heuristic 1

NAME OF DRONE	REMAINING SPACE	CUSTOMER												
0	0.04	0	0	2	2	2	3	3	4	5	1	1	6	
1	0.74	0	0	0	2	2	3	3	3	5	1	1	6	6
	(REMAINING BLOCKS)	6	7	7	8	8	8	9	9					

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 1 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Construction Heuristic 2

- While there are open containers
 - stack the block with the biggest charging time to the container with the largest free space.
 - create a power set made out of the blocks in the container.
 - select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
 - move the selected subset to the end of the container. Remove charging time
 - calculate the total length of the container.
 - if the total length of the container $>$ operation time
 - undo the last stacked block and close the container.



Χρόνος φόρτισης για την μεταφορά των πακέτων (*Charging Time of Drones*)

Name of the block	Charging time
9	0.65
8	0.64
7	0.54
6	0.53
5	0.52
4	0.48
3	0.47
2	0.46
1	0.43
0	0.39

Πίνακας: ΧΡΟΝΟΣ ΦΟΡΤΙΣΗΣ ΓΙΑ ΤΗΝ ΜΕΤΑΦΟΡΑ ΠΑΚΕΤΩΝ
(*CHARGING TIME OF DRONES*)



Παράδειγμα Construction Heuristic 2

NAME OF DRONE	REMAINING SPACE	CUSTOMER										
1	0.179	6	6	5	9	8	2	7	7	3	3	3
0	0.147	5	9	8	8	2	2	6	6	4	3	3
	(REMAINING BLOCKS)	2	2	1	1	1	1	0	0	0	0	0

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 2 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Construction Heuristic 3

- While there are open containers
 - For each one of the open containers
 - if the container's number is even number
 - add to the container the first enumerated block.
 - else
 - add to the container add the last block enumerated block.
 - create a power set made out of the blocks in the container.
 - select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
 - move the selected subset to the end of the container. Remove charging time
 - calculate the total length of the container.
 - if the total length of the container $>$ operation time
 - undo the last stacked block and close the container.



Παράδειγμα Construction Heuristic 3

NAME OF DRONE	REMAINING SPACE	CUSTOMER											
1	0.889	8	8	8	7	7	6	6	9	9			
0	0.691	0	0	0	0	0	1	1	1	1	2	2	2
	(REMAINING BLOCKS)	2	3	3	3	3	3	4	5	5	6	6	

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 3 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Improvement Heuristic 1 (1/3) (Kim, Moon, and Jung 2020)

- while total remaining space of containers \geq length of the 1st remaining block
- sort the containers in descending order of the remaining space
- Select a container that has the largest remaining space (1st) and a container that has the second-largest remaining space(2nd)
- Make combinations that have 2 elements made out of the intersection between the destinations of two selected containers
- select combination which has the largest gap between 2 elements on condition that this gap $<$ remaining space 2nd container
- if there are no appropriate combination between the 1st and 2nd container
- go back to container selection step and select the 1st container and the container that has the next largest space(3,4,5...)
- if there is no appropriate combination terminate the algorithm



Improvement Heuristic 1 (2/3)(Kim, Moon, and Jung 2020)

- remove the smaller block of the selected combination from the 2nd container and stack the larger block of the selected combination to the 2nd container
- create a power set made out of the blocks in the container.
- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack and select the next combination which has the next largest gap



Improvement Heuristic 1 (3/3)(Kim, Moon, and Jung 2020)

- Remove a larger destination block of the selected combination from the 1st container and stack a smaller destination block of the selected combination to the 1st container
- if there is enough space to stack the 1st remaining block
- create a power set made out of the blocks in the container.
- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack



Παράδειγμα Improvement Heuristic 1 (1/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMER											
0	1.373	3	3	6	6	7	7	4	5	1	0		
1	0.884	5	3	3	6	6	4	2	7	7	1		
	(REMAINING BLOCKS)	8	8	9	9								

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 1 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Παράδειγμα Improvement Heuristic 1 (2/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMERS											
0	0.312	3	3	6	6	7	7	8	1	0	5	5	
1	0.317	3	3	6	6	4	2	4	7	7	1		
	(REMAINING BLOCKS)	8	9	9									

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ IMPROVEMENT HEURISTIC 1 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Improvement Heuristic 2 (1/3)

- while the total remaining space of the containers \geq length of the 1st remaining block
- sort the containers in descending order of the remaining space
- get the first block of the first container
- if the remaining space of 2nd container $>$ removed block else return the removed block, break and terminate the algorithm
- Stack the removed block.
- create a power set made out of the blocks in the container.



