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Analitična določitev srednje sevalne temperature zapletene geometrijske oblike prostora

An Analytical Determination of the Mean Radiant Temperature for a Complex Room Geometry

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Sevalne toplotne izgube pomenijo sestavni del toplotnega ravnotežja človeka v prostoru. Pravilna določitev deleža sevalnega toplotnega toka je potrebna za oceno vpliva tega parametra na toplotno ugodje. Toplotno ravnotežje je odvisno predvsem od površinskih temperatur in kotnega faktorja med človekom in površinami prostora. Ker so notranje površine sestavljene iz različnih elementov, je izračun kotnega faktorja zahteven. V tem primeru pomeni računalniški program primerno orodje za izračun sevalnih toplotnih tokov, predvsem za zapleteno sestavljene površine, kakršne so v dejanskih razmerah.

Predstavljeni algoritem temelji na izračunu kotnih faktorjev, pri čemer je upoštevan zakon seštevnosti. Postopek izračuna omogoča določitev kotnih faktorjev za sestavljene površine in s tem upoštevanje zapletenega vpliva kotnih faktorjev na sevalni toplotni tok, kakršen je npr. pri sedeči osebi in znani usmeritvi. Matrično zasnovan postopek omogoča določitev vpliva različnih parametrov na srednjo sevalno temperaturo.

(Ključne besede: ugodje bivalno, prenos toplote, sevanje, temperature sevanja)

Radiative heat losses represent a substantial part of the total heat balance of the human body in a closed space. The correct determination of this contribution is necessary in order to gain an insight into the influence of this parameter on human thermal comfort. The thermal balance is strongly affected by surface temperatures and by the angle factor between a body and a wall surface. Since a room's internal surfaces are composed of various parts, the calculation of view factors becomes more complex. Therefore, a computer algorithm is a useful tool for determining the radiant heat exchange, particularly for the complex surface compositions encountered in practical situations.

The proposed algorithm is based on the computation of view factors, which are additive. This algorithm enables the computation of view factors for composite surfaces, thus allowing for the complex impact of view factors on thermal radiative heat exchange, as is the case for the seated posture and other orientations of the human body. The matrix-based approach makes it possible to determine the influence of various parameters on the mean radiant temperature.

(Keywords: thermal comfort, heat transfer, radiation, radiant temperature)

0 UVOD

Toplotno ugodje ljudi je odločilen dejavnik, ki določa kakovost bivalnega okolja v stavbah. Zagotovljeno je z vzdrževanjem vplivnih parametrov v predpisanih mejah ob hkratni izravnavi vseh motečih vplivov. Analiza sevalnega ogrevalnega sistema pokaže, da je pri zagotavljanju kakovosti bivalnega okolja odločilna razlika med temperaturo zraka v prostoru in dejansko temperaturo. Upoštevajoč toplotno ugodje imajo ljudje subjektivno nagnjenost k toplejšim obodnim

0 INTRODUCTION

The thermal comfort of people in confined environments is a crucial issue for the proper assessment of the indoor quality of buildings. It should be considered both as a requisite by itself and as a fundamental preliminary requirement for establishing other indoor needs. Thermal comfort is ensured by maintaining the declared values of the factors determining thermal comfort constant, while eliminating any disturbing influences causing local thermal discomfort. When analysing a radiant heating system, the most pronounced factor is stenam in hladnejšemu zraku; zato je primerna natančnejša določitev sevalnega dela prenosa toplote. Toplotno ravnotežje človeka je odvisno od sevalnega toplotnega toka med telesom in obodnimi stenami, ta pa je odvisen od površinskih temperatur in kota, katerega tvorita telo in opazovana površina. Za določitev toplotnega ugodja ali neugodja je zato treba najprej določiti kotne faktorje obodnih površin glede na položaj človeka.

Za preproste površine so algoritmi za izračun kotnih faktorjev že določeni. Vendar so v resničnem stanju površine sestavljene iz različnih neizotermnih elementov, ki onemogočajo neposredno uporabo algoritmov. Kot primer preprosto sestavljene neizotermne notranje površine so različni elementi, npr. stene, okna, vrata in ogrevala. Zaradi tega postane izračun kotnih faktorjev zelo zapleten in je potrebno dosledno upoštevanje temperaturnih karakteristik površin. Zato je vpeljan algoritem, ki omogoča izračun projekcijskega faktorja človeka glede na dano stanje.

