

## DIRECT AND INVERSE APPROXIMATION THEOREMS OF FUNCTIONS IN THE MUSIELAK-ORLICZ TYPE SPACES

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**Abstract.** In Musielak-Orlicz type spaces  $\mathcal{S}_M$ , direct and inverse approximation theorems are obtained in terms of the best approximations of functions and generalized moduli of smoothness. The question of the exact constants in Jackson-type inequalities is studied.

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### REFERENCES

- [1] F. ABDULLAYEV, S. CHAICHENKO, M. IMASH KYZY, A. SHIDLICH, *Direct and inverse approximation theorems in the weighted Orlicz-type spaces with a variable exponent*, Turk. J. Math., **44** (2020), 284–299.
- [2] F. G. ABDULLAYEV, P. ÖZKARTEPE, V. V. SAVCHUK, A. L. SHIDLICH, *Exact constants in direct and inverse approximation theorems for functions of several variables in the spaces  $\mathcal{S}^p$* , Filomat, **33**, 5 (2019), 1471–1484.
- [3] R. AKGÜN, Y. YILDIRIR, *Jackson-Stechkin type inequality in weighted Lorentz spaces*, Math. Inequal. Appl., **18** (2015), 1283–1293.
- [4] R. AKGÜN, V. KOKILASHVILI *The refined direct and converse inequalities of trigonometric approximation in weighted variable exponent Lebesgue spaces*, Georgian Math. J., **18** (2011), 399–423.
- [5] A. G. BABENKO, *On exact constant in the Jackson inequality in  $L_2$* , Math. Notes, **39**, 5 (1986), 355–363.
- [6] N. K. BARI, S. B. STECHKIN, *Best approximations and differential properties of two conjugate functions*, Trudy Moskov. Mat. Obsch., **5** (1956), 483–522 [in Russian].
- [7] S. N. BERNSTEIN, *On the best approximation of continuous functions by polynomials of given degree* (1912), in: *Collected Works*, 1, Acad. Nauk SSSR, Moscow, 11–104 (1952) [in Russian].
- [8] J. BOMAN, H. S. SHAPIRO, *Comparison theorems for a generalized modulus of continuity*, Ark. Mat., **9** (1971), 91–116.
- [9] J. BOMAN, *Equivalence of generalized moduli of continuity*, Ark. Mat., **18** (1980), 73–100.
- [10] P. BUTZER, R. NESSEL, *Fourier Analysis and Approximation. One-Dimensional Theory*, Birkhäuser, Basel, 1971.
- [11] S. CHAICHENKO, A. SHIDLICH, F. ABDULLAYEV, *Direct and inverse approximation theorems of functions in the Orlicz type spaces  $\mathcal{S}_M$* , Math. Slovaca, **69**, 6 (2019), 1367–1380.
- [12] N. I. CHERNYKH, *On the Jackson inequality in  $L_2$* , Tr. Mat. Inst. Akad. Nauk SSSR, **88** (1967), 71–74 [in Russian].
- [13] N. I. CHERNYKH, *On the best approximation of periodic functions by trigonometric polynomials in  $L_2$* , Mat. Zametki, **20**, 3 (1967), 513–522 [in Russian].
- [14] R. A. DEVORE, G. G. LORENTZ, *Constructive Approximation*, Springer, Berlin, 1993.
- [15] V. K. DZYADYK, I. A. SHEVCHUK, *Theory of uniform approximation of functions by polynomials*, Walter de Gruyter GmbH & Co. KG, Berlin, 2008.
- [16] A. GUVEN, D. ISRAFILOV, *Trigonometric approximation in generalized Lebesgue spaces  $L^{p(x)}$*  J. Math. Inequal., **4** (2010), 285–299.
- [17] G. H. HARDY, J. E. LITTLEWOOD, G. PÓLYA, *Inequalities*, Cambridge University Press, 1934.