Improvement Heuristic 2 (2/3)

- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack, return the block to the container we got it from and terminate the algorithm



Improvement Heuristic 2 (3/3)

- if the remaining space of the 1st container $>$ 1st block of the remaining blocks
- Stack to the 1st container the 1st block from the remaining blocks
- create a power set made out of the blocks in the container.
- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack and start over



Παράδειγμα Improvement Heuristic 2 (1/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMER											
0	1.373	3	3	6	6	7	7	4	5	1	0		
1	0.884	5	3	3	6	6	4	2	7	7	1		
	(REMAINING BLOCKS)	8	8	9	9								

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 1 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Παράδειγμα Improvement Heuristic 2 (2/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMERS										
0	0.709	3	6	6	7	7	4	8	5	1	0	
1	0.05	5	3	3	6	6	4	2	3	7	7	1
	(REMAINING BLOCKS)	8	9	9								

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ IMPROVEMENT HEURISTIC 2 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΙΚΡΟΥ ΜΕΓΕΘΟΥΣ



Improvement Heuristic 3 (1/3)

- while the total remaining space of the containers \geq length of the 1st remaining block
- sort the containers by remaining space in descending order.
- get the block with the largest name from the first container.
- if the remaining space of the second container $>$ total length of block we got from the first container else return the block and terminate the algorithm
- Stack the removed block.
- create a power set made out of the blocks in the container.



Improvement Heuristic 3 (2/3)

- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack and terminate the algorithm
- if the remaining space of 1st container $>$ 1st remaining block



Improvement Heuristic 3 (3/3)

- add remaining block
- create a power set made out of the blocks in the container.
- select a subset whose summed battery charging time is most similar to the battery charging time (1.5).
- move the selected subset to the end of the container. Remove charging time
- calculate the total length of the container.
- if the total length of the container $>$ operation time
- undo the last stack and start over



Παράδειγμα Improvement Heuristic 3 (1/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMER										
0	0.261	3	7	0	5	5	1	10	10	12	19	11
1	0.06	12	7	0	5	2	10	1	8	19	3	16
2	1.247	3	12	4	2	10	8	19	0	0	5	
3	1.078	3	7	4	2	10	0	5	12	19	11	
	(REMAINING BLOCKS)	6	6	6	6	6	18	18	18	18	18	13
		13	13	13	17	17	15	15	15	9	9	14

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ CONSTRUCTION HEURISTIC 1 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΕΣΑΙΟΥ ΜΕΓΕΘΟΥΣ



Παράδειγμα Improvement Heuristic 3 (2/2)

NAME OF DRONE	REMAINING SPACE	CUSTOMER										
0	0.261	3	7	0	5	5	1	10	10	12	19	11
1	0.06	12	7	0	5	2	10	1	8	19	3	16
2	0.681	3	4	2	10	8	6	12	0	0	5	
3	0.362	3	7	4	2	10	0	5	12	11	19	19
	(REMAINING BLOCKS)	6	6	6	6	18	18	18	18	18		
		13	13	13	13	17	17	15	15	15	9	
		9	14									

Πίνακας: ΠΑΡΑΔΕΙΓΜΑ ΧΡΗΣΗΣ IMPROVEMENT HEURISTIC 3 ΣΕ ΠΡΟΒΛΗΜΑ ΚΑΤΗΓΟΡΙΑΣ ΜΕΣΑΙΟΫ ΜΕΓΕΘΟΥΣ



- Intel®Core™i5 2.80 GHz
- 8 GB RAM.
- Python 3.8.



Αποτελέσματα αλγορίθμων (1/3)

Size	# Drones	# Destinations	Obj Function	Construction 1	Construction 2	Construction 3
Small0	2	10	33	8	11	11
Small1	2	10	24	4	6	5
Small2	2	10	29	7	12	10
Small3	2	10	34	14	20	19
Small4	2	10	22	2	4	2
Small5	2	10	33	12	17	12
Small6	2	10	25	4	7	4
Small7	2	10	29	10	15	13
Small8	2	10	29	9	13	12
Small9	2	10	25	6	8	7
Small10	2	10	34	12	18	14
Small11	2	10	26	6	8	8
Small12	2	10	27	7	11	10
Small13	2	10	30	10	16	12
Small14	2	10	34	12	18	16
Small15	2	10	25	7	11	7
Small16	2	10	26	4	8	6
Small17	2	10	29	7	13	10
Small18	2	10	36	12	20	17
Small19	2	10	33	11	19	13
Avg			32,42	8,2	12,75	10,4

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Αποτελέσματα αλγορίθμων (2/3)

Size	# Drones	# Destinations	Obj Function	Construction 1	Construction 2	Construction 3
Medium0	4	20	59	19	28	26
Medium1	4	20	73	29	45	39
Medium2	4	20	66	23	38	35
Medium3	4	20	65	21	35	30
Medium4	4	20	64	22	35	29
Medium5	4	20	56	16	28	24
Medium6	4	20	56	16	24	23
Medium7	4	20	57	17	27	23
Medium8	4	20	67	27	43	36
Medium9	4	20	67	28	39	34
Medium10	4	20	54	17	26	24
Medium11	4	20	63	20	35	31
Medium12	4	20	51	9	15	13
Medium13	4	20	60	23	32	28
Medium14	4	20	57	17	25	21
Medium15	4	20	60	20	32	28
Medium16	4	20	52	12	20	15
Medium17	4	20	58	14	22	21
Medium18	4	20	54	14	22	20
Medium19	4	20	64	27	36	32
Avg			66,125	19,55	30,35	26,6