Poprej je bila razvita metoda za izračun kotnega faktorja, ki temelji na neposrednem izračunu projekcijskega faktorja. Kotni faktorji so podani kot približki rešitev sistema enačb in so predstavljeni v obliki zbirke diagramov. V teh diagramih je kotni faktor podan neposredno kot funkcija brezdimenzijskega geometrijskega parametra. Enačbe so rešene za šest značilnih smeri (površin prostora), ki predstavljajo značilni prostor. Za te primere je predpostavljena razdelitev površin kvadra na podpovršine; zaradi simetrije človeškega telesa se število kotnih faktorjev zmanjša in so odvisni od usmeritve med človekom in delno površino. Za tipični prostor se število kotnih faktorjev zmanjša na šest za sedečega človeka, tri za stoječega in dva za primer neznane usmeritve.

Naslednji korak k poenostavitvi in s tem bolj uporabni obliki zapisa kotnih faktorjev je dobljen z metodo najmanjših kvadratov. Pri tem so kotni faktorji podani v obliki eksponentnih enačb v funkcijski odvisnosti od brezdimenzijskih geometrijskih parametrov. Ta poenostavljena metoda izračuna kotnih faktorjev zagotavlja dobro ujemanje izračunanih vrednosti z eksperimentalno izmerjenimi vrednostmi pa tudi z rešitvami sistema enačb. Način zapisa kotnih faktorjev skupaj s parametri omogoča preprosto uporabo računalniškega programa. Pri računanju resničnih stanj so obodne površine razdeljene na štiri površine kvadra (glede na položaj in usmeritev človeka) in z upoštevanjem zakona seštevnosti določen kotni faktor za celotno površino. Posplošen algoritem omogoča izračun kotnih faktorjev za poljubne neizotermne elemente obodnih površin prostora.

the difference between the indoor air temperature and the effective temperature. Regarding personal comfort, the human occupant has a subjective preference for a warmer building structure and cooler indoor air, indicating that radiative heat exchange should be favoured. The human body's thermal balance is strongly affected by radiative heat exchanges with surrounding surfaces, which are a function of the surface temperatures and the angle at which the human body senses them. This means that in order to establish local thermal comfort or discomfort, view factors of people with respect to the envelope surfaces must first be assessed.

Algorithms for computing these view factors for simple plane surfaces have already been determined. However, in practical cases, the room's internal surfaces are composed of various parts, each possessing a specific thermal situation. The complex internal surface of a room composed of a wall, a window, a door and a heating panel would be an example of this kind of mixture of composite plane surfaces. In this case, the calculation of view factors becomes much more complex and requires a careful management of the thermal and geometric properties of the surfaces. A comprehensive algorithm is introduced here which allows for the computation of angle factors of people with respect to the given complex situations.

In a previous study, a method of calculating the view factor was determined which avoids the direct calculation of the projected area factor. In this work, the view factors were given as solutions of equations and presented in the form of sets of graphs. In these graphs, the view factor was directly presented as a function of dimensionless geometrical parameters. The equations were solved for six relevant cases (room walls) that occur in a typical room. A division of parallel-piped surfaces into sub-surfaces has been proposed for these cases. Due to the symmetry of the human body, the number of view factors is reduced and the view factors are dependent on the orientation of the person and sub-surface. The number of view factors for the typical sub-surfaces of an enclosure is reduced to six for a seated person, three for a standing person and two when the orientation of a person is unknown.

Another step toward simplification, and thus to a more useful form of view factors, was suggested by the observation of graphs. There the view factors are given in the form of exponential equations dependent on dimensionless geometrical parameters. This simplified method for calculating the view factors enables good agreement between the calculated and actual values determined by solutions of equations and experimental data. The form of the view factors, along with the determined parameters, allows them to be used in computer algorithms. For practical applications, the surrounding surfaces should be divided into four rectangular sub-surfaces (with respect to the human body's position and orientation) and, by means of the additive property, computed to determine the whole view factor. This general algorithm could also be used for computing the view factor for non-isothermal elements of the wall.

