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Improvement of the method for detecting obstacles in front of moving trains and development of its algorithm

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Abstract: This article introduces a LiDAR-based system for detecting obstacles in front of moving trains with the aim of improving railway traffic safety. The system integrates an optimized operating algorithm supported by 2D and 3D visual representations of the detection process. LiDAR technology enables accurate and rapid obstacle recognition under various operational conditions, thereby enhancing reliability in real-time railway monitoring. The proposed approach is validated through scientifically grounded methods and experimental evaluation. The results demonstrate that the LiDAR-based system provides an effective framework for modernizing and automating safety processes in railway environments.

Keywords: LiDAR technology, moving train obstacle detection, rapid detection algorithm, long-range sensing, railway safety, railway station monitoring, point cloud processing, 3D object recognition, automated safety system, real-time detection

Harakatdagi poyezdlar oldidagi to‘siqlarni aniqlash usulini takomillashtirish va uning algoritmini ishlab chiqish

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Annotatsiya: Ushbu maqolada LiDAR texnologiyasi asosida yaratilgan harakatdagi poyezdlar oldidagi to‘siqlarni aniqlash tizimining temir yo‘l hatakat xavfsizligida qo‘llanilishi hamda uning ishlash algoritmi va 2D va 3D vizual tasvirlari ishlab chiqildi. LiDAR texnologiyasi yordamida poyezdlar oldidagi to‘siqlarni xavfsiz va tezkor aniqlash jarayonlari optimallashtiriladi. Ilmiy asoslangan usullar va tajribaviy natijalar yordamida LiDAR texnologiyasining samaradorligi tahlil qilinadi. Ushbu texnologiya asosida yaratilgan tizim temir yo‘l hududlarida avtomatlashtirilgan xavfsizlik jarayonlarini modernizatsiya qilishga imkon beradi.

Kalit so‘zlar: LiDAR texnologiyasi, harakatdagi poyezd oldidagi to‘siq, tezkor aniqlash algoritmi, uzoq masofadan aniqlash, temir yo‘l xavfsizligi, temir yo‘l stansiyasi monitoringi, nuqta buluti qayta ishlash, 3D obyektning aniqlash, avtomatlashtirilgan xavfsizlik tizimi, real vaqt rejimidagi aniqlash

1. Kirish

Hozirgi kunda jahon temir yo‘llarida yuqori tezlikda harakatlanuvchi poyezdlarga nisbatan talab ortib bormoqda. Bunday poyezdlarni yaratishda Germaniya, Yaponiya, Xitoy, Ispaniya kabi davlatlar yetakchi hisoblanadi. Poyezdlar tezligi ortib borgan sari temir yo‘ldan foydalanish xavfsizligini oshirish ham sezilarli tarzda ortadi. Temir yo‘ldan foydalanish xavfsizligini oshirish maqsadida butun dunyo olimlari turli ilmiy izlanishlar olib bormoqda. Ushbu ilmiy yangiliklarning bir qanchasi temir yo‘l xavfsizligi uchun joriy qilinib yuksak natijalarga erishildi. Buning isbotini hozirgi kundagi temir yo‘llarning rivojlanganligidan ham ko‘rishimiz mumkin.

Harakat tarkibi stansiya yo‘llarida, peregonlarda hamda temir yo‘l kesishmalarida harakatlanganda uning xavfsiz va turli xavf-xatarlarsiz o‘z manziliga yetib borishi ustuvor vazifa hisoblanadi. Bunda poyezdlarning temir yo‘l izlari bo‘ylab xavfsiz harakatlanishiga tahdid soluvchi asosiy

omillardan biri oldindagi turli to‘siqlarning vujudga kelishidir. Bunda temir yo‘l iziga turli jismlarning tushib qolishi, piyodalarning temir yo‘l izlarini belgilanmagan qismidan kesib o‘tishi hamda turli hayvonlarning temir yo‘l izlari bo‘ylab harakatlanishini misol qilib keltirishimiz mumkin. Quyida taklif qilinayotgan ilmiy ishda harakatlanayotgan poyezdlar oldidagi to‘siqlarni aniqlash uchun yuqori aniqlikdagi LiDAR texnologiyasi asosidagi takomillashtirilgan tizim ko‘rib chiqilgan.