- [18] D. JACKSON, *Über die Genauigkeit der Annäherung stetiger Funktionen durch ganze rationale Funktionen gegebenen Grades und trigonometrische Summen gegebener Ordnung*, Göttingen, 1911, Thesis.
- [19] S. Z. JAFAROV, *The inverse theorem of approximation of the function in Smirnov-Orlicz classes*, Math. Inequal. Appl., **12**, 4 (2012), 835–844.
- [20] S. Z. JAFAROV, *Approximation of conjugate functions by trigonometric polynomials in weighted Orlicz spaces*, J. Math. Inequal., **7**, 2 (2013), 271–281.
- [21] N. KORNEICHUK, *Exact constants in approximation theory*, Transl. from the Russian by K. Ivanov. Reprint of the hardback edition 1991. Encyclopedia of Mathematics and its Applications, **38**, Cambridge: Cambridge University Press.
- [22] A. I. KOZKO, A. V. ROZHDESTVENSKIY, *On Jackson's inequality for a generalized modulus of continuity in  $L_2$* , Sb. Math., **195**, 8 (2004), 1073–1115.
- [23] J. LINDENSTRAUSS, L. TZAFRIRI, *Classical Banach spaces I: Sequence Spaces*, Berlin, 1977.
- [24] J. MUSIELAK, *Orlicz Spaces and Modular Spaces*, Springer, Berlin, 1983.
- [25] H. S. SHAPIRO, *A Tauberian theorem related to approximation theory*, Acta Math., **120** (1968), 279–292.
- [26] I. I. SHARAPUDINOV *On direct and inverse theorems of approximation theory in variable Lebesgue and Sobolev spaces*, Azerbaijan Journal of Mathematics, **4**, 1 (2014), 55–72.
- [27] A. I. STEPANETS, *Approximation characteristics of the spaces  $\mathcal{S}_\phi^p$* , Ukrainian Math. J., **53**, 3 (2001), 446–475.
- [28] A. I. STEPANETS, *Methods of Approximation Theory*, VSP, Leiden-Boston, 2005.
- [29] A. I. STEPANETS, A. S. SERDYUK, *Direct and inverse theorems in the theory of the approximation of functions in the space  $\mathcal{S}^p$* , Ukrainian Math. J., **54**, 1 (2002), 126–148.
- [30] M. D. STERLIN, *Exact constants in inverse theorems of approximation theory*, Dokl. Akad. Nauk SSSR, **202** (1972), 545–547 [in Russian].
- [31] A. F. TIMAN, *Theory of approximation of functions of a real variable*, Fizmatgiz, Moscow, 1960 [in Russian]; English translation by J. Berry, International Series of Monographs on Pure and Applied Mathematics **34**, Pergamon Press and MacMillan, Oxford, 1963.
- [32] M. F. TIMAN, *Approximation and properties of periodic functions*, Nauk. dumka, Kiev, 2009 [in Russian].
- [33] S. B. VAKARCHUK, *Jackson-type inequalities and exact values of widths of classes of functions in the spaces  $S^p$* ,  $1 \leq p < \infty$ , Ukrainian Math. J., **56**, 5 (2004), 718–729.
- [34] S. B. VAKARCHUK, A. N. SHCHITOV, *On some extremal problems in the theory of approximation of functions in the spaces  $S^p$* ,  $1 \leq p < \infty$ , Ukrainian Math. J., **58**, 3 (2006), 340–356.
- [35] S. B. VAKARCHUK, *Jackson-type inequalities with generalized modulus of continuity and exact values of the  $n$ -widths of the classes of  $(\psi, \beta)$ -differential functions in  $L_2$* , I, Ukrainian Math. J., **68**, 6 (2016), 823–848.
- [36] S. N. VASIL'EV, *The Jackson-Stechkin inequality in  $L_2[-\pi, \pi]$* , Proc. Steklov Inst. Math., Suppl., **1**, (2001), S243–S253.
- [37] S. N. VASIL'EV, *Jackson inequality in  $L_2(T^N)$  with generalized modulus of continuity*, Proc. Steklov Inst. Math., Suppl., **265**, 1, (2009), S218–S226.