1 KOTNI FAKTOR MED ČLOVEKOM IN POVRŠINO PROSTORA

1 ANGLE FACTOR BETWEEN THE HUMAN BODY AND THE ROOM SURFACE

Kotni faktor med človekom in pravokotno izotermno površino $F_{P\rightarrow A}$ lahko izračunamo po enačbi, podani v [1] in standardu [2]:

As presented in the work of Fanger [1] and determined with a standard [2], the angle factor between the human body and a rectangular surface $F_{P\rightarrow A}$ can be computed as:

$$F_{P\rightarrow A}=\frac{1}{\pi}\cdot\int_{\frac{x}{y}=0}^{\frac{x}{y}=\frac{a}{c}}\int_{\frac{z}{y}=0}^{\frac{z}{y}=\frac{b}{c}}\frac{f_P}{\sqrt{\left[1+\left(\frac{x}{y}\right)^2+\left(\frac{z}{y}\right)^2\right]^3}}\,d\left(\frac{x}{y}\right)d\left(\frac{z}{y}\right) \qquad (1)$$

kjer sta a in b širina in višina izotermne površine A ter f_P projekcijski faktor. Pri praktični uporabi enačbe (1) se pojavita dva problema: določitev projekcijskega faktorja f_P in vpliv neizotermne sestavljene površine.

Zato je bila razvita metoda, ki ne temelji na neposrednem računanju kotnih faktorjev. V [1] so podani kot rešitve enačb, prikazane v obliki zbirke diagramov. V njih je kotni faktor podan neposredno kot funkcija brezdimenzijskih parametrov a/b in b/c. Enačbe so rešene za šest značilnih primerov (sten prostora). Izračun temelji na delitvi površine kvadra na štiri delne površine. Zaradi simetrije človeka se število kotnih faktorjev zmanjša in so odvisni od usmeritve človeka glede na delno površino. Za površine kvadra se število kotnih faktorjev zmanjša na šest za sedeč položaj, tri za stoječ in dva za primer neznane usmeritve.

Naslednji korak k poenostavitvi in s tem uporabnejši metodi določitve kotnih faktorjev je predlagan v [3]. Na temelju grafično predstavljenih rešitev enačb je narejena analiza s postopkom najmanjših kvadratov, s katero je dobljena eksponentna enačba kot funkcija brez-dimenzijskih parametrov a/c in b/c:

where a and b are the width and height of the isothermal surface A, and f_P is the projected area factor. However, two problems arise in the practical application of equation (1): the determination of the projected area factor f_P and the influence of the non-isothermal composite surface.

In order to calculate the view factor, a method which avoids the direct calculation of the projected area factor has been established. In the previous work of Fanger [1], the view factors are determined as solutions of equations and presented in the form of sets of graphs. In these graphs, the view factor is directly presented as a function of the dimensionless geometrical parameters a/c and b/c. Equations are solved for six relevant cases (room surfaces) that occur in a typical room. For this, a division of the parallelepiped surfaces into sub-surfaces is proposed. Due to the symmetry of the human body, the number of view factors is reduced and is dependent on the orientation of the person to the sub-surface. The number of view factors for typical sub-surfaces of an enclosure is reduced to six for a seated person, three for a standing person and two for person with unknown orientation.

Another step toward simplification, and thus to a more useful form of view factors, was made by Rizzo et al. [3]. As suggested by the observation of graphs, the view factors are given in the form of exponential equations dependent on geometrical parameters, the dimensionless parameters a/c and b/c in the following equation:

$$F_{P\rightarrow A}=F_{sat,\max}\cdot\left[1-\exp\left(\frac{a}{c}\right)\Big/\tau\right]\cdot\left[1-\exp\left(\frac{b}{c}\right)\Big/\tau\right] \qquad (2)$$

kjer sta

where

$$\tau=A+B\cdot\frac{a}{c}$$

in

and

$$\gamma=C+D\cdot\frac{b}{c}+E\cdot\frac{a}{c}$$

$F_{sat,\mathrm{maks}}$ pomeni največjo vrednost projekcijskega faktorja za dano podpovršino v odvisnosti od usmeritve (znana ali neznana) in položaja človeka (sedeč ali stoječ). Koeficienti A, B, C, D in E so določeni z linearno regresijo za parameter τ in večkratno aproksimacijo za parameter γ. Primerjava rezultatov, dobljenih s to metodo, z rezultati rešitev enačb in izmerjenih vrednosti, je dokazala