LiDAR (Light Detection and Ranging) – bu yorug‘lik nurlari (odatda lazer impulslari) yordamida obyektlarning masofasi va shaklini aniqlovchi texnologiya. U radar prinsipiga o‘xshaydi, lekin radio to‘lqinlar o‘rniga lazer nurlaridan foydalanadi.

2. Tadqiqot metodologiyasi

LiDAR TEXNOLOGIYASINING ISHLASH PRINSIPI. LiDAR texnologiyasi turli sohalarda

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qo'llanilishi mumkin. LiDAR texnologiyasini ishlab chiqaruvchi ilg'or kompaniyalardan Xitoyning Hesai Technology, AQSHning RoboSense va Ouster, Inc. hamda Avstriyaning RIEGL ni misol qilib keltirsak bo'ladi.

LiDAR ning ishlash prinsipi lazer nurlarini yuboradi, nur to'siqqa yoki obyektga urilib qaytadi, qaytgan nur qabul qilinadi va vaqt o'lchanadi, nur yuborilgan vaqtdan qaytgunga qadar bo'lgan vaqt orqali obyektgacha bo'lgan masofa aniqlanadi, shu tarzda millionlab nuqtalar yig'ilib 3D xarita (point cloud) hosil qilinadi.

LiDAR ning asosiy komponentlari:

- **Lazer manbai** – nur yuboradi;
- **Qabul qiluvchi detektor** – qaytgan signalni qabul qiladi;
- **Skanner va aylantiruvchi mexanizm** – 360° atrofni qamrab olish imkonini beradi;

- **GPS va IMU modullari** – koordinatalarni va qurilmalarni aniqlash uchun.

LiDAR ning afzalliklari:

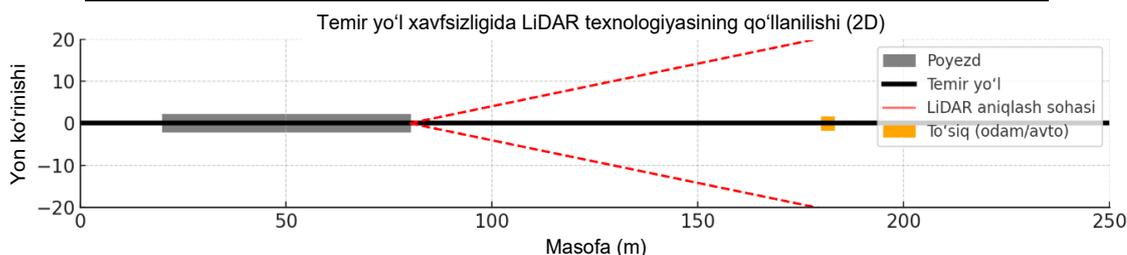
- Juda aniq ishlaydi (sm darajasida xatolik bilan);
- Uzoq masofadan (200-300 m gacha, ayrimlari 1 km dan ortiq) aniqlay oladi;
- Kunduz va tun sharoitida ishlay oladi;
- 3D ko'rinish va batafsil xarita yaratadi;
- Obyektning shakli, hajmi va joylashuvini ko'rsatadi

Quyida LiDAR tizimining temir yo'l xavfsizligidagi afzalliklarini keltiramiz:

1-jadval

LiDAR texnologiyasining temir yo'l xavfsizligidagi afzalliklari va uning qo'llanilish sohalari