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Αποτελέσματα αλγορίθμων (3/3)

Size	# Drones	# Destinations	Obj Function	Construction 1	Construction 2	Construction 3
Large0	10	50	165	65	95	88
Large1	10	50	153	48	73	67
Large2	10	50	154	49	74	68
Large3	10	50	163	63	93	87
Large4	10	50	150	40	70	71
Large5	10	50	142	50	72	75
Large6	10	50	144	44	64	59
Large7	10	50	147	42	67	61
Large8	10	50	135	36	55	55
Large9	10	50	140	36	60	58
Large10	10	50	146	47	76	70
Large11	10	50	140	40	60	54
Large12	10	50	144	34	63	58
Large13	10	50	148	52	78	72
Large14	10	50	157	62	87	81
Large15	10	50	143	43	63	57
Large16	10	50	140	40	60	55
Large17	10	50	178	68	108	101
Large18	10	50	138	38	58	53
Large19	10	50	141	39	61	56
Avg			148,4	46,8	71,85	67,3



BVNS και VND

- VND
- IMPROVEMENT HEURISTIC 1
- IMPROVEMENT HEURISTIC 2
- BVNS
- IMPROVEMENT HEURISTIC 1
- IMPROVEMENT HEURISTIC 2
- IMPROVEMENT HEURISTIC 3 (SHAKING)



Αποτελέσματα BVNS και VND (1/3)

Size	# Drones	# Destinations	Obj Function	VND	BVNS
Small0	2	10	33	8	8
Small1	2	10	24	3	4
Small2	2	10	29	7	7
Small3	2	10	34	13	14
Small4	2	10	22	2	2
Small5	2	10	33	12	12
Small6	2	10	25	4	4
Small7	2	10	29	9	9
Small8	2	10	29	9	9
Small9	2	10	25	6	6
Small10	2	10	34	12	12
Small11	2	10	26	6	6
Small12	2	10	27	7	7
Small13	2	10	30	10	10
Small14	2	10	34	11	12
Small15	2	10	25	6	6
Small16	2	10	26	4	4
Small17	2	10	29	7	7
Small18	2	10	36	12	12
Small19	2	10	33	11	11
Avg			32,43	7,95	8,1

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Αποτελέσματα BVNS και VND (2/3)

Size	# Drones	# Destinations	Obj Function	VND	BVNS
Medium0	4	20	59	19	19
Medium1	4	20	73	29	29
Medium2	4	20	66	23	22
Medium3	4	20	65	21	21
Medium4	4	20	64	21	21
Medium5	4	20	56	15	14
Medium6	4	20	56	16	16
Medium7	4	20	57	17	16
Medium8	4	20	67	26	25
Medium9	4	20	67	28	27
Medium10	4	20	54	16	15
Medium11	4	20	63	20	19
Medium12	4	20	51	8	8
Medium13	4	20	60	23	22
Medium14	4	20	57	17	16
Medium15	4	20	60	19	18
Medium16	4	20	52	12	10
Medium17	4	20	58	13	14
Medium18	4	20	54	14	14
Medium19	4	20	64	27	26
Avg			66,125	19,2	18,6

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Αποτελέσματα BVNS και VND (3/3)

Size	# Drones	# Destinations	Obj Function	VND	BVNS
Large0	10	50	165	64	62
Large1	10	50	153	47	46
Large2	10	50	154	48	46
Large3	10	50	163	63	63
Large4	10	50	150	40	40
Large5	10	50	142	49	48
Large6	10	50	144	43	42
Large7	10	50	147	41	40
Large8	10	50	135	36	36
Large9	10	50	140	35	33
Large10	10	50	146	47	47
Large11	10	50	140	39	38
Large12	10	50	144	34	34
Large13	10	50	148	51	50
Large14	10	50	157	61	61
Large15	10	50	143	43	43
Large16	10	50	140	39	38
Large17	10	50	178	68	68
Large18	10	50	138	38	38
Large19	10	50	141	38	38
Avg			148,4	46,2	45,55

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Συμπεράσματα

- Small
- Medium
- Large



Μελλοντικές κατευθύνσεις

- καιρικές συνθήκες
- ανθρώπινη παρέμβαση
- λιγότερα drones ανά πρόβλημα
- περισσότερα depots ανά πρόβλημα



Τέλος της παρουσίασης

Ευχαριστώ για την προσοχή σας!