$F_{sat,max}$ represents the maximum saturation value for a given sub-surface depending on human body orientation (known or unknown) and posture (seated or standing). The parameters A, B, C, D and E are determined by simple linear regression for the parameter τ and by multiple linear regression for the parameter γ. As shown by Nucara et al. [4], this simplified method for calculating the view factors enables good agreement between the upravičenost uporabe poenostavljene metode izračuna [4]. Oblika enačbe (2) omogoča preprosto uporabo koeficientov v računalniškem programu. Za reševanje dejanskih primerov je potrebna samo delitev obodnih površin na štiri delne površine (glede na usmeritev in položaj človeka), kotni faktor za celotno površino pa je določen z zakonom o seštevnosti.

calculated and actual values determined from solutions of equations, as well as experimental data. The form of equation (2) along with the determined parameters enables their use in computer algorithms. For practical applications, the surrounding surfaces should be divided into four rectangular sub-surfaces (with respect to the human body's position and orientation) and by means of the additive property computed for the whole view factor.

2 VPLIV SESTAVLJENIH POVRŠIN

Na sliki 1 je prikazan najpreprostejši primer enostavne izotermne površine. Če normala na površino *A* poteka skozi točko *P* (opazovana točka v prostoru, t. i. osrednja točka) in se ujema z ogliščem površine, potem lahko določimo kotni faktor z enačbo (2) v odvisnosti od usmeritve in položaja človeka. V primeru, da se normala ne ujema z ogliščem, kakor je prikazano na sliki (1), potem lahko določimo kotni faktor ob upoštevanju seštevnosti z enačbo (3):

2 THE INFLUENCE OF COMPOSITE ROOM SURFACES

The simplest example of an isothermal room surface is shown in Figure 1. If the normal from the subject *P* (the so-called generic point) coincides with the corner point of surface *A*, the view factor can be directly computed with equation (3) depending on the human body orientation and posture. In addition, if the normal does not coincide with the corner point (as shown in Figure 1), then the view factor can be determined by the application of the additive property in the following way:

$$F_{P\to A} = F_{P\to 1} + F_{P\to 2} + F_{P\to 3} + F_{P\to 4}$$

ali or (3)

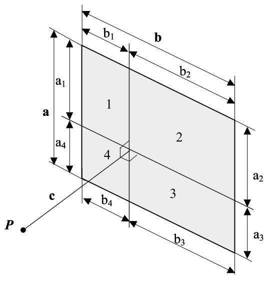
$$F_{P\to A} = \sum_{i=1}^{4} F_{P\to i}$$

kjer *i*-ta površina pomeni delno površino $a_i b_i$.

Enačbo (3) lahko uporabimo kot splošni algoritem za izračun kotnega faktorja za poljuben element površine. Z delitvijo površine, pri čemer element *A* že pomeni delni element stene, na naslednje štiri delne elemente (na sl. 2. delni elementi 1, 2, 3, 4), lahko izračunamo kotni faktor za vsako delno površino z enačbo (3). S ponovitvijo postopka za vse obodne površine prostora (ki so sestavljene iz različnih elementov) in za vse položaje človeka lahko določimo skupni kotni faktor.

where surface *i* represents sub-surface $a_i b_i$.

Equation (3) can be used as a general algorithm for calculating the view factor for an arbitrary element of the wall. By division of the surface, where element *A* of the wall represents the sub-surface, into four sub-surfaces (1, 2, 3, 4), the view factor can then be determined by solving equation (3) for every sub-surface. By repeating this procedure for all room walls (composed of different elements) and for all positions of the person in the room, the total view factor can be estimated.



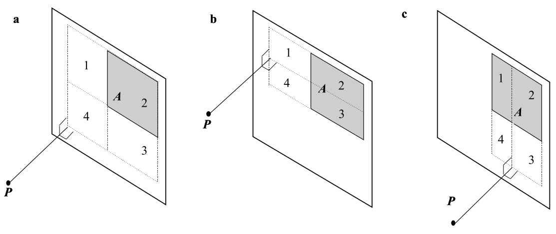
Sl. 1. *Kotni faktor med osrednjo točko P in površino A (z izmerami a x b)*
Fig. 1. *View factor between generic point P and surface A (dimensions a x b)*

Enačba (3) velja le v primeru, če se normala med točko in površino ujema z ogliščem površine kvadra (pogoj za uporabo eksperimentalno določenih kotnih faktorjev). Vendar lahko v vsakem primeru določimo normalo na ravnino, v kateri je opazovana površina tako, da se ujema s točko *P*. Kotni faktor površine določimo z delitvijo ravnine na štiri delne površine, od katerih je ena opazovana površina.