Afzalliklar	Ta'rifi
Uzoq masofadan aniqlash	200 metr va unadan uzoqroq masofada to'siqlarni ko'rishi mumkin, bu poyezd tezligi yuqori bo'lganda juda muhim.
3D to'siq aniqlash	Kamera faqat rasm beradi, LiDAR esa obyektning hajmi, balandligi va joylashuvini aniqlaydi. Masalan, temir yo'l izlari ustidagi odammi yoki faqat plastik jismlari – farqlashi mumkin.
Kunduz va tun rejimida ishlash	Qorong'ulikda ham, hatto yoritish bo'lmasa ham, lazer yordamida to'siqlarni aniqlaydi.
Har xil ob-havoda ishlash	Yomg'ir, qor va tuman paytida ham ma'lum darajada samarali ishlaydi (lekin signal biroz sustlashishi mumkin)
Real vaqt monitoringi	Millisekund darajasida javob qaytarib, tezkor signal beradi (masalan, poyezd mashinisti yoki avtomatlashtirilgan tormoz tizimiga).
Temir yo'l tizimidagi qo'llanilish sohalari	Ta'rifi
Temir yo'l izi ustidagi to'siqlarni aniqlash tizimi	Poyezd harakat yo'lida odam, hayvon, mashina yoki jisim paydo bo'lsa, LiDAR uni 3D shaklda aniqlaydi va ogohlantirish yuboradi.
Stansiya xavfsizligi	Stansiya platforma yo'llaridan yo'lovchilar xavfli hududga tushib qolsa (masalan, rels ustiga yiqilsa), LiDAR tizimi tezda ogohlantiradi.
Avtomatlashtirilgan poyezdlar	O'zini-o'zi boshqaruvchi poyezdlar uchun asosiy tizim bo'lib xizmat qiladi.
Texnik nazorat	Temir yo'l relslari, ko'priklar va tunnellar bo'ylab 3D skanerlash orqali deformatsiyalarni aniqlash.



1-rasm. Poyezd bortiga o'rnatilgan LiDAR asosidagi harakatdagi poyezdlar oldidagi to'siqni aniqlash tizimi 2D sxemasi

Poyezd kabinasiga o'rnatilgan LiDAR texnologiyasi orqali yaratilgan harakatdagi tarkib oldidagi to'siqlarni aniqlash tizimining 2D ko'rinishi, ya'ni x, y o'qlari orqali yon va uzunlik masofalari bilan tasvirlangan (1-rasm). Bunda tizimning to'siqni aniqlash chegara diapazonlarini ko'rinishimiz mumkin. Yon yo'nalishda 20 metrgacha, oldingi yo'nalish bo'yicha 200 metrgacha bo'lgan masofada joylashgan to'siqni aniqlay oladi hamda uni 3D shaklini yaratib qisqa vaqt ichida poyezd mashinistini ogohlantiradi yoki avtomatik tormozlash tizimini ishga tushuradi.

3. Natijalar

Temir yo'l satnsiyalari, stansiya oralig'idagi yo'llar va temir yo'l kesishmalarida xavfsizlikni ta'minlash eng ustuvor vazifa hisoblanadi. Temir yo'lida harakat xavfsizligini ta'minlash uchun turli tizimlar yaratilgan. Bunga misol qilib staniyadagi elektr markazlashtirish tizimlari, peregondagi harakatni boshqarish tizimlari: avtoblokirovka, yarim avtoblokirovka, temir yo'l kesishmasida harakat xavfsizligini ta'minlovchi tizimlar va