V običajnem primeru, ko je zid sestavljen iz elementov z različnimi površinskimi temperaturami (npr. okno, ogrevalo), lahko določimo kotni faktor za posamezni element po opisanem postopku. Štiri delne površine oblikujemo tako, da se normala skozi opazovano točko ujema z ogliščem površine na ravnini elementa; preostala oglišča delnih površin so določena z oglišči elementa. Na sliki 2 je prikazanih nekaj možnih razporeditev.

Equation (3) functions only if the normal from the subject coincides with the common corner point of the rectangles (a condition for using the experimentally determined view factors). Nevertheless, in the case of isothermal sub-surfaces with equal temperature, we are able to sweep the normal from the surface in such a way, that it coincides with the normal from the subject. The view factor for an arbitrary human position in the room can be determined by splitting the surface into four sub-surfaces and applying the additive property. This general algorithm can also be used for computing the view factor for non-isothermal elements of the wall.

In the usual case, where the wall is composed of elements with different temperatures (e.g. windows, heating panels), the view factor can be determined in a similar way to the sub-surface. The four sub-surfaces are constructed in such a way that the normal from the subject represents one corner of the surface; other corners and the middle point of the sub-surfaces are determined by corners of the element. Some possible arrangements are shown in Figure 2.



Sl. 2. *Primeri geometrijskih pogojev za izračun kotnega faktorja za osrednjo točko P*

Fig. 2. *Examples of geometrical conditions for calculating the view factor for generic point P*

Kotni faktor je določen z enačbo (3) z upoštevanjem seštevnosti:

The view factor is then determined using equation (3) by means of the additive property in the following way:

za primer na sl. 2a:

for the case in Figure 2a:

$$F_{P\to A}=F_{P\to(1+2+3+4)}-F_{P\to(1+4)}-F_{P\to(3+4)}+F_{P\to 4} \qquad (4a)$$

za primer na sl. 2b:

for the case in Figure 2b:

$$F_{P\to A}=F_{P\to(1+2+3+4)}-F_{P\to 1}-F_{P\to 4} \qquad (4b)$$

za primer na sl. 2c:

for the case in Figure 2c:

$$F_{P\to A}=F_{P\to(1+2+3+4)}-F_{P\to 3}-F_{P\to 4} \qquad (4c).$$

Da lahko uporabimo računalniški program za izračun kotnih faktorjev za celotni tloris prostora, moramo ustrezno definirati koordinatni sistem. Delitev površine elementa ali ravnine na delne površine in upoštevanje zakona seštevnosti zahteva pravilno

In order to create a computer algorithm for calculating the view factor for an entire floor plan, attention must be paid to the proper determination of the coordinate system. The division of the surface into four sub-surfaces and an application of the addoločitev predznaka za posamezno delno površino. Glede na postopno razvrstitev delnih površin, kakor je prikazana na slikah 2a, b in c, ter določitev kotnega faktorja z enačbami (4a, b in c), lahko algoritem posplošimo:

ditive property requires the determination of the sign for certain sub-surfaces. According to the arrangements shown in Figures 2a, b, c and the equations (4) for computing the relevant view factor, one can deduce a general algorithm:

$$F_{P \to A} = \sum_{i=1}^{4} F_{P \to i} \cdot sign\left(a_i \cdot b_i\right) \qquad (5).$$

Ko določimo kotne faktorje za posamezne elemente, lahko izračunamo kotni faktor za sestavljeno površino z enačbo:

When the view factors for individual sub-surfaces are determined, the view factor for the composed wall can be expressed as:

$$F_{P \to \substack{stena|_{usmeritev} \\ wall|_{orientation}}} = F_{P \to \substack{celotna\ površina|_{usmeritev} \\ total\ surface|_{orientation}}} - \sum_{\substack{delna\ površina|_{usmeritev} \\ sub\text{-}surface|_{orientation}}} F_{P \to \substack{delna\ površina \\ sub\text{-}surface}} \qquad (6)$$

ter povprečno sevalno temperaturo T_{mrt} za znano usmeritev v prostoru:

and the mean radiant temperature T_{mrt} for a given orientation in the room is then:

$$T_{mrt}^4 = \sum_{i=1}^{N} F_{P \to i} \cdot T_i^4 \qquad (7),$$

kjer je T_i absolutna površinska temperatura i-te notranje površine in $F_P \to_i$ kotni faktor med človekom (osrednjo točko v prostoru) in i-to površino (ali podpovršino).

where T_i is the absolute temperature of the i-th internal surface and $F_P \to_i$ is the view factor between the person (generic point in room) and i-th surface (or sub-surface).

3 PRIMER

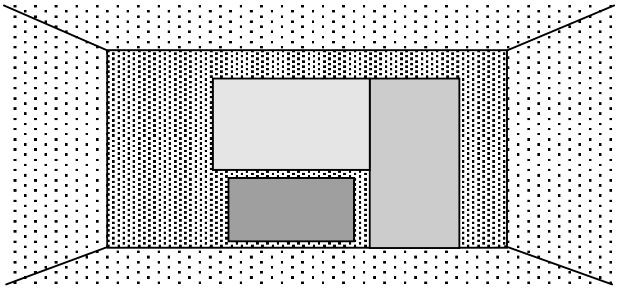
Uporabnost predstavljenega postopka je prikazana na primeru izračuna povprečne sevalne temperature za zid, sestavljen iz različnih elementov. Na sliki 3 je primer preproste zunanje stene, sestavljene iz vrat, okna in ogrevala (radiatorja).

V preglednici 1 so podane geometrijske in temperaturne predpostavke za posamezne površine. Zaradi preglednosti je pri računanju sevalne temperature upoštevana samo ena stena. Ker algoritem temelji na uporabi enačbe (2), so potrebni geometrijski parametri določeni avtomatično z definicijo elementov stene (ali prostora), razen višine osrednje točke, ki je definirana s predpostavljenim položajem človeka. Na ta način so izbrani koeficienti enačbe (2), ki so določeni glede na položaj človeka in s tem posredno odvisni od geometrijske oblike prostora in elementov.

3 CASE STUDY

The potential use of the introduced algorithm can easily be shown by means of an application aimed at the calculation of the mean radiant temperature for a wall which is composed of different elements. In Figure 3, an example of a wall composed of a door, window and heating panel is shown.

Table 1 contains the geometric and thermal assumptions for the wall surfaces; for the sake of clarity, the influence of only one wall on mean radiant temperature is analysed. Since the algorithm is based on the use of equation (2), the required geometrical parameters are automatically defined by given wall (or room) elements, except for the height of a generic point which is determined by the proposed body posture. The parameters used in equation (2) are defined by the body posture and, thus, are chosen depending on the geometry of the room and its elements.



Sl. 3. *Primer predpostavljene sestave zunanje stene*
Fig. 3. *Assumed composition of the wall in this case*

Preglednica 1. *Parametri stenskih površin*
Table 1. *Parameters of the wall surfaces*

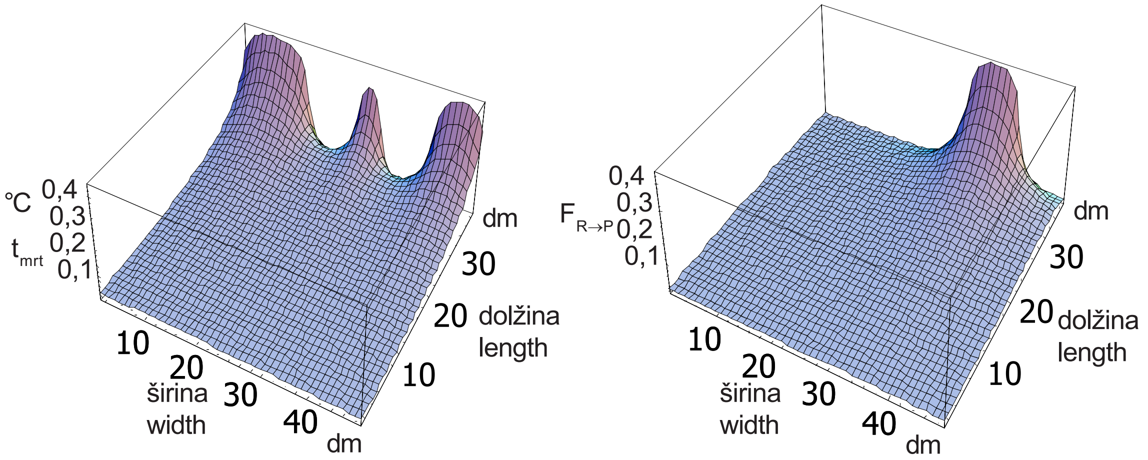
element	dolžina length m	višina height m	površinska temperatura surface temperature °C
stena wall	5	3	18
vrata door	1	2	16
okno window	2	1	14
ogrevalo heating panel	1	0,8	50