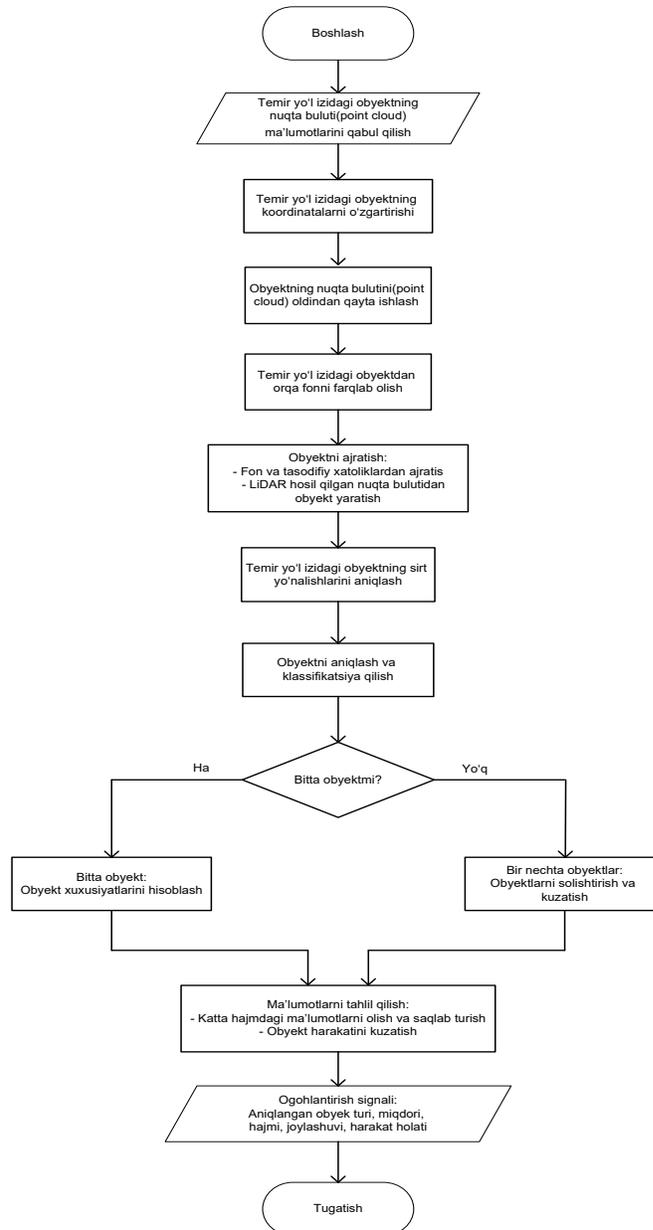


boshqa tizimlarni keltirishimiz mumkin. Har bir tizimning harakat xavfsizligini ta'minlovchi o'z vazifalari mavjud.

Hozirgi kunda temir yo'l hududlarida poyezdlar bilan turli to'qnashuvlar miqdori ortib bormoqda. Bunga yechim sifatida ushbu taklif etilayotgan yangi LiDAR texnologiyasiga asoslangan harakatdagi poyezdlar oldidagi to'siqni aniqlovchi tizim eng maqbul yechim bo'la oladi. Oddiy kameralar orqali temir yo'lni nazorat qiluvchi hududlarni taashkil qilsa bo'ladi, lekin bu nazorat tizimi bir qator noqulayliklarni keltirib chiqaradi. Bulardan kamera tasvirlarini kuzatib turuvchi alohida nazoratchi monitor qarshisida o'tirishiga to'g'ri keladi. Kamera uzatgan tasvirlardan biror xavfni sezgani bilan tezkor

reaksiya bildirsa olmaydi. Ushbu holat baxtsiz hodisalar yuzaga kelishini keltirib chiqarishi mumkin.

Bu holatlarni hisobga olgan holda harakat tarkibi oldidagi to'siqlarni aniqlovchi LiDAR asosidagi yangi tizim inson omilisiz to'liq avtomatlashtirilgan tizim hisoblanadi. Ushbu tizim poyezdlar oldidagi xavfni juda tez vaqtda aniqlash orqali to'qnashuvlarning oldini oladi. Ushbu tizimni stasionar ustunlarga o'rnatish orqali ham temir yo'l izlaridagi odamlar, turli jismlarni 3D shaklini yaratilgan dastur orqali aniqlab stansiyada harakatni boshqaruvchi dispetcherga va yaqinlashib kelayotgan poyezd mashinistini tezkor ogohlantirish orqali turli xavflarni oldini oladi.



2-rasm. Harakatdagi poyezdlar oldidagi to'siqlarni aniqlashning LiDAR texnologiyasiga asoslangan tizim algoritmi

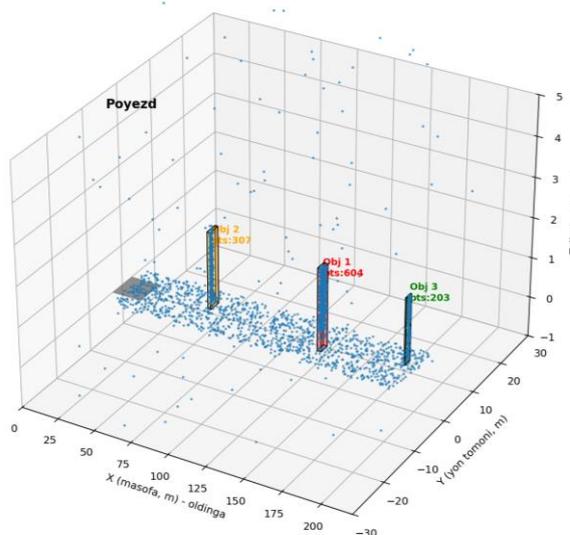


Yuqoridagi 2-rasmda harakatdagi poyezdlar oldidagi to'siqlarni aniqlashning LiDAR texnologiyasiga asoslangan tizim algoritmi ishlab chiqilgan. Quyida ushbu algoritmi uchta qismga bo'lib tahlil qilamiz:

1-qismda: LiDAR yo'ldagi ma'lumotlarni qabul qilib oladi, tizmda nuqta bulutini qayta ishlash, obyektning orqa fonga nisbatan to'g'ri ajratish va faqat obyektning ajratib olish sirt yo'nalishlarini bir xilda ushlab turuvchi algoritmi ishga tushiradi va aniq obyekt sifatida ajratib oladi. Shundan so'ng obyektning holatini hisoblash bloki orqali obyektning nechtaligi aniqlanadi bitta obyekt bo'lsa aniq alohida obyekt sifatida ajratib oladi;

2-qismda: Obyektlar soni bittadan ko'p bo'lsa bir nechta obyektlarni aniqlash blokiga o'tadi. Undan ma'lumotlarni vaqtinchalik saqlab turish xotirasi blokiga va Katta hajmdagi ma'lumotlarni tahlil qilish blokiga o'tadi ular bilan birga obyektning kuzatish algoritmi hamda obyekt harakatini kuzatib tahlil qilish bloklari ishlaydi. LiDAR texnologiyasi orqali tizim obyektning bitta yoki bir nechtaligini aniqlagandan so'ng nuqta buluti(point)larini na'munaviy obyektlar bilan solishtirib obyektning aniqlash blokini ishlaydi. Ushbu blokda aniqlangan yangi obyekt oldindan dastur orqali kiritilgan na'munaviy obyektlar(odam, poyezd vagoni, turli mavjud jismlar) bilan solishtiriladi va obyekt turi aniqlanadi;

3-qismda Obyekt turi aniqlagandan so'ng obyekt ma'lumotlarini taqqoslash blokini obyekt ma'lumotlarini taqqoslab agar to'g'riligi aniqlansa ogohlantirish signali blokiga yuboriladi bunda ogohlantirish signali beriladi: to'siq turi, miqdori, hajmi, joylashuvi, harakat holati haqida.



3-rasm. Harakatdagi poyezdlar oldidagi to'siqlarni aniqlashning LiDAR texnologiyasiga asoslangan tizim algoritmi asosida Python dasturlash tilida yozilgan bir nechta obyektlarning 3D ko'rinishi.

Yuqoridagi 3-rasmda harakatdagi poyezdlar oldidagi to'siqlarni aniqlashning LiDAR texnologiyasiga asoslangan tizim algoritmi asosida tuzilgan dasturning Python dasturlash muhiti Plots oynasida shakllangan 3D vizual tasviri yaratilgan. Ushbu holatda LiDAR texnologiyasi asosida, harakatlanayotgan poyezd oldidagi bir nechta obyektning tuzilishi generatsiya qilingan.

4. Xulosa

LiDAR texnologiyasi asosida yaratilgan harakatdagi poyezdlar oldidagi to'siqlarni aniqlovchi tizim temir yo'l stansiyalari, peregonlari, temir yo'l kesishmalari hududlarida harakat xavfsizligini sezilarli darajada oshiradi. Ushbu tizim yordamida temir yo'l hududida biror to'siq paydo bo'lganda uni tezda aniqlash va poyezd mashinistiga zaruriy choralarni ko'rish uchun ogohlantirish signali beradi va real vaqt rejimida obyektlarni aniqlaydi. Yaratilgan tizim inson omilidan kelib chiqadigan xatoliklarni kamaytiradi va temir yo'l transportida favqulodda hodisalar xavfini sezilarli ravishda kamaytiradi. LiDAR nurlari millimetrgacha bo'lgan aniqlikda masofa o'lchash imkonini beradi. Bu poyezd oldida eng kichik to'siqni ham aniqlashga yordam beradi.

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