Na naslednjih slikah so prikazani izračunani kotni faktorji stene ter povprečna sevalna temperatura. Ker je algoritem splošen, ga lahko uporabimo za različne sestavljene površine, npr:

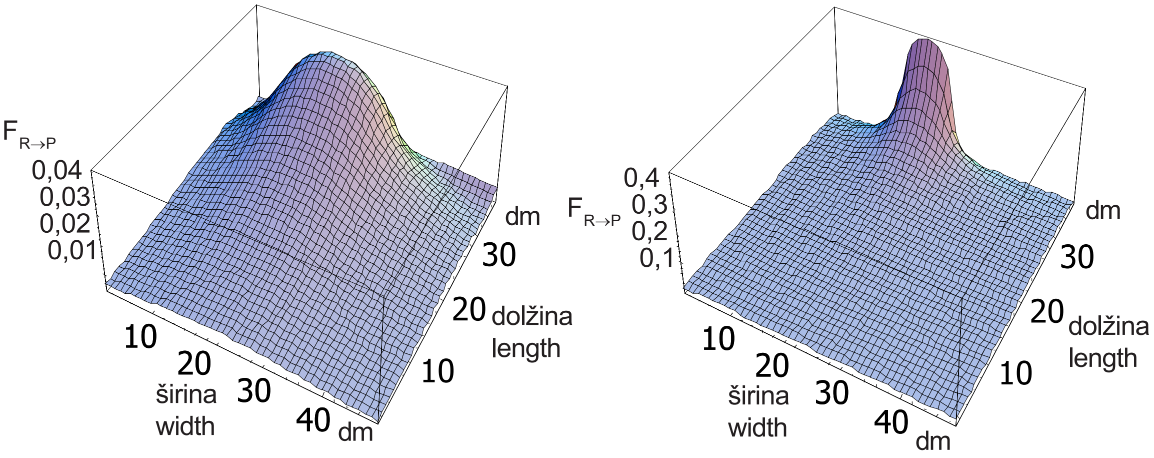
- poljubno lego elementa stene ali
- geometrijsko obliko elementa ali
- površinsko temperaturo.

In the following figures, the calculated view factors and mean radiant temperatures are presented. In these examples, the height of the generic point is used as a variable. Since the algorithm possesses a general structure, it is easily applied to different surface compositions, such as:

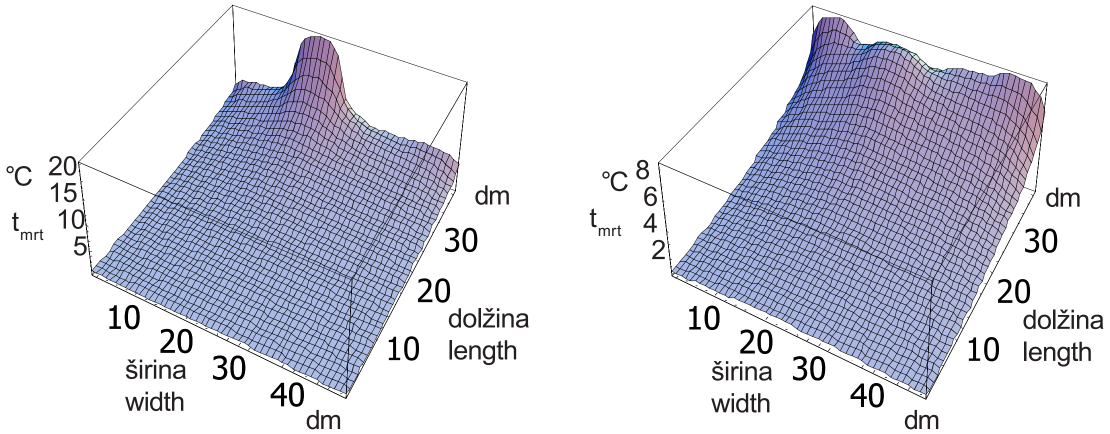
- the position of the element within the wall,
- the arbitrary geometry of the element,
- the surface temperature of the element.



Sl. 4. *Izračunani kotni faktor za steno (levo) in vrata (desno)*
Fig. 4. *Calculated view factor for wall (left) and door (right)*



Sl. 5. *Kotni faktor za okno (levo) in ogrevalo (desno)*
Fig. 5. *Calculated view factor for window (left) and heating panel (right)*



Sl. 6. *Srednja sevalna temperatura t_{mrt} za različne višine: 0,6 m nad tlemi (levo) in 1,2 m (desno)*

Fig. 6. *Calculated mean radiant temperature t_{mrt} for different heights: 0.6 m above the floor (left) and 1.2 m (right)*

4 SKLEPI

Prikazana metoda predstavlja analitični postopek k določitvi optimalnega toplotnega okolja v stavbah. Predlagani algoritem temelji na izračunu kotnih faktorjev ob upoštevanju zakona seštevnosti. S tem je omogočen izračun povprečne sevalne temperature za sestavljene površine ob hkratnem upoštevanju zapletenega vpliva usmerjenosti človeka v prostoru. Zaradi matričnega načina izračuna je mogoča analiza vpliva različnih parametrov tako na povprečno sevalno temperaturo kakor tudi na pričakovano toplotno ugodje oz. neugodje. Hkrati je mogoče tudi upoštevanje drugih parametrov (temperaturni gradient, relativna hitrost zraka itn.), ki vplivajo na toplotno ugodje in so izraženi kot vrednost pričakovane povprečne presoje (PVM).

Za zagotovitev najboljših toplotnih razmer mora biti doseženo ravnotežje med toplotnimi viri in ponori. Metoda omogoča določitev vpliva karakteristik toplotnega vira - ogrevala (temperatura, geometrijska oblika) na povprečno sevalno temperaturo, ki predstavlja del toplotnega okolja. Za boljšo predstavljivost so lahko rezultati izračuna podani v obliki različnih izometričnih diagramov.

Ta metoda je učinkovito orodje za natančno določitev medsebojnega vpliva ogrevalnega sistema in gradbene konstrukcije, s čimer lahko dosežemo največje mogoče področje toplotnega ugodja. V idealnem primeru lahko to metodo uporabimo v fazi načrtovanja objekta in s tem določimo najboljše možno razmerje med toplotno-tehničnimi lastnostmi stavbe in ogrevalnega sistema.

4 CONCLUSIONS

The thermal comfort of people in confined environments is a crucial issue for the proper assessment of the indoor quality of buildings. The method presented in this paper represents an analytical tool for determining the optimum thermal environment for people in buildings. The proposed algorithm is based on the computation of view factors using the additive property. This algorithm enables the calculation of mean radiant temperature for composite room surfaces, even allowing for the complex impact of body posture. The matrix-based approach allows us to determine the effect of various parameters on mean radiant temperature, as well as on thermal comfort or discomfort. This approach also enables the consideration of other parameters (air temperature gradient, air velocity etc.) whose impact on thermal sensation is expressed as the predicted mean vote (PMV) value.

In order to achieve optimum thermal conditions, the thermal balance between heat sources and sinks must be established. This method enables the determination of the influence of heating source characteristics (temperature, geometrical parameters) on mean radiant temperature as a part of the overall environmental conditions. A graphical rendering of an isometric map is used for better visual interpretation of the results.

This method presents a useful tool for determining the correct interplay between heating system and building structure, thus achieving the maximum possible thermal comfort area. This method could, ideally, be incorporated into the architectural planning phase of buildings in order to determine the best relationship between the the building's structure and its heating system.

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5 REFERENCES

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